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Low-voltage switchgear and controlgear –
Part 2: Circuit-breakers

Appareillage à basse tension –
Partie 2: Disjoncteurs



IEC 60947-2:2016-06+AMD1:2019-07 CSV(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 60947-2 edition 5.1 contains the fifth edition (2016-06) [documents 121A/71/FDIS and 121A/83/RVD], its corrigendum (2016-11) and its amendment 1 (2019-07) [documents 121A/286/FDIS and 121A/302/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 60947-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage.

This fifth edition constitutes a technical revision.

This edition includes the following significant additions with respect to the previous edition:

- tests for verification of selectivity in Annex A (see A.5.3);
- critical load current tests for d.c. circuit-breakers (see 8.3.9);
- new Annex P for circuit-breakers for use in photovoltaic applications;
- new Annex R for residual-current circuit-breakers with automatic reclosing functions.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60947 series, published under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60947-1:2007 and its Amendment 1:2010 and Amendment 2:2014.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1 and its amendments when applicable, for example, 1.2.3 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007/AMD1:2010, or Annex A of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

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The contents of the corrigendum of October 2019 have been included in this copy.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

1.1 Scope and object

This part of IEC 60947 series applies to circuit-breakers, intended to be installed and operated by instructed or skilled persons, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.; it also contains additional requirements for integrally fused circuit-breakers.

Circuit-breakers rated above 1 000 V a.c. but not exceeding 1 500 V a.c. may also be tested to this standard.

It applies whatever the rated currents, the method of construction or the proposed applications of the circuit-breakers may be.

The requirements for circuit-breakers which are also intended to provide earth leakage protection are contained in Annex B.

The additional requirements for circuit-breakers with electronic over-current protection are contained in Annex F.

The additional requirements for circuit-breakers for IT systems are contained in Annex H.

The requirements and test methods for electromagnetic compatibility of circuit-breakers are contained in Annex J.

The requirements for circuit-breakers not fulfilling the requirements for over-current protection are contained in Annex L.

The requirements for modular residual current devices (without integral current breaking device) are contained in Annex M.

The requirements and test methods for electromagnetic compatibility of circuit-breaker auxiliaries are contained in Annex N.

The requirements and test methods for d.c. circuit-breakers for use in photovoltaic (PV) applications are contained in Annex P.

The requirements and test methods for circuit-breakers incorporating residual current protection with automatic reclosing functions are contained in Annex R.

Supplementary requirements for circuit-breakers used as direct-on-line starters are given in IEC 60947-4-1, applicable to low-voltage contactors and starters.

The requirements for circuit-breakers for the protection of wiring installations in buildings and similar applications, and designed for use by uninstructed persons, are contained in IEC 60898.

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The requirements for circuit-breakers for equipment (for example electrical appliances) are contained in IEC 60934.

For certain specific applications (for example traction, rolling mills, marine service, downstream of variable frequency drives, use in explosive atmospheres) particular or additional requirements may be necessary.

NOTE Circuit-breakers which are dealt with in this standard can be provided with devices for automatic opening under predetermined conditions other than those of over-current and undervoltage as, for example, reversal of power or current. This standard does not deal with the verification of operation under such pre-determined conditions.

The object of this standard is to state:

a) the characteristics of circuit-breakers;

b) the conditions with which circuit-breakers shall comply with reference to:

   1) operation and behaviour in normal service;

   2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (selectivity and back-up protection);

   3) dielectric properties;

c) tests intended for confirming that these conditions have been met and the methods to be adopted for these tests;

d) information to be marked on or given with the apparatus.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60228, *Conductors of insulated cables*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

~~IEC 60364 (all parts), *Low-voltage electrical installations*~~

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

~~IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*~~

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~~IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*~~

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61545, *Connecting devices – Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units*

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016

~~CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*~~

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1, as well as the following apply.

NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*, IEC 60050-441, the reference to this publication is given in brackets.

2.1
circuit-breaker
a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit

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[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
frame size
a term designating a group of circuit-breakers, the external physical dimensions of which are common to a range of current ratings.

Note 1 to entry: Frame size is expressed in amperes corresponding to the highest current rating of the group.

Note 2 to entry: Within a frame size, the width may vary according to the number of poles.

Note 3 to entry: This definition does not imply dimensional standardization.

2.1.2
construction break
a significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing

2.2
integrally fused circuit-breaker
a combination, in a single device, of a circuit-breaker and fuses, one fuse being placed in series with each pole of the circuit-breaker intended to be connected to a phase conductor

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
current-limiting circuit-breaker
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

Note 1 to entry: Reference may be made to either the symmetrical or asymmetrical prospective peak value of let-through current.

Note 2 to entry: The let-through current is also referred to as the cut-off current (see IEC 60050-441:1984, 441-17-12).

Note 3 to entry: Templates for the graphical representation of the cut-off current characteristic and the let-through energy characteristic are given from Figure K.2 to Figure K.5 and examples of the use of the templates in Figure K.6 and in Figure K.7.

2.4
plug-in circuit-breaker
a circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed

Note 1 to entry: Some circuit-breakers may be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

2.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be withdrawn from the main circuit, and, in the disconnected position, to achieve an isolating distance in accordance with specified requirements

2.6
moulded-case circuit-breaker
a circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker

[SOURCE: IEC 60050-441:1984, 441-14-24]

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2.7
air circuit-breaker
a circuit-breaker in which the contacts open and close in air at atmospheric pressure

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
vacuum circuit-breaker
a circuit-breaker in which the contacts open and close within a highly evacuated envelope

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
gas circuit-breaker
a circuit-breaker in which the contacts open and close in a gas other than air at atmospheric or higher pressure

2.10
making-current release
a release which permits a circuit-breaker to open, without any intentional time-delay, during a closing operation, if the making current exceeds a predetermined value, and which is rendered inoperative when the circuit-breaker is in the closed position

2.11
short-circuit release
an over-current release intended for protection against short circuits

2.12
short-time delay short-circuit release
an over-current release intended to operate at the end of the short-time delay

2.13
alarm switch
an auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

2.14
circuit-breaker with lock-out device preventing closing
a circuit-breaker in which each of the moving contacts is prevented from closing sufficiently to be capable of passing current if the closing command is initiated while specified conditions remain established

2.15
short-circuit breaking (or making) capacity
a breaking (or making) capacity for which the prescribed conditions include a short circuit

2.15.1
ultimate short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the circuit-breaker to carry its rated current continuously

2.15.2
service short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the circuit-breaker to carry its rated current continuously

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2.16
opening time
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

– in the case of a directly operated circuit-breaker, the instant of initiation of the opening time is the instant of initiation of a current large enough to cause the circuit-breaker to operate;

– in the case of a circuit-breaker operated by any form of auxiliary power, the instant of initiation of the opening time is the instant of application or removal of the auxiliary power to the opening release.

Note 2 to entry: For circuit-breakers "opening time" is commonly referred to as "tripping time", although, strictly speaking, tripping time applies to the time between the instant of initiation of the opening time and the instant when the opening command becomes irreversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modified – addition of Notes to entry.]

2.17
over-current protective co-ordination

2.17.1
over-current selectivity
co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

2.17.2
total selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate

2.17.3
partial selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current, without causing the other protective device to operate

2.17.4
selectivity limit current
I_s
current co-ordinate of the intersection between the total time-current characteristic of the protective device on the load side and the pre-arcing (for fuses), or tripping (for circuit-breakers) time-current characteristic of the other protective device

Note 1 to entry: The selectivity limit current (see Figure A.1) is a limiting value of current:

– below which, in the presence of two over-current protective devices in series, the protective device on the load side completes its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is ensured);

– above which, in the presence of two over-current protective devices in series, the protective device on the load side may not complete its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is not ensured).

2.17.5
take-over current
I_B
current co-ordinate of the intersection between the maximum break time current characteristics of two over-current protective devices in series

Note 1 to entry: This applies to two over-current protective devices in series for operating times ≥ 0,05 s. For operating times < 0,05 s, the two over-current devices in series are considered as an association (see Annex A).

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2.18
***I*²*t* characteristic of a circuit-breaker**
information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

2.19
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

2.20
rated instantaneous short-circuit current setting
I_i
rated value of the current causing the operation of a release without any intentional time-delay

2.21
overload current setting
I_r
current setting of an adjustable overload release

Note 1 to entry: In case of a non-adjustable overload release, this value is equal to the rated current I_n.

2.22
programmable logic controller
PLC
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

[SOURCE: IEC 61131-1:2003, 3.5, modified – deletion of the note.]

2.23
closing release
closing coil
release, energized by a source of voltage, which triggers the closing of the circuit-breaker

Note 1 to entry: A closing release is an auxiliary device of the circuit-breaker, and is different from the "closing device" mentioned in the figures of Annex A, and in IEC 60947-1, which is part of the test setup and is intended to establish the short-circuit current.

3 Classification

Circuit-breakers may be classified:

3.1 According to their selectivity category, A or B (see 4.4)

3.2 According to the interrupting medium, for example:

– air-break;
– vacuum break;
– gas-break.

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3.3 According to the design, for example:

– open construction;
– moulded case.

3.4 According to the method of controlling the operating mechanism, viz:

– dependent manual operation;
– independent manual operation;
– dependent power operation;
– independent power operation;
– stored energy operation.

3.5 According to the suitability for isolation:

– suitable for isolation;
– not suitable for isolation.

3.6 According to the provision for maintenance:

– maintainable;
– non-maintainable.

3.7 According to the method of installation, for example:

– fixed;
– plug-in;
– withdrawable.

3.8 According to the degree of protection provided by the enclosure (see 7.1.12 of IEC 60947-1:2007)

4 Characteristics of circuit-breakers

4.1 Summary of characteristics

The characteristics of a circuit-breaker shall be stated in terms of the following, as applicable:

– type of circuit-breaker (4.2);
– rated and limiting values of the main circuit (4.3);
– selectivity categories (4.4);
– control circuits (4.5);
– auxiliary circuits (4.6);
– releases (4.7);
– integral fuses (integrally fused circuit-breakers) (4.8).

4.2 Type of circuit-breaker

The following shall be stated:

– number of poles;
– kind of current (a.c. or d.c.) and, in the case of a.c., number of phases and rated frequency.

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4.3 Rated and limiting values of the main circuit

4.3.1 General

The rated values established for a circuit-breaker shall be stated in accordance with 4.3.2 to 4.4, but it is not necessary to establish all the rated values listed.

4.3.2 Rated voltages

4.3.2.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following amplification:

– Circuit-breakers covered by item a) of Note 2 (of IEC 60947-1:2007)

U_e is generally stated as the voltage between phases.

NOTE 1 In Canada and the USA, the rated operational voltage U_e is stated as

a) the voltage between phases and earth, together with the voltage between phases (for example 277 V/480 V) for three-phase four-wire neutral earthed systems;

b) the voltage between phases (for example 480 V) for three-phase three-wire unearthed or impedance earthed systems.

Circuit-breakers for unearthed or impedance earthed systems (IT) require additional tests according to Annex H.

– Circuit-breakers covered by item b) of Note 2:

These circuit-breakers require additional tests according to Annex C.

U_e shall be stated as the voltage between phases preceded by the letter C.

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by item b) of Note 2 (of IEC 60947-1:2007) are identified by the voltage between phases only.

4.3.2.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

4.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

4.3.3 Currents

4.3.3.1 Conventional free-air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

4.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

4.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 4.3.2.4 of IEC 60947-1:2007) and is equal to the conventional free-air thermal current (I_{th}).

4.3.3.4 Current rating for four-pole circuit-breakers

Subclause 7.1.9 of IEC 60947-1:2007 applies.

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4.3.4 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

4.3.5 Rated duty

The rated duties considered as normal are:

– the eight-hour duty (see 4.3.4.1 of IEC 60947-1:2007),

– the uninterrupted duty (see 4.3.4.2 of IEC 60947-1:2007).

4.3.6 Short-circuit characteristics

4.3.6.1 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of a circuit-breaker is the value of short-circuit making capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage at rated frequency and at a specified power factor for a.c., or time constant for d.c. It is expressed as the maximum prospective peak current.

For a.c. the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor *n* of Table 2 (see 4.3.6.3).

For d.c., the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity.

A rated short-circuit making capacity implies that the circuit-breaker shall be able to make the current corresponding to that rated capacity at the appropriate applied voltage related to the rated operational voltage.

4.3.6.2 Rated short-circuit breaking capacities

4.3.6.2.1 General

The rated short-circuit breaking capacities of a circuit-breaker are the values of short-circuit breaking capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage, under specified conditions.

A rated short-circuit breaking capacity requires that the circuit-breaker shall be able to break any value of short-circuit current up to and including the value corresponding to the rated capacity at a power-frequency recovery voltage corresponding to the prescribed test voltage values and:

– for a.c., at any power factor not less than that of Table 11 (see 8.3.2.2.4);

– for d.c., with any time constant not greater than that of Table 11 (see 8.3.2.2.5).

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 8.3.2.2.6), no short-circuit breaking capacity is guaranteed.

For a.c., the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in Table 11, irrespective of the value of the inherent d.c. component, on the assumption that the a.c. component is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;

– rated service short-circuit breaking capacity.

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4.3.6.2.2 Rated ultimate short-circuit breaking capacity (I_{cu})

The rated ultimate short-circuit breaking capacity of a circuit-breaker is the value of ultimate short-circuit breaking capacity (see 2.15.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.5. It is expressed as the value of the prospective breaking current, in kA (r.m.s. value of the a.c. component in the case of a.c.).

4.3.6.2.3 Rated service short-circuit breaking capacity (I_{cs})

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 2.15.2) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.4. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example I_{cs} = 25 % I_{cu}).

I_{cs} shall be at least equal to 25 % of I_{cu}.

Table 1 (void)

4.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor, for a.c. circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 2.

Table 2 – Ratio *n* between short-circuit making capacity and short-circuit breaking capacity and related power factor (for a.c. circuit-breakers)

Short-circuit breaking capacity kA r.m.s.	Power factor	Minimum value required for n $n = \frac{\text{short - circuit making capacity}}{\text{short - circuit breaking capacity}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 7.2.1.1 and 7.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 2. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

4.3.6.4 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of a circuit-breaker is the value of short-time withstand current assigned to that circuit-breaker by the manufacturer under the test conditions specified in 8.3.6.3.

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For a.c., the value of this current is the r.m.s. value of the a.c. component of the prospective short-circuit current, assumed constant during the short-time delay.

The short-time delay associated with the rated short-time withstand current shall be at least 0,05 s, preferred values being as follows:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

The rated short-time withstand current shall be not less than the appropriate values shown in Table 3.

Table 3 – Minimum values of rated short-time withstand current

Rated current I_n A	Rated short-time withstand current I_{cw} – Minimum values kA
$I_n \leq 2\,500$	12 I_n or 5 kA, whichever is the greater
$I_n > 2\,500$	30 kA

4.4 Selectivity categories

Circuit-breakers according to this standard are divided into two selectivity categories:

– **Selectivity category B** comprises circuit-breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 4.3.6.4.

  Selectivity of circuit-breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.

– **Selectivity category A** comprises all other circuit-breakers.

  These circuit-breakers may provide selectivity under short-circuit conditions by other means.

  A circuit-breaker of selectivity category A may have an intentional short-time delay with a short-time withstand current less than that according to 4.3.6.4. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two selectivity categories (see Table 9 and 8.3.4, 8.3.5, 8.3.6 and 8.3.8).

Table 4 (void)

4.5 Control circuits

4.5.1 Electrical control circuits

Subclause 4.5.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, with the following addition:

If the rated control supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 5.

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Table 5 – Preferred values of the rated control supply voltage, if different from that of the main circuit

Direct current V	Single-phase alternating current V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic)

Subclause 4.5.2 of IEC 60947-1:2007 applies.

4.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

4.7 Releases

4.7.1 Types

For the purpose of this standard, the following types of releases are considered:

1) shunt release;
2) over-current release:
   a) instantaneous;
   b) definite time delay;
   c) inverse time delay:
      – independent of previous load;
      – dependent on previous load (for example thermal type release).

NOTE 1 The term "overload release" is used to identify over-current releases intended for protection against overloads (see 2.4.30 of IEC 60947-1:2007). The term "short-circuit release" is used to identify over-current releases intended for protection against short circuits (see 2.11).

NOTE 2 The term "adjustable release" used in this standard also includes interchangeable releases.

3) undervoltage release (for opening);
4) closing release;
~~4)~~5) other releases.

4.7.2 Characteristics

The following characteristics shall be considered:

1) shunt release and undervoltage release (for opening), and closing release:
   – rated control circuit voltage (U_c);
   – kind of current;
   – rated frequency, if a.c.
2) over-current release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if a.c.;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

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The rated current of an over-current release is the value of current (r.m.s. if a.c.) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 8.3.2.5, without the temperature-rise exceeding the values specified in Table 7.

4.7.3 Current setting of over-current releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 4.7.1, item 2)), the current setting (or range of current-settings, as applicable) shall be marked or displayed on the release or on its scale. The marking or display may be either directly in amperes or as a multiple of the current value. Means shall be available from the manufacturer to read the display regardless of the status of the circuit-breaker.

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 6, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

In the case of indirect releases operated by current transformers, the marking may refer either to the primary current of the current transformer through which they are supplied, or to the current setting of the overload release. In either case, the ratio of the current transformer shall be stated.

Unless otherwise specified

– the operating value of overload releases other than those of the thermal type is independent of the ambient air temperature within the limits of –5 °C to +40 °C;

– for releases of the thermal type, the values stated are for a reference temperature of +30 °C ± 2 °C. The manufacturer shall be prepared to state the influence of variations in the ambient air temperature (see 7.2.1.2.4, item b)).

4.7.4 Tripping time setting of over-current releases

The tripping time shall be stated as follows, depending on the type of over-current release:

1) Definite time-delay over-current releases

   The time-delay of such releases is independent of the over-current. The tripping time setting shall be stated as the duration in seconds of the opening time of the circuit-breaker, if the time-delay is not adjustable, or the extreme values of the opening time, if the time-delay is adjustable.

2) Inverse time-delay over-current releases

   The time-delay of such releases is dependent on the over-current.

   The time/current characteristics shall be given in the form of curves supplied by the manufacturer. These shall indicate how the opening time, starting from the cold state, varies with current within the range of operation of the release. The manufacturer shall indicate, by suitable means, the tolerances applicable to these curves.

   These curves shall be given for each extreme value of the current setting and, if the time setting for a given current setting is adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

   It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006.

4.8 Integral fuses (integrally fused circuit-breakers)

Subclause 4.8 of IEC 60947-1:2007/AMD1:2010 applies.

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The manufacturer shall provide the necessary information.

5 Product information

5.1 Nature of the information

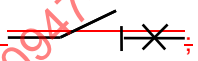
Subclause 5.1 of IEC 60947-1:2007 applies, as far as appropriate for a particular design.

In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 2.1.1). See Annex G.

5.2 Marking

Each circuit-breaker shall be marked in a durable manner; data to be provided and corresponding locations are indicated in Table 13.

~~a) The following data shall be marked on the circuit-breaker itself or on a nameplate or nameplates attached to the circuit-breaker, and located in a place such that they are visible and legible when the circuit-breaker is installed;~~

- ~~rated current (I_n);~~
- ~~suitability for isolation, if applicable, with the symbol  ;~~
- ~~indication of the open and closed positions, with  and  respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007).~~

~~b) The following data shall also be marked externally on the circuit-breaker, as specified in item a), except that they need not be visible when the circuit-breaker is installed;~~

- ~~manufacturer's name or trade mark;~~
- ~~type designation or serial number;~~
- ~~IEC 60947-2 if the manufacturer claims compliance with this standard;~~
- ~~selectivity category;~~
- ~~rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H);~~
- ~~rated impulse withstand voltage (U_{imp});~~
- ~~value (or range) of the rated frequency (for example 50 Hz), and/or the indication "d.c." (or the symbol ⎓);~~
- ~~rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e);~~
- ~~rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e);~~
- ~~rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B;~~
- ~~line and load terminals, unless their connection is immaterial;~~
- ~~neutral pole terminals, if applicable, by the letter N;~~
- ~~protective earth terminal, where applicable, by the symbol  (see 7.1.10.3 of IEC 60947-1:2007);~~
- ~~reference temperature for non-compensated thermal releases, if different from 30 °C;~~
- ~~range of the current setting (I_r) of adjustable overload release;~~
- ~~range of the rated instantaneous short-circuit current setting (I_i), for ajustable releases.~~

~~Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.~~

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c) The following data shall either be marked on the circuit-breaker as specified in item b), or shall be made available in the manufacturer's published information:

- rated short-circuit making capacity (I_{cm}), if higher than that specified in 4.3.6.1;
- rated insulation voltage (U_i), if higher than the maximum rated operational voltage;
- pollution degree if other than 3;
- conventional enclosed thermal current (I_{the}) if different from the rated current;
- IP Code, where applicable (see Annex C of IEC 60947-1:2007/AMD1:2010);
- minimum enclosure size and ventilation data (if any) to which marked ratings apply;
- details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures;
- suitability for environment A or environment B, as applicable;
- r.m.s. sensing, if applicable, according to F.4.1.1;
- minimum cable cross-section, if different from Table 9 of IEC 60947-1:2007, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu};
- values of tightening torque for the circuit-breaker terminals.

a) The following data concerning the opening and closing devices of the circuit-breaker shall be placed either on their own nameplates or on the nameplate of the circuit-breaker; alternatively, if space available is insufficient, they shall be made available in the manufacturer's published information:

- rated control circuit voltage of the closing device (see 7.2.1.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014) and rated frequency for a.c.;
- rated control circuit voltage of the shunt release (see 7.2.1.4 of IEC 60947-1:2007/AMD2:2014) and/or of the under-voltage release (or of the no-voltage release) (see 7.2.1.3 of IEC 60947-1:2007), and rated frequency for a.c.;
- rated current of indirect over-current releases;
- number and type of auxiliary contacts and kind of current, rated frequency (if a.c.) and rated voltages of the auxiliary switches, if different from those of the main circuit.

b) Terminal marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies (see also item b) above).

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Table 13 – Product information

Item	Information	Marking location
1.1	rated current (I_n)	Visible
1.2	suitability for isolation, if applicable, with the symbol  (IEC 60617-S00288:2001-07 combined with IEC 60617-S00219:2001-07)	Visible
1.3	indication of the open and closed position with O (IEC 60417-5008;2002-10) and I (IEC 60417-5007;2002-10) respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007)	Visible
2.1	manufacturer's name or trade mark	Marked
2.2	type designation or catalogue reference	Marked
2.3	IEC 60947-2, if the manufacturer claims compliance with the standard	Marked
2.4	selectivity category A or B	Marked
2.5	rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H)	Marked
2.6	unsuitability for IT systems, if applicable, with the symbol  (IEC 60417-6363:2016-07)	Marked
2.7	rated impulse withstand voltage (U_{imp})	Marked
2.8	value (or range) of the rated frequency, and/or the indication "d.c." for the symbol ⎓ (IEC 60417-5031:2002-10))	Marked
2.9	rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e)	Marked
2.10	rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e)	Marked
2.11	rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B	Marked
2.12	range of the current setting (I_r) of the adjustable overload release	Marked [a]
2.13	range of the rated instantaneous short-circuit current setting (I_i), for adjustable releases	Marked [a]
2.14	reference temperature for non-compensated thermal releases, if different from 30 °C	Marked
2.15	terminals identification, according to 7.1.8.4 of IEC 60947-1:2007	Marked
2.16	line and load terminals, if applicable	Marked
2.17	neutral pole terminals, if applicable, by the letter N	Marked
2.18	protective earth terminal, where applicable, by the symbol  (IEC 60417-5019:2006-08) (see 7.1.10.3 of IEC 60947-1:2007)	Marked
3.1	rated short-circuit making capacity (I_{cm}), if higher than that specified in 4.3.6.1	Literature
3.2	rated insulation voltage (U_i), if higher than the maximum rated operational voltage	Literature
3.3	pollution degree if other than 3	Literature
3.4	conventional enclosed thermal current (I_{the}) if different from the rated current	Literature
3.5	IP code, where applicable (see Annex C of IEC 60947-1:2007/AMD1:2010)	Literature
3.6	minimum enclosure size and ventilation data (if any) to which marked ratings apply	Literature
3.7	details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures	Literature
3.8	suitability for environment A or environment B per Annex J, as applicable	Literature
3.9	RMS sensing, if applicable, in accordance with F.4.1.1	Literature
3.10	minimum cable cross-section, if different from Table 9 of IEC 60947-1:2007, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu}	Literature
3.11	values of tightening torque for the circuit-breaker terminals	Literature
3.12	current derating for terminals and connections, if applicable	Literature
4.1	for closing releases (see 2.23) and/or motor-operators, rated control circuit voltage, kind of current and rated frequency for a.c.	Aux

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Item	Information	Marking location
4.2	rated control circuit voltage of the shunt release and/or of the under-voltage release (or of the no-voltage release), kind of current and rated frequency for a.c.	Aux
4.3	rated current of indirect over-current releases	Aux
4.4	number and type of auxiliary contacts, rated operational currents at the rated operational voltages, and rated frequency for a.c.	Aux
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked:marked on the circuit-breaker Literature:provided in the manufacturer's literature Aux:marked on the auxiliaries or on the circuit-breaker, if marking space is sufficient; additionally, data shall be made available in the manufacturer's literature		
[a] Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.		

5.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Additional information for the decommissioning and dismantling of the circuit-breaker shall be provided to the user in the case of a foreseeable hazardous condition, for example due to stored energy or hazardous substances.

6 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Pollution degree (see 6.1.3.2 of IEC 60947-1:2007).

Unless otherwise stated by the manufacturer, a circuit-breaker is intended for installation under environmental conditions of pollution degree 3.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

Subclause 7.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies with the following modifications:

The requirements of 7.1.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 do not apply to parts with a mass lower than 2 g (insignificant mass, in accordance with 3.14 of IEC 60695-2-11:2014). For products containing a plurality of small parts, the total mass of non-tested parts located in close proximity to each other shall not exceed 10 g. Proximity shall be based on engineering judgment that takes into consideration the risk of propagation of fire.

Where, in 7.1.2.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, the test temperature is to be specified, ~~the test temperature required by this standard is 960 °C~~ the value required by this document for the parts necessary to retain in position current-carrying parts is:

– 960 °C for the main circuit;

– 850 °C for the other circuits.

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7.1.2 Withdrawable circuit-breakers

In the disconnected position, the isolating contacts of the main circuit and, where applicable, auxiliary circuits of withdrawable circuit-breakers shall have isolating distances which comply with the requirements specified for the isolating function, taking account of manufacturing tolerances and changes in dimensions due to wear.

The withdrawable mechanism shall be fitted with a reliable indicating device which indicates unambiguously the positions of the isolating contacts.

The withdrawable mechanism shall be fitted with interlocks which only permit the isolating contacts to be separated or reclosed when the main contacts of the circuit-breaker are open.

In addition, the withdrawable mechanism shall be fitted with interlocks which only permit the main contacts to be closed

– when the isolating contacts are fully closed, or
– when the specified isolating distance is achieved between the fixed and moving parts of the isolating contacts (disconnected position).

When the circuit-breaker is in the disconnected position, means shall be provided to ensure that the specified isolating distances between the isolating contacts cannot be inadvertently reduced.

7.1.3 Additional requirements for circuit-breakers suitable for isolation

For additional requirements concerning performance, see 7.2.7.

Subclause 7.1.7 of IEC 60947-1:2007/AMD1:2010 applies with the following addition:

If the tripped position is not the indicated open position, it should be clearly identified.

7.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2007 and in Table 15 of IEC 60947-1:2007/AMD1:2010.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:2007, clearances shall be obtained from Table F.2 of IEC 60664-1:2007.

7.1.5 Requirements for the safety of the operator

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

Compliance is checked by the provisions of 8.3.2.6.1, item b).

7.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 2.1.2) if any one of the following features are not the same:

– material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
– size, material, configuration and method of attachment of the main contacts;
– any integral manual operating mechanism, its materials and physical characteristics;
– moulding and insulating materials;

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– the principle of operation, materials and construction of the arc extinction device;

– the basic design of the over-current tripping devices, admitting, however, the variations detailed in a), b) and c) below.

Variations in the following do not constitute a construction break:

a) dimensions of terminals, provided that creepage and clearance distances are not reduced;

b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;

c) secondary windings of current transformer operated releases;

d) external operating means, additional to the integral operating means;

e) type designation and/or purely aesthetic features (e.g. labels);

f) in the case of the 2-pole and 4-pole variants, replacement of the trip unit in one pole by a link, to provide an unprotected neutral;

g) creating a 2-pole breaker from a 3-pole breaker by removing the centre current path;

h) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;

i) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

7.1.7 Additional requirements for circuit-breakers provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies with the following addition:

If a pole with an appropriate making and breaking capacity is used as a neutral pole, then all poles, including the neutral pole, may operate substantially together.

7.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs)

Annex S of IEC 60947-1:2007 applies. For the purposes of this standard, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

7.2 Performance requirements

7.2.1 Operating conditions

7.2.1.1 Closing

7.2.1.1.1 General

For a circuit-breaker to be closed safely on to the making current corresponding to its rated short-circuit making capacity, it is essential that it should be operated with the same speed and the same firmness as during the type test for proving the short-circuit making capacity.

7.2.1.1.2 Dependent manual closing

For a circuit-breaker having a dependent manual closing mechanism, it is not possible to assign a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

Such a circuit-breaker should not be used in circuits having a prospective peak making current exceeding 10 kA.

However, this does not apply in the case of a circuit-breaker having a dependent manual closing mechanism and incorporating an integral fast-acting opening release which causes the circuit-breaker to break safely, irrespective of the speed and firmness with which it is

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closed on to prospective peak currents exceeding 10 kA; in this case, a rated short-circuit making capacity can be assigned.

7.2.1.1.3 Independent manual closing

A circuit-breaker having an independent manual closing mechanism can be assigned a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

7.2.1.1.4 Dependent power closing

The power-operated closing mechanism, including intermediate control relays where necessary, shall be capable of securing the closing of the circuit-breaker in any condition between no-load and its rated making capacity, when the supply voltage, measured during the closing operation, remains between the limits of 110 % and 85 % of the rated control supply voltage, and, when a.c., at the rated frequency.

At 110 % of the rated control supply voltage, the closing operation performed on no-load shall not cause any damage to the circuit-breaker.

At 85 % of the rated control supply voltage, the closing operation shall be performed when the current established by the circuit-breaker is equal to its rated making capacity within the limits allowed by the operation of its relays or releases and, if a maximum time limit is stated for the closing operation, in a time not exceeding this maximum time limit.

7.2.1.1.5 Independent power closing

A circuit-breaker having an independent power closing operation can be assigned a rated short-circuit making capacity irrespective of the conditions of power closing.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating in accordance with the manufacturer's specification.

7.2.1.1.6 Stored energy closing

This type of closing mechanism shall be capable of ensuring closing of the circuit-breaker in any condition between no-load and its rated making capacity.

When the stored energy is retained within the circuit-breaker, a device shall be provided which indicates when the storing mechanism is fully charged.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating when the auxiliary supply voltage is between 85 % and 110 % of the rated control supply voltage.

It shall not be possible for the moving contacts to move from the open position unless the charge is sufficient for satisfactory completion of the closing operation.

When the energy storing mechanism is manually operated, the direction of operation shall be indicated.

This last requirement does not apply to circuit-breakers with an independent manual closing operation.

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7.2.1.2 Opening

7.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 2.4.23 of IEC 60947-1:2007) and, unless otherwise agreed between manufacturer and user, circuit-breakers shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

7.2.1.2.2 Opening by undervoltage releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies.

7.2.1.2.3 Opening by shunt releases

Subclause 7.2.1.4 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.1.2.4 Opening by over-current releases

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker with an accuracy of ±20 % of the tripping current value of the current setting for all values of the current setting of the short-circuit current release.

Where necessary for over-current co-ordination (see 2.17), the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 2.5.19 of IEC 60947-1:2007) as a function of prospective current (r.m.s. symmetrical);

– I^2t characteristics (see 2.18) for circuit-breakers of selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 8.3.5.1).

Conformity with this information may be checked during the relevant type tests in test sequences II and III (see 8.3.4 and 8.3.5).

NOTE 1 It is possible to provide other forms of data to verify co-ordination characteristics of circuit-breakers, for example, tests on combinations of short-circuit protective devices.

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

The release shall cause tripping of the circuit-breaker with an accuracy of ±10 % of the tripping current value of the current setting for all values of current setting of the overload release.

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 6.

At the reference temperature (see 4.7.3) and at 1,05 times the current setting (see 2.4.37 of IEC 60947-1:2007), i.e. with the conventional non-tripping current (see 2.5.30 of IEC 60947-1:2007), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 2.5.30 of IEC 60947-1:2007) from the cold state, i.e. with the circuit-breaker at the reference temperature.

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see 2.5.31 of IEC 60947-1:2007), tripping shall then occur in less than the conventional time later.

NOTE 2 The reference temperature is the ambient air temperature on which the time-current characteristic of the circuit-breaker is based.

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Table 6 – Characteristics of the opening operation of inverse time-delay over-current opening releases at the reference temperature

All poles loaded		Conventional time h
Conventional non-tripping current	Conventional tripping current	
1,05 times current setting	1,30 times current setting	2 [a]
[a] 1 h when $I_n \leq 63$ A		

If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 6 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 %/K.

The width of the temperature band shall be at least 10 K on either side of the reference temperature.

7.2.2 Temperature-rise

7.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 8.3.2.5, shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.3.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.4.5 and 8.3.6.4.

7.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 7 are applicable only if the ambient air temperature remains within the limits given in 6.1.1 of IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the over-current releases ~~which~~ that may be associated with it, shall be capable of carrying its rated current I_n, under the conditions of Clause 8, without the temperature~~-~~ rises exceeding the limits specified in Table 7.

7.2.2.4 Control circuits

The control circuits, including control circuit devices, used for the closing and opening operations of a circuit-breaker, shall permit the rated duty, as specified in 4.3.5, and also the temperature-rise tests under the test conditions specified in 8.3.2.5, to be made without the temperature rises exceeding the limits specified in Table 7.

The requirements of this subclause shall be verified on a new circuit-breaker. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 8.3.3.7.

7.2.2.5 Auxiliary circuits

Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional thermal current without the temperature-rises exceeding the limits specified in Table 7 when tested in accordance with 8.3.2.5.

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Table 7 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which need not be touched for normal operation:	
Metallic	50
non-metallic	60
[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.	
[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 8.	

7.2.3 Dielectric properties

7.2.3.1 General

Subclauses 7.2.3 a) and 7.2.3 b) of IEC 60947-1:2007 apply.

Type tests shall be made in accordance with 8.3.3.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 8.3.3.6.

Routine tests shall be made in accordance with 8.4.6.

7.2.3.2 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1:2007 applies.

For circuit-breakers rated above 1 000 V a.c., the impulse withstand voltage shall be agreed between the manufacturer and the user but shall not be less than the corresponding values for 1 000 V a.c.

7.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

Power-frequency tests are used in the following cases:

– dielectric tests as type tests for the verification of solid insulation;
– dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
– routine tests.

7.2.3.4 Clearances

Subclause 7.2.3.3 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.3.5 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

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7.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 8.3.3.4.1, item 3) of IEC 60947-1:2007/AMD1:2010/AMD2:2014, or d.c. tests (test voltages for d.c. tests are under consideration).

For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests.

7.2.3.7 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

7.2.4 Ability to make and break under no load, normal load and overload conditions

7.2.4.1 Overload performance

This requirement applies to circuit-breakers of rated current up to and including 630 A.

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 8.3.3.5.

Each operating cycle consists of a making operation followed by a breaking operation.

7.2.4.2 Operational performance capability

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 8:

– for the test of operational performance without current in the main circuit under the test conditions specified in 8.3.3.4.3;
– for the test of operational performance with current in the main circuit under the test conditions specified in 8.3.3.4.4.

Each operating cycle consists of, either a closing operation followed by an opening operation (test of operational performance without current), or a making operation followed by a breaking operation (test of operational performance with current).

Table 8 – Number of operating cycles

1	2	3	4	5
Rated current [a]	Number of operating cycles per hour [b]	Number of operating cycles		
A		Without current	With current [c]	Total
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

[a] This means the maximum rated current for a given frame size.
[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.
[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

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7.2.5 Ability to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 4.3.6.1 and 4.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 4.3.6.2.

The rated short-time withstand current shall be in accordance with 4.3.6.4.

NOTE It is the manufacturer's responsibility to ensure that the tripping characteristic of the circuit-breaker is compatible with the capability of the circuit-breaker to withstand the inherent thermal and electrodynamic stresses.

7.2.6 Vacant

7.2.7 Additional requirements for circuit-breakers suitable for isolation

Subclause 7.2.7 of IEC 60947-1:2007 applies and tests shall be made in accordance with 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 and 8.3.7.8, as applicable.

7.2.8 Specific requirements for integrally fused circuit-breakers

NOTE For the co-ordination between circuit-breakers and separate fuses associated in the same circuit, see 7.2.9.

An integrally fused circuit-breaker shall comply with this standard in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 8.3.7).

The circuit-breaker shall function, without causing the fuses to operate, at the occurrence of over-currents not exceeding the selectivity limit current I_s declared by the manufacturer.

For all over-currents up to and including the rated ultimate short-circuit breaking capacity assigned to the composite unit, the circuit-breaker shall open when one or more fuses operate (in order to prevent single-phasing). If the circuit-breaker is stated by the manufacturer to be with lock-out device preventing closing (see 2.14), it shall not be possible to reclose the circuit-breaker until either the melted fuse-links or any missing fuse-links have been replaced or the lock-out means has been reset.

7.2.9 Co-ordination between a circuit-breaker and another short-circuit protective device

For the co-ordination between a circuit-breaker and another short-circuit protective device, see Annex A.

7.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

8 Tests

8.1 Kind of tests

8.1.1 General

Subclause 8.1 of IEC 60947-1:2007 applies, with the following additions:

The tests to verify the characteristics of circuit-breakers are:

– type tests (see 8.3);

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– routine tests (see 8.4);

– special tests (see 8.5).

8.1.2 Type tests

Type tests include the following tests:

Test	Subclause
Temperature-rise	8.3.2.5
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Short-circuit breaking capacities	8.3.4 and 8.3.5
Short-time withstand current (where applicable)	8.3.6
Performance of integrally fused circuit-breakers	8.3.7
Critical d.c. load current	8.3.9

Type tests shall be carried out by the manufacturer, in his workshop or at any suitable laboratory of his choice.

8.1.3 Routine tests

Routine tests comprise the tests listed in 8.4.

8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

8.3 Type tests

In order to avoid repetition of identical tests applicable to the various test sequences, the general test conditions have been grouped together at the beginning of this subclause under three headings:

– test conditions applicable to all sequences (8.3.3 to 8.3.8);

– test conditions applicable to temperature-rise tests (8.3.2.5);

– test conditions applicable to short-circuit tests (8.3.2.6).

Wherever appropriate, these general test conditions refer back to, or are based on, the general rules of IEC 60947-1.

Each test sequence refers back to the general test conditions applicable. This requires the use of cross-references, but enables each test sequence to be presented in a much simplified form.

Throughout this clause the term "test" has been used for every test to be made; "verification" should be interpreted as "test for the verification" and has been used where it is intended to verify the condition of the circuit-breaker following an earlier test in a test sequence whereby it may have been adversely affected.

In order to facilitate locating a particular test condition or test, an alphabetical index is given ~~in 8.3.1.3~~ below, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

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8.3.1 Test sequences

8.3.1.1 General

Type tests are grouped together in a number of sequences, as shown in Table 9.

For each sequence, tests shall be made in the order listed unless otherwise specified in this standard.

8.3.1.2 Tests omitted from sequence I and made separately

With reference to 8.1.1 of IEC 60947-1:2007, the following tests of test sequence I (see 8.3.3) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (8.3.3.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 8.3.3.2.3 only on the phase poles at the maximum setting, at room temperature and without the additional test of item b) to verify the time-current characteristic;

– test of dielectric properties (8.3.3.3);

– test of under-voltage releases of 8.3.3.4.2.3 and 8.3.3.4.3 to verify the requirements of 7.2.1.3 of IEC 60947-1:2007, and tests of under-voltage releases at alternative frequencies (see 8.3.2.1);

– test of shunt releases of 8.3.3.4.2.4 and 8.3.3.4.3 to verify the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014, and tests of shunt releases at alternative frequencies (see 8.3.2.1);

– additional tests for operational performance capability without current for withdrawable circuit-breakers (8.3.3.4.5).

8.3.1.3 Applicability of sequences according to the relationship between short-circuit ratings

The applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} is given in Table 9a.

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Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	8.3.2.1
Arrangement of circuit-breakers for short-circuit tests	8.3.2.6.1
Frequency	8.3.2.2.3
Power factor	8.3.2.2.4
Records (interpretation of)	8.3.2.6.6
Recovery voltage	8.3.2.2.6
Short-circuit test circuits	8.3.2.6.2
Short-circuit test procedure	8.3.2.6.4
Temperature-rise test	8.3.2.5
Time constant	8.3.2.2.5
Tolerances	8.3.2.2.2
Tests (for overall schema of test sequences, see Table 9)	**Subclause**
Critical d.c. load current	8.3.9
Dielectric properties	8.3.3.3
Dielectric withstand (verification)	8.3.3.6 – 8.3.4.4 – 8.3.5.4 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.6
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H – see H.2
Indication of main contact position	8.3.3.10
Integrally fused circuit-breakers (short-circuit tests)	8.3.7.2 – 8.3.7.6 – 8.3.7.7
Operational performance capability	8.3.3.4 – 8.3.4.3 – 8.3.4.5
Overload performance	8.3.3.5
Overload releases (verification)	8.3.3.8 – ~~8.3.4.5~~ 8.3.4.6 – 8.3.5.2 – 8.3.5.5 – 8.3.6.2 – 8.3.6.7 – 8.3.7.5 – 8.3.7.9 – 8.3.8.2 – 8.3.8.8
Service short-circuit breaking capacity	8.3.4.2 – 8.3.8.4
Short-circuit breaking capacity test at maximum short-time withstand current	8.3.6.5
Short-time withstand current	8.3.6.3 – 8.3.8.3
Temperature-rise (verification)	8.3.3.7 – 8.3.4.5 – 8.3.6.4 – 8.3.7.3 – 8.3.8.7
Tripping limits and characteristics	8.3.3.2
Ultimate short-circuit breaking capacity	8.3.5.3
Withdrawable circuit-breakers (additional tests)	8.3.3.4.5

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Table 9 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (8.3.3)	All circuit-breakers	Tripping limits and characteristics Dielectric properties Mechanical operation and operational performance capability Overload performance (where applicable) Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Verification of undervoltage and shunt releases (where applicable) Verification of main contact position (where applicable)
II Rated service short-circuit breaking capacity (8.3.4)	All circuit-breakers [b]	Rated service short-circuit breaking capacity Verification of operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
III Rated ultimate short-circuit breaking capacity (8.3.5)	All circuit-breakers [c] of selectivity category A and circuit-breakers of selectivity category B with instantaneous override[d]	Verification of overload releases Rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
IV Rated short-time withstand current (8.3.6)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with ~~a rated~~ an assigned short-time withstand current (see 4.4)	Verification of overload releases Rated short-time withstand current Verification of temperature-rise Short-circuit breaking capacity at maximum short-time withstand current Verification of dielectric withstand Verification of overload releases
V Performance of integrally fused circuit-breakers (8.3.7)	Stage 1 Integrally fused circuit-breakers Stage 2	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand Verification of overload releases Short-circuit at 1,1 times the take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
VI Combined test sequence (8.3.8)	Circuit-breakers of selectivity category B: when $I_{cw} = I_{cs}$ (replaces test sequences II and IV) when $I_{cw} = I_{cs} = I_{cu}$ (replaces test sequences II, III and IV)	Verification of overload releases Rated short-time withstand current Rated service short-circuit breaking capacity Operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
Critical d.c. load current (8.3.9)	Circuit-breakers with d.c. ratings	Critical d.c. load current tests
Individual pole short-circuit test sequence (Annex C)	Circuit-breakers for use on phase-earthed systems	Individual pole short-circuit breaking capacity (I_{su}) Verification of dielectric withstand Verification of overload releases
Test sequence for circuit-breakers for IT systems (Annex H)	Circuit-breakers for use in IT systems	Individual pole short-circuit breaking capacity (I_{IT}) Verification of dielectric withstand Verification of overload releases

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a For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs} , I_{cu} and I_{cw}, see Table 9a.
b Except where Sequence VI is applied.
c Except
– where $I_{cs} = I_{cu}$ (but see 8.3.5),
– where sequence VI is applied,
– for integrally fused circuit-breakers.
d See note to 8.3.5.1

Table 9a – Applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} [a]

I_{cs}, I_{cu} and I_{cw} relationship	Test sequence	Selectivity category			
		A	A Integrally fused	B	B Integrally fused
CASE 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ for selectivity category A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ for selectivity	II			X	X
category B	III			X [b]	
	IV			X	X
	V				X
	VI (combined)			X [c]	X [c]
CASE 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ for selectivity category A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ for selectivity	III				
category B	IV			X	
	V				
	VI (combined)			X [c]	

a This table applies to any one value of U_e. For multiple U_e ratings, the table applies to each U_e rating. The applicability of a test sequence is indicated by X in the relevant space.
b Test applicable only if $I_{cu} > I_{cw}$.
c At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of selectivity category B, in which case it replaces test sequences II and IV.
d Test sequence IV applies only to circuit-breakers with a rated short-time withstand current (see 4.4).

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8.3.1.4 Alternative test programmes for a.c. circuit-breakers having a different number of poles

These alternative test programmes may only be applied to a.c. ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 9, and construction breaks are the same for all variants. In the case of 1-pole circuit-breakers the voltage ratings shall be equal to or lower than the line-to neutral voltage of the variant tested to Table 9. A 2-pole circuit-breaker produced by removing the centre current path from a 3-pole circuit-breaker tested to programme 1 or programme 2 of this subclause need not be tested as it is considered to be covered by the tests on the 3-pole variant.

Compliance with the test requirements is met by carrying out one of the alternative programmes 1 or 2 below.

– Programme 1: The applicable test sequences according to Table 9 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9b shall be carried out on the other variants.
– Programme 2: The applicable test sequences according to Table 9 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9c shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated below:

	Programme 1					**Programme 2**			
	1-pole	2-poles	3-poles	4-poles		1-pole	2-poles	3-poles	4-poles
Construction 1[a]	□	□	■	□		○	○	○	■
Construction 2	–	–	■	□		–	–	–	■
Construction 3	–	–	■	□		–	–	–	■
…	–	–	■	□		–	–	–	■
Construction *n*	–	–	■	□		–	–	–	■
Key	■ fully tested per Table 9 □ tested per Table 9b ○ tested per Table 9c – no test required								
[a] Construction 1 is the construction which covers the max rating.									

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Table 9b – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General	X	X
	8.3.3.2.2	Short-circuit releases	X[a]	X[e]
	8.3.3.2.3 a)[k] – instantaneous/definite time-delay – inverse time-delay or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: 	X X	 X[e]
	8.3.3.2.4	Additional test for definite time-delay releases:		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation	X[d]	X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers	X	
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current	X 4th pole and adjacent pole only (see 8.3.2.6.4)	
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breakers for IT systems		

NOTE The applicability of a test or test sequence is indicated by X in the relevant space.

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[a] One test on one pair of phase poles chosen at random. In the case of an electronic trip unit, this test may be made on one pole chosen at random.

[b] This test sequence also applies when, for the 3-pole testing, Sequence III on the 3-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] ~~One sample of maximum current rating only, tested~~ Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] In case of 4-poles devices with different levels of neutral protection (e.g. 60 % or 100 %), only the variant with the highest level has to be tested according to Table 9b.

[g] One sample of maximum current rating only, for each test sequence.

[h] One sample of maximum current rating for each test sequence; in the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

Table 9c – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General		X
	8.3.3.2.2	Short-circuit releases		X [e]
	8.3.3.2.3 a)[k] or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: – instantaneous/definite time-delay – inverse time-delay		X[e]
	8.3.3.2.4	Additional test for definite time-delay releases		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation		X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers		
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current		
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		

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Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breaker for IT systems		

NOTE The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Vacant.

[b] This test sequence also applies when, for the 4-poles testing, Sequence III on the 4-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] ~~One sample of maximum current rating only, tested~~ Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] Vacant.

[g] One sample of maximum current rating only, for each test sequence.

[h] Vacant.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

8.3.2 General test conditions

NOTE Tests according to the requirements of this standard do not preclude the need for additional tests concerning circuit-breakers incorporated in assemblies, for example tests in accordance with IEC 61439 series.

8.3.2.1 General requirements

Unless otherwise agreed by the manufacturer, each test sequence shall be made on a sample circuit-breaker (or set of samples) in a clean and new condition.

The number of samples to be tested for each test sequence and the test conditions (for example setting of overload releases, terminal connections), according to the circuit-breaker parameters, are given in Table 10 or, where applicable, for the alternative test programmes in Table 9b and Table 9c (see 8.3.1.4).

Where necessary, additional information is given in the relevant subclauses.

Unless otherwise specified, tests are to be performed on a circuit-breaker having the maximum rated current for a given frame size and are deemed to cover all rated currents of that frame size.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, further samples shall be tested in accordance with Table 9b and/or Table 10 as applicable.

Unless otherwise stated, short-circuit releases shall be set at maximum (time and current) for all tests.

The circuit-breakers to be tested shall, in all their essential details, correspond to the design of the type which they represent.

Unless otherwise stated, the tests shall be made with the same kind of current and, in the case of a.c., at the same rated frequency and with the same number of phases as in the intended service. Tests performed at 50 Hz cover 60 Hz applications and vice-versa, except for the performance of under-voltage and shunt releases (see 7.2.2 of IEC 60947-1:2007/AMD2:2010 and 7.2.2.6 of IEC 60947-1:2007).

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If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 7.2.1.1.4. In addition, electrically controlled mechanisms shall be energized via the appropriate circuit-breaker control circuits complete with switching devices. It shall be verified that the circuit-breaker operates correctly on no-load when it is operated under the above conditions.

In case of circuit-breakers with dependent manual operation (see 2.4.12 of 60947-1:2007), the circuit-breaker shall be operated with an operating speed, during actuation, of 0,1 m/s ± 25 %, this speed being measured where the operating means of the test apparatus touches the actuating means of the circuit-breaker under test. For rotary handles the angular velocity shall correspond substantially to the above conditions, referred to the speed of the operating means (at its extremities) of the circuit-breaker under test.

The circuit-breaker under test shall be mounted complete on its own support or an equivalent support.

Circuit-breakers shall be tested in free air.

If a circuit-breaker may be used in specified individual enclosures and has been tested in free air, it shall be additionally tested in the smallest of such enclosures stated by the manufacturer, using a new sample, for each of the following:

a) A short-circuit test according to 8.3.5, at U_e max, and corresponding I_{cu}, with release settings at maximum (see Footnote [a] of Table 10).

b) A temperature rise test according to the general conditions of 8.3.2.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 4.3.3.2). The temperature rises shall meet the requirements of 7.2.2 except that the temperature rise of the terminals shall not exceed 70 K.

Details of these tests, including the dimensions of the enclosure, shall be stated in the test report.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one circuit-breaker only.

However, if a circuit-breaker may be used in specified individual enclosures and is tested throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air need not be made provided that such enclosure is bare metallic, without insulation. Details, including the dimensions of the enclosure, shall be stated in the test report.

~~For the tests in free air, for tests concerning overload performance (8.3.3.5), short-circuit (8.3.4.2, 8.3.5.8, 8.3.6.5, 8.3.7.2, 8.3.7.6, 8.3.7.7 and 8.3.8.4), and short-time withstand current (8.3.6.3 and 8.3.8.3) where applicable, a metallic screen shall be placed on all sides of the circuit-breaker in accordance with the manufacturer's instructions. Details, including distances of the metallic screen from the circuit-breaker, shall be stated in the test report.~~

For the tests in free air concerning overload performance, short-circuit, and short-time withstand current where applicable, a metallic screen shall be placed on all sides of the circuit-breaker in accordance with the manufacturer's instructions. Details, including distances of the metallic screen from the circuit-breaker, shall be stated in the test report.

The characteristics of the metallic screen shall be as follows:

- structure: woven wire mesh; or
  perforated metal; or
  expanded metal;
- ratio hole area/total area: 0,45 to 0,65;
- size of hole: not exceeding 30 mm^2;

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- finish: bare or conductive plating;
- resistance: shall be included in the calculation for the prospective fault current in the fusible element circuit (see 8.3.4.1.2, item d) of IEC 60947-1:2007) when measured from the furthest point on the metallic screen likely to be reached by arc emissions.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see ~~5.2 e)~~ Table 13, item 3.11).

Maintenance or replacements of parts is not permitted.

If, for convenience of testing, it appears useful to increase the severity of a test (for example to adopt a higher frequency of operation in order to reduce the duration of the test), this shall not be done without the consent of the manufacturer.

For single-phase tests on individual poles of multipole circuit-breakers intended for use on phase-earthed systems, see Annex C.

For additional tests for circuit-breakers for unearthed or impedance earth systems (IT), see Annex H.

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Table 10 – Number of samples for test *(1 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temper-ature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 8.3.3		X	g
II (I_{cs}) and VI (combined)	X			X		2	1		X	U_e	X		X	h
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X		X	h
							2	X		U_e	X			b
							3		X	U_e	X		X	j
		X		X	X	3	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e max	X		X	k
			X	X	X	4	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X		X	e
							4		X	U_e max	X		X	k
III (I_{cu})	X			X		2	1		X	U_e	X			g
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X			g
							2	X		U_e	X			b
							3		X	U_e	X			c
		X		X	X	3	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X			e
							4		X	U_e max	X			d

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Table 10 *(2 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Temperature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	g
							2		X	U_e max		X		X	X	m
			X	X	X	3	1		X	U_e max corr.		X	X		X	g
							2		X	U_e max corr.	X		X		X	i
							3		X	U_e max	X		X		X	n, d
V Integral fused (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	f, g
							2	X		U_e max	X					b
Individual pole (Annex C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					g
							2	X		U_e max	I_{su}					–
Individual pole (Annex H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					g

Key

Mul. = multiple; Corr. = corresponding; Intermed. = intermediate

NOTE 1 Table 10 applies to the test programmes of Table 9. In the case of the alternative test programmes (see 8.3.1.4), Table 9b and Table 9c are applicable.

NOTE 2 The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Min means the minimum I_n of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum I_n. Max means the maximum I_n of a given frame size.

[b] This sample is omitted in the following cases:

–a circuit-breaker having a single non-adjustable current setting for a given frame size;

–a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);

–a circuit-breaker with electronic overcurrent protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).

[c] Connections reversed.

[d] Connections reversed, if terminals unmarked.

[e] To be agreed between testing station and manufacturer.

[f] If terminals unmarked, an additional sample shall be tested with connections reversed.

[g] In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction, under the conditions applicable to sample 1.

[h] The requirement of footnote g applies to sequence VI (combined) and also to sequence II where $I_{cs} = I_{cu}$.

[i] This sample is selected based on the highest value of thermal energy (I_{cw}^2t; where "t" is the corresponding short-time delay, see 4.3.6.4). This sample is omitted if the highest thermal energy condition is met by sample 1 or 3.

[j] This sample, with connections reversed, is only required when sequence III is replaced by sequence II (I_{cu}= I_{cs}, see 8.3.5).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced by sequence II ($I_{cu} = I_{cs}$, see 8.3.5) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 8.3.8), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 4.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

[n] This sample is only required when sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

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8.3.2.2 Test quantities

8.3.2.2.1 Values of test quantities

Subclause 8.3.2.2.1 of IEC 60947-1:2007 applies.

8.3.2.2.2 Tolerances on test quantities

Subclause 8.3.2.2.2 of IEC 60947-1:2007 applies.

8.3.2.2.3 Frequency of the test circuit for a.c.

All tests shall be made at the rated frequency of the circuit-breaker. For all short-circuit tests, if the rated breaking capacity is essentially dependent on the value of the frequency, the tolerance shall not exceed ±5 %.

If the manufacturer declares the rated breaking capacity to be substantially unaffected by the value of the frequency, the tolerance shall not exceed ±25 %.

8.3.2.2.4 Power factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

Table 11 – Values of power factors and time constants corresponding to test currents

Test current *I* kA	Power factor			Time constant ms		
	Short-circuit	Operational performance capability	Overload	Short-circuit	Operational performance capability	Overload
$I \leq 3$	0,9			5		
$3 < I \leq 4{,}5$	0,8			5		
$4{,}5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5	0,8	0,5	5	2	2,5
$10 < I \leq 20$	0,3			10		
$20 < I \leq 50$	0,25			15		
$50 < I$	0,2			15		

8.3.2.2.5 Time constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

8.3.2.2.6 Power-frequency recovery voltage

Subclause 8.3.2.2.3, item a) of IEC 60947-1:2007/AMD2:2014 applies.

8.3.2.2.7 Ripple of the test current for d.c.

The test current shall comply with the requirements of 6.3.1 of IEC 62475:2010.

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8.3.2.3 Evaluation of test results

The condition of the circuit-breaker after tests shall be checked by the verifications applicable to each sequence.

A circuit-breaker is deemed to have met the requirements of this standard if it meets the requirements of each sequence as applicable.

The case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of a superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

8.3.2.4 Test reports

Subclause 8.3.2.4 of IEC 60947-1:2007 applies.

8.3.2.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 7.2.2.

Subclause 8.3.3.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except 8.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 8.3.2.1.

During the temperature rise test of sequence I (see 8.3.3.7) coils of under-voltage releases, where applicable, shall be supplied at one rated frequency and corresponding voltage, chosen at random. Additional tests to verify coils at other rated frequencies and voltages shall be made outside the sequence.

~~For four-pole circuit-breakers, a test shall first be made on the three poles which incorporate over-current releases. For a circuit-breaker having a value of rated current not exceeding 63 A, an additional test shall be made by passing the test current through the fourth pole and its adjacent pole. For higher rated current values, the method of testing shall be the subject of a separate agreement between manufacturer and user.~~

For four-pole circuit-breakers, a test shall first be carried out on the 3-phase poles; for the neutral pole, the additional single-phase test of 8.3.3.3.4 of IEC 60947-1:2007 applies only when there is a construction break between the neutral pole and the phase poles (see 7.1.6), in which case the test current is the rated current of the neutral pole.

8.3.2.6 Test conditions for short-circuit tests

8.3.2.6.1 General requirements

Subclause 8.3.4.1.1 of IEC 60947-1:2007 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 8.3.2.1.

b) Unless it can be shown that, with the manual operating means in any position, there is no opening around the manual operating means through which a music wire of 0,26 mm diameter can be inserted so as to reach the arc chamber area, the following test arrangement shall apply:

   For opening operations only, a clear, low density polyethylene sheet, 0,05 mm ± 0,01 mm thick, of a size 100 mm × 100 mm, positioned as shown in Figure 1, fixed and reasonably stretched in a frame, is placed at a distance of 10 mm from:

   – either the maximum projection of the manual closing means of a circuit-breaker without recess for this closing means;

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– or the rim of the recess for the manual closing means of a circuit-breaker with recess for this closing means.

The polyethylene sheet shall have the following physical properties:

– density at 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3;

– melting point: 110 °C to 120 °C.

On the side remote from the circuit-breaker there shall be an appropriate backing to obviate tearing of the polyethylene sheet due to the pressure wave which may occur during the short-circuit test (see Figure 1).

For tests other than those in an individual enclosure, a shield which may be of insulating material or of metal is placed between the metallic screen and the polyethylene sheet (see Figure 1).

NOTE This test arrangement applies to O operations only, since it is difficult to arrange for CO operations and it is accepted that O operations are no less severe than CO operations (see 8.3.2.6.4).

c) The circuit-breaker shall be operated during tests to simulate service conditions as closely as possible

A circuit-breaker having a dependent power operation shall be closed during tests with the control supply (voltage or pressure) at 85 % of its rated value.

A circuit-breaker having an independent power operation shall be closed during tests with the operating mechanism charged to its maximum value stated by the manufacturer.

A circuit-breaker having a stored energy operation shall be closed during tests with the operating means charged at 85 % of the rated voltage of the auxiliary supply.

d) If a circuit-breaker is fitted with adjustable over-current releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without over-current releases but fitted with a shunt release, this release shall be energized by the application of a voltage equal to 70 % of the rated control supply voltage of the release (see 7.2.1.2.3), at a time not earlier than that of the initiation of the short-circuit nor later than 10 ms after the initiation of the short-circuit.

e) For all these tests, the line side of the test circuit shall be connected to the corresponding terminals of the circuit-breaker as marked by the manufacturer. In the absence of such markings, the test connections shall be as specified in Table 10.

8.3.2.6.2 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies.

8.3.2.6.3 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

8.3.2.6.4 Test procedure

8.3.2.6.4.1 General

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies, with the following addition.

8.3.2.6.4.2 Common tests on one-, two-, three- and four-pole circuit-breakers

After calibration of the test circuit in accordance with 8.3.2.6.3, the temporary connections are replaced by the circuit-breaker under test and its connecting cables if applicable.

Tests for the performance under short-circuit conditions shall be made according to the sequences in Table 9 (see 8.3.1).

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For circuit-breakers having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

– approximately 50 cm on the supply side;

– approximately 25 cm on the load side.

For ratings ≤ 20 A, the manufacturer may specify a larger cross-section, in which case this cross-section shall be used for all relevant short-circuit tests, and stated in the test report. In addition, a verification of inverse-time delay releases according to 8.3.3.2.3 b) shall be made with this cross-section.

The sequence of operations shall be that which is applicable to each test sequence, as specified in 8.3.4.2, 8.3.5.3, 8.3.6.5 and 8.3.7.7.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.3 Additional tests on four-pole circuit-breakers

~~The requirements of 8.3.2.6.4.2 apply.~~

Additional sequences of operations on one or more new samples, in accordance with Table 10, shall be ~~made~~ carried out on the fourth pole and its adjacent pole, according to test sequences III or V, as applicable, and test sequence IV if applicable. This requirement applies even when test sequence III is replaced by test sequence II (I_{cu} = I_{cs}) or test sequence IV is replaced by test sequence VI (I_{cw} = I_{cs}), i.e., additional tests according to test sequence III or V, and test sequence IV, as applicable, are required.

Alternatively, at the request of the manufacturer, these tests may be combined with the ~~three-pole~~ tests of 8.3.2.6.4.2 and made on the same samples, in which case the test in each relevant test sequence shall comprise

– the test on three adjacent poles,

– the test on the fourth pole and the adjacent pole.

The tests on the fourth pole and the adjacent pole are made at an applied voltage of $U_e/\sqrt{3}$, in the circuit shown in Figure 12 of IEC 60947-1:2007/AMD1:2010 with the connections C1 and C2 removed. The test current shall be agreed between manufacturer and user but shall be not less than 60 % of I_{cu} or I_{cw}, as applicable.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.4 Test operations

The following symbols are used for defining the sequence of operations:

O represents a breaking operation;

CO represents a making operation followed, after the appropriate opening time, by a breaking operation:

t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the circuit-breaker (see 2.19), but not less than 3 min. The actual value of *t* shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, but not exceeding 1 h, during which time the circuit-breaker shall not be displaced. Attempts to reclose the circuit-breaker during the resetting time shall be spaced by at least 1 min.

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The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests may be recorded in the test report (see 7.2.1.2.4, item a)).

8.3.2.6.5 Behaviour of the circuit-breaker during short-circuit making and breaking tests

Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies.

8.3.2.6.6 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

8.3.2.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, as applicable, the following conditions shall be met:

– there shall be no damage to the insulation on conductors used to wire the device;
– the polyethylene sheet, where applicable, shall show no holes visible with normal or corrected vision without additional magnification. Minuscule holes of less than 0,26 mm diameter can be ignored;
– the case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

Additionally, after the short-circuit tests, the circuit-breaker shall comply with the verifications specified for each test sequence, as applicable.

8.3.3 Test sequence I: General performance characteristics

8.3.3.1 General

This test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Mechanical operation and operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Verification of dielectric withstand	8.3.3.6
Verification of temperature-rise	8.3.3.7
Verification of overload releases	8.3.3.8
Verification of undervoltage and shunt releases (if applicable)	8.3.3.9
Verification of main contact position (for circuit-breakers suitable for isolation)	8.3.3.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

See 8.3.1 for tests that may be omitted from the sequence and made on separate samples.

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8.3.3.2 Test of tripping limits and characteristics

8.3.3.2.1 General

Subclause 8.3.3.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.3.2.5).

When the over-current opening release is normally a built-in part of the circuit-breaker, it shall be verified inside the corresponding circuit-breaker.

Any separate release shall be mounted approximately as under normal service conditions. The complete circuit-breaker shall be mounted in accordance with 8.3.2.1. The equipment under test shall be protected against undue external heating or cooling.

The connections of the separate release, if appropriate, or of the complete circuit-breaker shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Tables 9 and 10 of 8.3.3.3.4 of IEC 60947-1:2007) and of length according to 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

For circuit-breakers with adjustable over-current releases, tests shall be made at:

a) minimum current setting and minimum time-delay setting, as applicable; and

b) maximum current setting and maximum time-delay setting, as applicable,

in each case with conductors corresponding to the rated current I_n (see 4.7.2).

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

For circuit-breakers having a neutral pole provided with an overload release, the verification of this overload release shall be made on the neutral pole alone.

The tests may be made at any convenient voltage.

8.3.3.2.2 Short-circuit releases

The operation of short-circuit releases (see 4.7.1) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained:

– for 0,2 s in the case of instantaneous releases (see 2.20);

– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate:

– within 0,2 s in the case of instantaneous releases (see 2.20);

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– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers with an electronic overcurrent release, the operation of the short-circuit releases shall be verified by one test only on each pole individually.

For circuit-breakers with electromagnetic overcurrent releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. For circuit-breakers having an identified neutral pole provided with a short-circuit release, the neutral pole shall be tested in series with one phase pole chosen at random. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for ~~indivudal~~ individual poles), at which value they shall operate:

– within 0,2 s in the case of instantaneous releases (see 2.20);
– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

8.3.3.2.3 Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 4.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms. The operation of multipole overload releases shall be verified with all phase poles loaded simultaneously with the test current.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

At a test current having a value equal to 90 % of the current setting, the release shall not operate, the current being maintained

– for 0,2 s in the case of instantaneous releases (see 2.20),
– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 110 % of the current setting, the release shall operate

– within 0,2 s in the case of instantaneous releases (see 2.20),
– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers having an identified neutral pole provided with an overload release (see ~~8.3.3.2.3~~ 8.3.3.2.1), the test current for this release shall have a value equal to 1,2 times 110 % of the current setting.

b) Inverse time-delay releases

The operating characteristics of inverse time-delay overload releases shall be verified in accordance with the performance requirements of 7.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see ~~8.3.3.2.4~~ 8.3.3.2.1), the test currents for this release shall be those given in Table 6 except that the test current at the conventional tripping current shall be multiplied by the factor 1,2.

For releases dependent on ambient air temperature, the operating characteristic shall be verified at the reference temperature (see 4.7.3 and ~~5.2 item b)~~ Table 13 item 2.14), the release being energized on all phase poles.

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If this test is made at a different ambient air temperature, a correction shall be made in accordance with the manufacturer's temperature/current data.

For thermal-magnetic releases declared by the manufacturer to be independent of ambient air temperature, the operating characteristic shall be verified by two measurements, one at 30 °C ± 2 °C, the other at 20 °C ± 2 °C or at 40 °C ± 2 °C, the release being energized on all phase poles.

For electronic releases, the operating characteristic shall be verified at the ambient temperature of the test room (see 6.1.1 of IEC 60947-1:2007/AMD2:2014), the release being energised on all phase poles.

An additional test, at a current value to be agreed between manufacturer and user, shall be made to verify that the time/current characteristics of the release conform (within the stated tolerances) to the curves provided by the manufacturer.

NOTE In addition to the tests in this subclause, the releases of circuit-breakers are also verified on each pole singly, during test sequences III, IV, V and VI (see 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 and 8.3.8.8).

8.3.3.2.4 Additional tests for definite time-delay releases

Definite time-delay releases shall be tested to verify the values of the time-delay and the non-tripping duration

a) Time-delay

This test is made at a current equal to 1,5 times the current setting:

– in the case of overload releases, with all phase poles loaded;

– for circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test current for this release shall be 1,5 times the current setting;

– in the case of electromagnetic short-circuit releases, with two poles in series carrying the test current, using successively all possible combinations of phase poles having a short-circuit release.

– in the case of electronic short-circuit releases, on one pole chosen at random.

The time-delay measured, shall be between the limits stated by the manufacturer.

If the test current overlaps with another tripping characteristic (e.g. an instantaneous tripping characteristic), the trip setting (e.g. I_{sd}, see Figure K.1) and the test current shall be reduced as necessary to prevent premature tripping. Both values shall be recorded in the test report.

b) Non-tripping duration

This test is made under the same conditions as for the test of item a) above for both overload and short-circuit releases:

Firstly, the test current equal to 1,5 times the current setting is maintained for a time interval equal to the non-tripping duration stated by the manufacturer; then, the current is reduced to the value corresponding to the overload current setting (I_r) and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

8.3.3.3 Test of dielectric properties

Subclause 8.3.3.4.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except for item 5), with the following additions:

(i) with reference to 8.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2007: the normal positions of operation include the tripped position, if any;

(ii) with reference to 8.3.3.4.1, item 3 c), of IEC 60947-1:2007/AMD1:2010/AMD2:2014: for the purposes of this standard circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) circuit-breakers not declared as suitable for isolation shall be tested with the test voltage applied across the poles of the main circuit, the line terminals being connected together

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and the load terminals being connected together. The test voltage shall be in accordance with Table 12 of IEC 60947-1:2007;

(iv) for circuit-breakers suitable for isolation (see 3.5) and having an operational voltage greater than 50 V, the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(v) circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater;

(vi) withdrawable circuit-breakers (see 7.1.2) shall be subject to verification of impulse withstand voltage, as per 8.3.3.4.1, item 2) b) of IEC 60947-1:2007. The test voltage shall be selected from Table 14 of IEC 60947-1:2007, and shall be applied between the withdrawable unit's main contacts and their associated fixed contacts, in the disconnected position. Acceptance criteria are as per 8.3.3.4.1, item 2) d) of IEC 60947-1:2007.

8.3.3.4 Tests of mechanical operation and of operational performance capability

8.3.3.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 8.3.2.1 except that, for the purpose of these tests, the circuit-breaker may be mounted on a metal frame. The circuit-breaker shall be protected against undue external heating or cooling.

The tests shall be made at the ambient temperature of the test room.

The control supply voltage of each control circuit shall be measured at its terminals at the rated current.

All resistors or impedances forming part of the control device shall be in circuit, However, no supplementary impedances shall be inserted between the current source and the terminals of the device.

The tests of 8.3.3.4.2, 8.3.3.4.3 and 8.3.3.4.4 shall be made on the same circuit-breaker but the order in which these tests are carried out is optional. However, for the tests of undervoltage and shunt releases the tests of 8.3.3.4.2 and 8.3.3.4.3 may, alternatively, be made on a new sample.

In the case of maintainable circuit-breakers, if it is desired to carry out a number of operations greater than that specified in Table 8, these additional operations shall be carried out first, followed by maintenance in accordance with the manufacturer's instructions, and then by the number of operations in accordance with Table 8, without any further maintenance being permitted during the remainder of this test sequence.

For convenience of testing it is permissible to subdivide each of the tests into two or more periods. No such period should, however, be less than 3 h.

8.3.3.4.2 Construction and mechanical operation

8.3.3.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 7.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 7.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

8.3.3.4.2.2 Mechanical operation

Tests shall be made as specified in 8.3.3.4.1 for the following purposes:

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– to prove satisfactory tripping of the circuit-breaker with the closing ~~device~~ release energized;

– to prove satisfactory behaviour of the circuit-breaker when the closing operation is initiated with the tripping device actuated;

– to prove that the operation of a power-operated device, when the circuit-breaker is already closed, shall neither cause damage to the circuit-breaker nor endanger the operator.

The mechanical operation of a circuit-breaker may be checked under no-load conditions.

A circuit-breaker with dependent power operation shall comply with the requirements stated in 7.2.1.1.4.

A circuit-breaker with dependent power operation shall operate with the operating mechanism charged to the minimum and maximum limits stated by the manufacturer.

A circuit-breaker with stored energy operation shall comply with the requirements stated in 7.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control supply voltage. It shall also be verified that the moving contacts cannot be moved from the open position when the operating mechanism is charged to slightly below the full charge as evidenced by the indicating device.

For a trip-free circuit-breaker it shall not be possible to maintain the contacts in the touching or closed position when the tripping release is in the position to trip the circuit-breaker.

If the closing and opening times of a circuit-breaker are stated by the manufacturer, such times shall comply with the stated values.

8.3.3.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 7.2.1.3 of IEC 60947-1:2007. For this purpose, the release shall be fitted to a circuit-breaker having the maximum current rating for which the release is suitable.

i) Drop-out voltage

It shall be verified that the release operates to open the circuit-breaker between the voltage limits specified.

The voltage shall be reduced from rated control supply voltage at a rate to reach 0 V in approximately 30 s.

The test for the lower limit is made without current in the main circuit and without previous heating of the release coil.

In the case of a release with a range of rated control supply voltage, this test applies to the maximum voltage of the range.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control supply voltage to the release and rated current in the main poles of the circuit-breaker. This test may be combined with the temperature-rise test of 8.3.3.7.

In the case of a release with a range of rated control supply voltage, this test is made at both the minimum and maximum rated control supply voltages.

ii) Test for limits of operation

Starting with the circuit-breaker open, at the temperature of the test room, and with the supply voltage at 30 % rated maximum control supply voltage, it shall be verified that the circuit-breaker cannot be closed by the operation of the actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the circuit-breaker can be closed by the operation of the actuator.

iii) Performance under overvoltage conditions

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With the circuit-breaker closed and without current in the main circuit, it shall be verified that the undervoltage release will withstand the application of 110 % rated control supply voltage for 4 h without impairing its functions.

8.3.3.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. For this purpose, the release shall be fitted to a circuit-breaker having the maximum rated current for which the release is suitable.

It shall be verified that the release will operate to open the circuit-breaker at 70 % rated control supply voltage when tested at an ambient temperature of +55 °C ± 2 °C without current in the main poles of the circuit-breaker. In the case of a release having a range of rated control supply voltages, the test voltage shall be 70 % of the minimum rated control supply voltage.

8.3.3.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 8.3.2.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 8; the number of operating cycles per hour is given in column 2 of this table.

The tests shall be carried out without current in the main circuit of the circuit-breaker.

For circuit-breakers which can be fitted with shunt releases, 10 % of the total number of operating cycles shall be closing/tripping operations, with the shunt release energized at maximum rated control supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles shall be closing/tripping operations at the minimum rated control supply voltage, this voltage to the release being removed after each closing operation, to trip the circuit-breaker.

In each case, half the relevant number of operating cycles shall be made at the beginning and the other half at the end of the tests.

For circuit-breakers fitted with undervoltage releases, prior to the operational performance test, without the undervoltage release being energized, it shall be verified that the circuit-breaker cannot be closed by attempting 10 times to effect a closing operation of the circuit-breaker.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing ~~devices~~ releases, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature-rises of the electrical components do not exceed the limits indicated in Table 7.

In the case of manually operated circuit-breakers, they shall be operated as in normal use.

8.3.3.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, the test circuit being in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 8.

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The circuit-breaker shall be operated so as to make and break its rated current at its maximum rated operational voltage, assigned by the manufacturer, at a power factor or time constant as applicable in accordance with Table 11, the tolerance being in accordance with 8.3.2.2.2.

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

For circuit-breakers fitted with adjustable releases, the tests shall be made with the overload setting at maximum and the short-circuit setting at minimum.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing ~~devices~~ releases, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature rises of the electrical components do not exceed the values indicated in Table 7.

Manually operated circuit-breakers shall be operated as in normal use.

8.3.3.4.5 Additional test of operational performance capability without current for withdrawable circuit-breakers

A test of operational performance capability without current shall be carried out on the withdrawal mechanism and associated interlocks of withdrawable circuit-breakers.

The number of operating cycles shall be 100.

After this test, the isolating contacts, withdrawal mechanism and interlocks shall be suitable for further service. This shall be verified by inspection.

8.3.3.5 Overload performance

This test applies to circuit-breakers of rated current up to and including 630 A.

NOTE 1 At the request of the manufacturer, the test can also be made on circuit-breakers of rated current higher than 630 A.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The test shall be made at a voltage corresponding to the maximum operational voltage $U_{e\ max}$ assigned by the manufacturer to the circuit-breaker, taking into account the requirement for recovery voltage of Table 12 (see also 8.3.2.2.3 a) of IEC 60947-1:2007/AMD2:2014).

For circuit-breakers fitted with adjustable releases, the test shall be made with its releases set at maximum.

The circuit-breaker shall be opened nine times manually and three times automatically by the action of an overload release, except for circuit-breakers having a short-circuit release of a maximum setting less than the test current, in which case all 12 operations shall be automatic.

If the testing means do not withstand the let-through energy occurring during the automatic operation, the test may be performed as follows, with the agreement of the manufacturer:

– 12 manual operations;
– three additional operations with automatic opening, made at any convenient voltage.

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During each of the manually operated cycles, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The number of operating cycles per hour shall be that specified in column 2 of Table 8. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced sufficiently so that the circuit-breaker may be closed, the full current being established.

If test conditions at the testing station do not permit testing at the operating rate given in Table 8, a slower rate may be used, but details shall be stated in the test report.

The values of the test current and of the recovery voltage shall be in accordance with Table 12, at the power factor or time constant, as applicable, in accordance with Table 11, the tolerances being in accordance with 8.3.2.2.2.

NOTE 2 With the agreement of the manufacturer the test can be made under more severe conditions than specified.

Table 12 – Test circuit characteristics for overload performance

	Alternating current	Direct current
Current	6 I_n	2,5 I_n
Recovery voltage	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = maximum operational voltage of the circuit-breaker.		

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

The prospective current at the supply terminals of the circuit-breaker shall be at least 10 times the test current, or at least 50 kA, whichever of the two values is the lower.

8.3.3.6 Verification of dielectric withstand

8.3.3.6.1 General

The test shall be performed on the circuit-breaker whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

8.3.3.6.2 Test voltage

Subclause 8.3.3.4.1, item ~~3)~~ 4) b), of IEC 60947-1:2007/AMD1:2010 applies.

~~The value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s., or 1 415 V d.c. if an a.c. voltage cannot be applied. The value of U_e referred to is that at which the preceding switching and/or short-circuit tests have been performed.~~

8.3.3.6.3 Application of the test voltage

The test voltage shall be applied for 5 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the circuit-breaker open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is not required. For the purposes of this standard, circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For circuit-breakers suitable for isolation the leakage current shall be measured in accordance with 8.3.3.3, item (iv), except that the leakage current shall not exceed 2 mA.

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8.3.3.6.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

8.3.3.7 Verification of temperature-rise

Following the test according to 8.3.3.6, a temperature-rise test shall be made at the conventional thermal current according to 8.3.2.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 7.

8.3.3.8 Verification of overload releases

Immediately following the test according to 8.3.3.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 7.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. Alternatively, this test may be made using a 3-phase supply.

This test may be made at any convenient voltage.

The operating time shall not exceed the conventional tripping time.

With the manufacturer's consent, a time interval between the tests of 8.3.3.7 and 8.3.3.8 may occur.

The test may, alternatively, be made at the ambient air temperature at a test current corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

8.3.3.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 8.3.3.4.2.3 i), except that the tests for upper and lower limits shall be made at the temperature of the test room without current in the main circuit. The release shall not operate at 70 % of the minimum control supply voltage and shall operate at 35 % of the maximum rated control supply voltage.

Circuit-breakers fitted with shunt releases shall be subjected to the test of 8.3.3.4.2.4, except that the test may be made at the temperature of the test room. The release shall operate at 70 % of the minimum rated control supply voltage.

8.3.3.10 Verification of the main contact position

For circuit-breakers suitable for isolation (see 3.5), following the verification of 8.3.3.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007/AMD1:2010.

8.3.4 Test sequence II: Rated service short-circuit breaking capacity

8.3.4.1 General

Except when the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Rated service short-circuit breaking capacity	8.3.4.2
Verification of operational performance capability	8.3.4.3
Verification of dielectric withstand	8.3.4.4

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Verification of temperature-rise	8.3.4.5
Verification of overload releases	8.3.4.6

For the case where I_{cs} = I_{cu}, see 8.3.5.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.4.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 4.3.6.2.3.

The power factor for this test shall be according to Table 11, for the appropriate test current.

The sequence of operations shall be:

O – *t* – CO – *t* – CO

In the case of integrally fused circuit-breakers, any blown fuse shall be replaced after each operation. The time interval *t* may need to be extended for this purpose.

8.3.4.3 Verification of operational performance capability

Following the test according to 8.3.4.2, the operational performance capability shall be verified in accordance with 8.3.3.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 8.3.4.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 8.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 10.

8.3.4.4 Verification of dielectric withstand

Following the test according to 8.3.4.3, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.6.

8.3.4.5 Verification of temperature-rise

Following the test according to 8.3.4.4, the temperature-rise at the main terminals shall be verified in accordance with 8.3.2.5. The temperature-rise shall not exceed the values given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.4.6 Verification of overload releases

Immediately following the test according to 8.3.4.5, the operation of overload releases shall be verified in accordance with 8.3.3.8.

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With the manufacturer's consent, a time interval between the tests of 8.3.4.5 and 8.3.4.6 may occur.

8.3.5 Test sequence III: Rated ultimate short-circuit breaking capacity

8.3.5.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers of selectivity category A and to circuit-breakers of selectivity category B having a rated ultimate short-circuit breaking capacity higher than the rated short-time withstand current.

NOTE For this type of selectivity category B circuit-breaker, the instantaneous release operates at values of current in excess of those stated in column 2 of Table 3 (4.3.6.4); this type of release can be referred to as "instantaneous override".

For circuit-breakers of selectivity category B having a rated short-time withstand current equal to their rated ultimate short-circuit breaking capacity, this test sequence need not be made, since, in this case, the ultimate short-circuit breaking capacity is verified when carrying out test sequence IV.

For integrally fused circuit-breakers, test sequence V applies in place of this sequence.

Where $I_{cs} = I_{cu}$, this test sequence need not be made, in which case construction break tests are required in Sequence II (see Table 10) and the following verifications shall additionally be made in test sequence II:

– the verification of 8.3.5.2, at the beginning of the test sequence;
– the verification of 8.3.5.5, at the end of the test sequence.

This test sequence comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.5.2
Rated ultimate short-circuit breaking capacity	8.3.5.3
Verification of dielectric withstand	8.3.5.4
Verification of overload releases	8.3.5.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.5.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting on each pole separately. This test may be made at any convenient voltage.

If the ambient temperature differs from the reference temperature, the test current shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

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The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature, on a pole singly.

8.3.5.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 8.3.5.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 8.3.2.

The sequence of operations shall be:

O – *t* – CO

8.3.5.4 Verification of dielectric withstand

Following the test according to 8.3.5.3 the dielectric withstand shall be verified according to 8.3.3.6. For circuit breakers suitable for isolation, the leakage current shall not exceed 6 mA.

8.3.5.5 Verification of overload releases

Following the test according to 8.3.5.4, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.6 Test sequence IV: Rated short-time withstand current

8.3.6.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers with a rated short-time withstand current (see 4.4); it comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.6.2
Rated short-time withstand current	8.3.6.3
Verification of temperature-rise	8.3.6.4
Short-circuit breaking capacity at maximum short-time withstand current	8.3.6.5
Verification of dielectric withstand	8.3.6.6
Verification of overload releases	8.3.6.7

Where integrally fused circuit-breakers are of selectivity category B, they shall meet the requirements of this sequence.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.6.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.6.3 Test of rated short-time withstand current

Subclause 8.3.4.3 of IEC 60947-1:2007 applies with the following addition:

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For the purpose of this test only, any over-current release, including the instantaneous override, if any, likely to operate during the test, shall be rendered inoperative.

8.3.6.4 Verification of temperature-rise

Following the test according to 8.3.6.3, the temperature-rise at the main terminals shall be verified according to 8.3.2.5. The temperature-rise shall not exceed the value given in Table 7.

With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (8.3.6.6). This verification need not be made where, for a given frame size, the test of 8.3.7.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.6.5 Test of short-circuit breaking capacity at the maximum short-time withstand current

Following the test according to 8.3.6.4, a short-circuit test shall be made with the following sequence of operations:

O – *t* – CO

under the general conditions of 8.3.2, with a value of prospective current equal to that of the short-time withstand current test (see 8.3.6.3) and at the highest voltage applicable to the rated short-time withstand current.

The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release, and the instantaneous override, if any, shall not operate. If the circuit-breaker has a making current release (see 2.10), this requirement does not apply to the CO operation, if the prospective current exceeds the pre-determined value, since it will then operate; this exception also applies to the test on the fourth pole and the adjacent pole, in accordance with 8.3.2.6.4.3.

8.3.6.6 Verification of dielectric withstand

Following the test carried out according to 8.3.6.5, the dielectric withstand shall be verified according to 8.3.3.6.

8.3.6.7 Verification of overload releases

Following the test according to 8.3.6.6, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.7 Test sequence V: Performance of integrally fused circuit-breakers

8.3.7.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the following tests:

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	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	8.3.7.2
	Verification of temperature-rise	8.3.7.3
	Verification of dielectric withstand	8.3.7.4
Stage 2	Verification of overload releases	8.3.7.5
	Short-circuit at 1,1 times take-over current	8.3.7.6
	Short-circuit at ultimate short-circuit breaking capacity	8.3.7.7
	Verification of dielectric withstand	8.3.7.8
	Verification of overload releases	8.3.7.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 8.3.7.2 to 8.3.7.4;
– Stage 2 comprises the tests according to 8.3.7.5 to 8.3.7.9.

The two stages may be carried out:

– on two separate circuit-breakers, or
– on the same circuit-breaker, with maintenance between them, or
– on the same circuit-breaker, without any maintenance, in which case the test according to 8.3.7.4 may be omitted.

The test according to 8.3.7.3 need only be made if $I_{cs} > I_s$.

Tests according to 8.3.7.2, 8.3.7.6 and 8.3.7.7 shall be made at the maximum operational voltage of the circuit-breaker.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.7.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer (see 2.17.4).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one O operation at the conclusion of which the fuses shall still be intact.

8.3.7.3 Verification of temperature-rise

NOTE This verification of temperature-rise is made since the fuses can have blown during the short-circuit test of test sequence II, 8.3.4.2, in which case the test of 8.3.7.2 is more severe.

Following the test according to 8.3.7.2 the temperature-rise at the main terminals shall be verified, in accordance with 8.3.2.5.

The temperature-rise shall not exceed the value given in Table 7.

8.3.7.4 Verification of dielectric withstand

Following the test according to 8.3.7.3 the dielectric withstand shall be verified according to 8.3.3.6.

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8.3.7.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.7.6 Short-circuit at 1,1 times the take-over current

Following the test according to 8.3.7.5 a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer (see 2.17.5).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one "O" operation at the conclusion of which at least two of the fuses shall have blown.

8.3.7.7 Short-circuit at rated ultimate short-circuit breaking capacity

Following the test according to 8.3.7.6, a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to the ultimate short-circuit breaking capacity I_{cu}, as declared by the manufacturer.

For the purpose of this test, a new set of fuses shall be fitted.

The sequence of operations shall be:

$$O - t - CO$$

a further new set of fuses being fitted during the time interval t, which may need to be extended for that purpose.

8.3.7.8 Verification of dielectric withstand

Following the test according to 8.3.7.7 and with a new set of fuses fitted, the dielectric withstand shall be verified according to 8.3.5.4.

8.3.7.9 Verification of overload releases

Following the test according to 8.3.7.8, the operation of overload releases shall be verified in accordance with 8.3.5.2 except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.8 Test sequence VI: combined test sequence

8.3.8.1 General

At the discretion of, or in agreement with the manufacturer, this test sequence may be applied to circuit-breakers of selectivity category B:

a) when the rated short-time withstand current and the rated service short-circuit breaking capacity have the same value ($I_{cw} = I_{cs}$); in this case it replaces test sequences II and IV;

b) when the rated short-time withstand current, the rated service short-circuit breaking capacity and the rated ultimate short-circuit breaking capacity have the same value ($I_{cw} = I_{cs} = I_{cu}$); in this case it replaces test sequences II, III and IV.

This test sequence comprises the following tests:

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Test	Subclauses
Verification of overload releases	8.3.8.2
Rated short-time withstand current	8.3.8.3
Rated service short-circuit breaking capacity*	8.3.8.4
Verification of operational performance capability	8.3.8.5
Verification of dielectric withstand	8.3.8.6
Verification of temperature-rise	8.3.8.7
Verification of overload releases	8.3.8.8
* For circuit-breakers falling into the case of 8.3.8.1b) above, this is also the rated ultimate short-circuit breaking capacity.	

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.8.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.8.3 Test of rated short-time withstand current

Following the test according to 8.3.8.2, a test shall be made at the rated short-time withstand current according to 8.3.6.3.

This test does not need to be made on the sample of minimum I_n specified in Table 10.

8.3.8.4 Test of rated service short-circuit breaking capacity

Following the test according to 8.3.8.3, a test shall be made at the rated service short-circuit breaking capacity according to 8.3.4.2, at the highest voltage applicable to the rated short-time withstand current. The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release.

During this test the instantaneous override (if any) shall not operate, and the making current release (if any) shall operate.

8.3.8.5 Verification of operational performance capability

Following the test according to 8.3.8.4, the operational performance capability shall be verified in accordance with 8.3.4.3.

8.3.8.6 Verification of dielectric withstand

Following the test according to 8.3.8.5, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured according to 8.3.3.6.

8.3.8.7 Verification of temperature-rise

Following the test according to 8.3.8.6, the temperature-rise at the main terminals shall be verified in accordance with 8.3.4.5.

The temperature-rise shall not exceed the value given in Table 7.

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This verification need not be made where, for a given frame size, the test of 8.3.8.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.8.8 Verification of overload releases

After cooling down following the test according to 8.3.8.7, the operation of overload releases shall be verified in accordance with 8.3.3.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.9 Critical d.c. load current test

This test applies only to circuit-breakers with d.c. ratings.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 10 – sequence I, except that for application of footnote g, construction breaks relative to the over-current tripping devices shall not be considered.

The test shall be made at the maximum operational d.c. voltage (U_e max) assigned by the manufacturer to the circuit-breaker.

For circuit-breakers fitted with adjustable releases, the test shall be made with the releases set at the maximum.

The circuit-breaker shall be closed and opened 5 times on to each of the test currents listed below. If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

During each CO cycle, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The time constant shall be in accordance with Table 11 as for operational performance; at the discretion of the manufacturer, a higher value may be used, in which case this value shall be stated in the test report.

The number of operating cycles per hour shall be in accordance with Table 8.

The arcing time during the test shall be recorded and shall not exceed 1 s.

The test current values shall be: 4 A, 8 A, 16 A, 32 A and 63 A d.c., with ± 10 % tolerance, but not exceeding the rated current; the critical value is determined by taking the maximum mean arcing time, for each direction of current if applicable. The highest and lowest values of test current shall demonstrate shorter mean arcing times than the critical value; if necessary, the range of test currents shall be extended upwards or downwards by applying a 2 times ratio as many times as necessary, up to, but not exceeding, the rated current to find the critical value. If no critical value of current is found within these criteria, no further test according to this subclause is required.

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The tolerances on test quantities other than the current shall be in accordance with 8.3.2.2.2.

Following this test, the same sample shall be subjected to an operational performance verification of 50 operations, under the same conditions, at the current and in the direction corresponding to the critical value. After this test, the dielectric withstand shall be verified according to 8.3.3.6 with a d.c. test voltage.

8.4 Routine tests

8.4.1 General

For the definition of routine tests, see 2.6.2 and 8.1.3 of IEC 60947-1:2007.

The following tests apply:

– mechanical operation (8.4.2);
– verification of the calibration of overcurrent releases (8.4.3);
– verification of the operation of undervoltage and shunt releases (8.4.4);
– additional tests for CBRs to Annex B (8.4.5);
– dielectric tests (see note) (8.4.6);
– verification of clearances (8.4.7).

NOTE If by the control of materials and manufacturing processes, the integrity of the dielectric properties has been proven, these tests can be replaced by sampling tests according to a recognized sampling plan (see IEC 60410). [1]

However, operation of the circuit-breaker during manufacture and/or other routine test may take the place of the tests listed above provided the same conditions apply and the number of operations is not less than that specified.

The tests of 8.4.3, 8.4.4 and 8.4.5 shall be made with the releases fitted to the circuit-breaker or to an appropriate test equipment simulating the behaviour of the circuit-breaker.

In the context of the tests of 8.4.2, 8.4.3, 8.4.4, 8.4.6 and 8.4.7, the term "circuit-breakers" covers CBRs, where applicable.

8.4.2 Mechanical operation tests

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

The following tests shall be made on manually-operated circuit-breakers:

– two close-open operations;
– two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

The following tests shall be made on power-operated circuit-breakers at 110 % of the maximum rated control supply voltage and/or of the rated supply pressure, and at 85 % of the minimum rated control supply voltage and/or of the rated supply pressure:

– two close-open operations;
– two trip-free operations;

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[1] This publication was withdrawn.

– for automatic reclosing circuit-breakers, two automatic reclosing operations.

8.4.3 Verification of the calibration of overcurrent releases

8.4.3.1 Inverse time-delay releases

The verification of the calibration of inverse time-delay releases shall be made at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curve provided by the manufacturer.

This verification may be made at any convenient temperature, correction being made for any difference from the reference temperature (see 4.7.3).

8.4.3.2 Instantaneous and definite time-delay releases

The verification of the calibration of instantaneous and definite time-delay releases shall check the non-operation and operation of the releases at the values of current given in 8.3.3.2.2 or 8.3.3.2.3, item a), as applicable, without measurement of break time being required.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the circuit-breaker occurs. Tripping shall occur between the lower and upper limits of test current.

8.4.4 Verification of the operation of undervoltage and shunt releases

8.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 7.2.1.3 of IEC 60947-1:2007 as follows:

a) Hold-in voltage

The release shall close on to a voltage corresponding to 85 % of the minimum rated control supply voltage.

b) Drop-out voltage

The release shall open when the voltage is reduced to a value within the range corresponding to the limits of 70 % and 35 % of the rated control supply voltage, adjusted to take account of the need to operate under the conditions specified in 8.3.3.4.2.3 i). In the case of releases having a range of rated control supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

8.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. The test may be made at any convenient temperature provided the test voltage is reduced to take account of the need for the release to operate under the conditions specified in 8.3.3.4.2.4. In the case of a release having a range of rated control supply voltages, the test voltage shall be related to 70 % of the minimum rated control supply voltage.

8.4.5 Additional tests for CBRs

The following additional tests shall be made on CBRs or r.c. units.

a) Operation of the test device

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The CBR shall be subjected to two close-trip operations or, in the case of r.c. units, to two reset-trip operations, tripping by the manual operation of the test device with the CBR supplied at the lowest rated operational voltage.

b) Verification of the calibration of the residual current tripping device of the CBR

Using an alternating sinusoidal residual current, it shall be verified that

– the CBR does not trip with a residual current of 0,5 times $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable;

– the CBR trips with a residual current of $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable.

8.4.6 Dielectric tests

The test conditions shall be in accordance with 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014, except that the use of metal foil is not required. The test voltage shall be applied as follows:

– with the circuit-breaker in the open position, between each pair of terminals which are electrically connected together when the circuit-breaker is closed;

– for circuit-breakers not incorporating electronic circuits connected to the main poles, with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable;

– for circuit-breakers incorporating electronic circuits connected to the main poles, with the circuit-breaker in the open position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable, either on the incoming side or on the outgoing side, depending on the position of the electronic components.

Alternatively, disconnection of electronic circuits connected to the main poles is permitted, in which case the test voltage shall be applied with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable.

The method of test shall be as in a) or b) or c) below at the manufacturer's discretion:

a) Two tests shall be made:

1) Impulse withstand voltage

The test voltage shall not be less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or the peak value corresponding to 2 U_i whichever is the greater, and

2) Power frequency withstand voltage

The test apparatus shall be as stated in 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010, except that the overcurrent trip shall be set to 25 mA. However, at the discretion of the manufacturer, for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the trip setting of the overcurrent relay; for example, for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

The value of the test voltage shall be 2 U_e max, with a minimum of 1 000 V r.m.s., applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of U_{imp}, 2 U_i, 2 U_e max or 1 000 V r.m.s.

c) An insulation resistance test at 500 V d.c. The insulation resistance shall be not less than 1 MΩ at any point.

If dielectric properties are tested according to a sampling plan in accordance with the note to 8.4.1, a power frequency withstand test shall be made according to 8.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 12A of

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IEC 60947-1:2007/AMD2:2010. Circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater.

8.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2007

Subclause 8.3.3.4.3 of IEC 60947-1:2007 applies, except that for the purposes of this standard this test shall be a routine test.

NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:2007 is covered by the tests of 8.4.6.

8.5 Special tests – Damp heat, salt mist, vibration and shock

The following special tests shall be made either at the discretion of the manufacturer or according to agreement between the manufacturer and user (see 2.6.4 of IEC 60947-1:2007). As special tests, unless specifically called for, these additional tests are not mandatory, and it is not necessary for a circuit-breaker to satisfy any of these tests to conform to this standard.

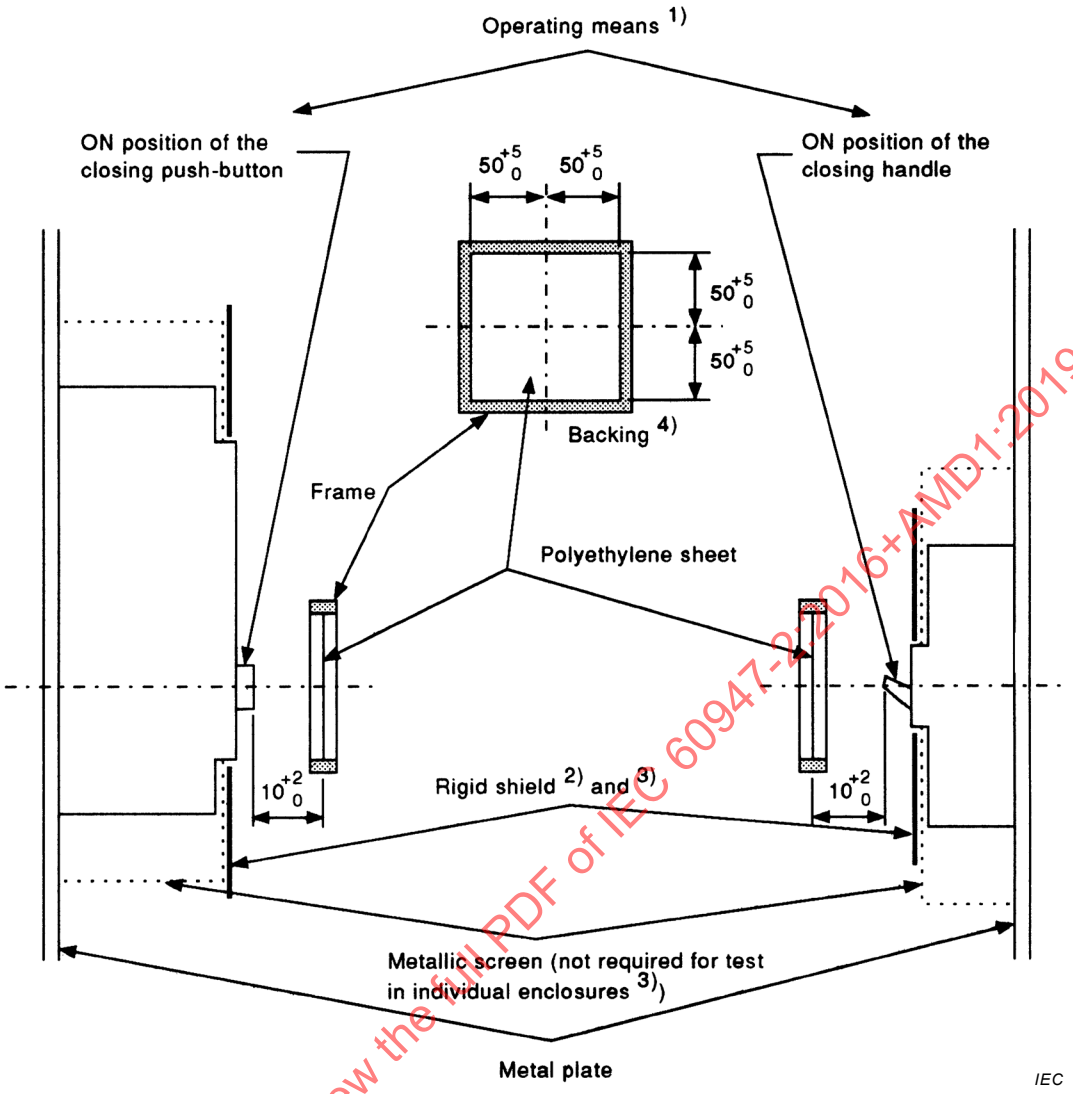
Annex Q of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

During the test sequences according to Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote e) of Table Q.1 of IEC 60947-1:2007, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energised with rated voltage. The circuit-breaker shall be operated according to 8.4.2 during the last hour of the test.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.

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Case of circuit-breaker with closing push-button

Case of circuit-breaker with a closing handle

Dimensions in millimetres

1) The operating means includes any extension which is normally fitted for the closing operation.

2) The purpose of the rigid shield is to prevent emissions from areas other than those of the handle or push-button from reaching the polyethylene sheet (not required for tests in individual enclosures).

3) The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

4) Made of any suitable rigid material to obviate tearing of the polyethylene sheet.

Figure 1 – Test arrangement (connecting cables not shown) for short-circuit tests

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Annex A
(normative)

Co-ordination between a circuit-breaker and another short-circuit protective device associated in the same circuit

A.1 General

To ensure co-ordination between a circuit-breaker (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their dynamic behaviour as an association.

NOTE An SCPD can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure A.1 – or of another circuit-breaker (C_2) (see Figure A.2 and Figure A.3).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. It is recommended that this should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time. Preferred templates for the representation of cut-off current and let-through energy (I^2t) characteristics are given in Annex K.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances the SCPD may be mounted in locations remote from C_1. The SCPD may be protecting a main feeder supplying a number of circuit-breakers C_1 or just an individual circuit-breaker.

For such applications, the user or specifier may have to decide, on the basis of a desk study, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the circuit-breaker manufacturer should make available.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of selectivity (see 2.5.23 of IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3) as well as consideration of back-up protection (see 2.5.24 of IEC 60947-1:2007).

Consideration of selectivity can either be carried out by desk study or by test (see A.5), whereas the verification of back-up protection normally requires the use of tests (see A.6).

When considering short-circuit breaking capacity, reference may be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

A.2 Scope and object

This annex gives guidance on and requirements for the co-ordination of circuit-breakers with other SCPDs associated in the same circuit, as regards selectivity as well as back-up protection.

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The object of this annex is to state:

– the general requirements for the co-ordination of a circuit-breaker with another SCPD;
– the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

A.3 General requirements for the co-ordination of a circuit-breaker with another SCPD

A.3.1 General considerations

Ideally, the co-ordination should be such that a circuit-breaker (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu}.

NOTE 1 If the value of the prospective fault current at the point of installation is less than the rated ultimate short-circuit breaking capacity of C_1, it can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

a) If the value of the selectivity limit current I_s (see 2.17.4) is too low, there is a risk of unnecessary loss of selectivity.
b) If the value of the prospective fault current at the point of installation exceeds the rated ultimate short-circuit breaking capacity of C_1, the SCPD shall be so selected that the behaviour of C_1 is in accordance with A.3.3 and the take-over current I_B (see 2.17.5), if any, complies with the requirements of A.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1. If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short circuit.

NOTE 2 In the case of interchangeable releases, these considerations apply to each relevant release.

A.3.2 Take-over current

For the purpose of back-up protection the take-over current I_B shall not exceed the rated ultimate short-circuit breaking capacity I_{cu} of C_1 alone (see Figure A.3a)).

A.3.3 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 7.2.1.2.4, item a).

A.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the circuit-breaker shall provide information on the type and the characteristics of the SCPD to be used with C_1, and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (see 2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of this standard, or any other relevant standard.

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If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

A.5 Verification of selectivity

A.5.1 General

Selectivity can normally be considered by the manufacturer by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD (see A.5.2). Selectivity can also be determined by tests (see A.5.3).

In certain cases, tests on the association will show a higher level of I_s than obtained by a desk study, for example:

– when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;

– when the opening time of the SCPD is less than that corresponding to one half-cycle.

To obtain improved selectivity when the associated SCPD is a circuit-breaker, an intentional short-time delay is sometimes provided for C_2.

Selectivity may be partial (see Figure A.3a)) or total up to the rated ultimate short-circuit breaking capacity Icu of C1.

Two illustrations of total selectivity are given in Figure A.2a) and Figure A.2b).

A.5.2 Consideration of selectivity by desk study

A.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by comparison of characteristics

   Selectivity in the time-delayed over-current zone is verified by comparison of the time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this standard.

b) Circuit-breaker (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics

   Selectivity in the overload zone is determined by the comparison of time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

A.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time/current characteristics, of selectivity between two circuit-breakers in the fault current (short-circuit) zone (see Figure A.2a)), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by consideration of peak let-through current

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In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2, taking into account the tolerance.

NOTE 1 Example of selectivity calculation

C_2 = 800 A MCCB; I_i = 8 kA r.m.s. – 12 kA r.m.s. (10 kA setting ± 20 %); C_1 = 125 A MCCB.

Minimum tripping level of C_2 is 8 × 1,414 = 11,3 kA peak.

Let-through current of C_1 at 15 kA r.m.s. prospective, due to the current limitation of C_1, is 11 kA peak, from test data.

Therefore the system is selective to at least 15 kA r.m.s. prospective.

NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) Circuit-breaker (C_1) with fuse as SCPD

Selectivity in the fault-current (short-circuit) zone (see Figure A.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

c) Fuse (C_1) with circuit-breaker as SCPD

Selectivity in the instantaneous tripping short-circuit zone is determined from the let-through current of the fuse.

The selectivity limit current I_s is the maximum value at which the peak let-through current of the fuse is lower than the peak value corresponding to the instantaneous tripping level (I_i) of circuit-breaker taking into account the tolerance.

A.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this standard, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream circuit-breaker will give a more precise value for the selectivity limit.

A.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure A.5, where:

– C_1 may be a circuit-breaker in compliance with this standard or another IEC standard or a fuse in accordance with the appropriate IEC standard;

– settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 8.3.2.6.4 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

The test shall consist of an O – t – CO operation, the CO operation being made by closing the downstream device C_1. If the downstream device is a fuse, the operation shall be made by closing C_2.

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The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

– Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies;
– During each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;
– In addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

A.6 Verification of back-up protection

A.6.1 Determination of the take-over current

Compliance with the requirements of A.3.2 can be checked by comparing the operating characteristics of C_1 and the associated SCPD for all settings of C_1 and, if applicable, for all settings of C_2.

A.6.2 Verification of back-up protection

Back-up protection can be verified either by tests, or by comparison of characteristics.

a) Verification by tests

Compliance with the requirements of A.3.3 is normally verified by tests in accordance with A.6.3. In this case, all the conditions for the tests shall be as specified in 8.3.2.6 with the adjustable resistors and inductors for the short-circuit tests on the supply side of the association.

b) Verification by comparison of characteristics

In some practical cases and where the SCPD is a circuit-breaker (see Figure A.3a) and Figure A.3b)), it may be possible for the manufacturer to compare the operating characteristics of C_1 and of the associated SCPD, special attention being paid to the following:

– the Joule integral value of C_1 at its I_{cu} and that of the SCPD at the prospective current of association;
– the effects on C_1 (e.g. by arc energy, by maximum peak current, cut-off current) at the peak operating current of the SCPD.

The suitability of the association may be evaluated by considering the maximum total operating I^2t characteristic of the SCPD, over the range from the rated short-circuit breaking capacity I_{cu} of C_1 up to the prospective short-circuit current of the application, but not exceeding the maximum let-through I^2t of C_1 at its rated short-circuit breaking capacity or other lower limiting value stated by the manufacturer.

NOTE Where the associated SCPD is a fuse, the validity of the desk study is limited up to I_{cu} of C_1.

A.6.3 Tests for verification of back-up protection

If C_1 is fitted with adjustable over-current opening releases, the operating characteristics shall be those corresponding to the minimum time and current settings.

If C_1 can be fitted with instantaneous over-current opening releases, the operating characteristics to be used shall be those corresponding to C_1 fitted with such releases.

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If the associated SCPD is a circuit-breaker (C_2) fitted with adjustable over-current opening releases, the operating characteristics to be used shall be those corresponding to the maximum time and current settings.

If the associated SCPD consists of a set of fuses, each test shall be made using a new set of fuses, even if some of the fuses used during a previous test have not blown.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the associated SCPD is a circuit-breaker (C_2), the full length of cable (75 cm) associated with this circuit-breaker may be on the supply side (see Figure A.4).

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5, the CO operation being made on C1.

A test is made with the maximum prospective current for the proposed application. This shall not exceed the rated conditional short-circuit (see 4.3.6.4 of IEC 60947-1:2007/AMD2:2014).

A further test shall be made at a value of prospective current equal to the rated short-circuit breaking capacity I_{cu} (or I_{cs}) of C_1, for which test a new sample C_1 may be used, and also, if the associated SCPD is a circuit-breaker, a new sample C_2.

During each operation

a) If the associated SCPD is a circuit-breaker (C_2):
   - either both C_1 and C_2 shall trip at both test currents, no further tests then being required.

     This is the general case and provides back-up protection only.
   - or C_1 shall trip and C_2 shall be in the closed position at the end of each operation, at both test currents, no further tests then being required.

     The contacts of C_2 are allowed to separate momentarily during each operation. In this case restoration of the supply is provided, in addition to back-up protection (see Note 1 to Figure A.3a)). The duration of contact separation of C_2, if any, shall be recorded during these tests.
   - or C_1 shall trip at the lower test current, and both C_1 and C_2 shall trip at the higher test current.

     The contacts of C_2 are allowed to separate momentarily at the lower test current. Additional tests shall be made at intermediate currents to determine the lowest current at which both C_1 and C_2 trip, up to which current restoration of supply is provided. The duration of contact separation of C_2, if any, shall be recorded during these tests.

b) If the associated SCPD is a fuse (or a set of fuses):
   - in the case of a single-phase circuit at least one fuse shall blow;
   - in the case of a multi-phase circuit either two or more fuses shall blow, or one fuse shall blow and C_1 shall trip.

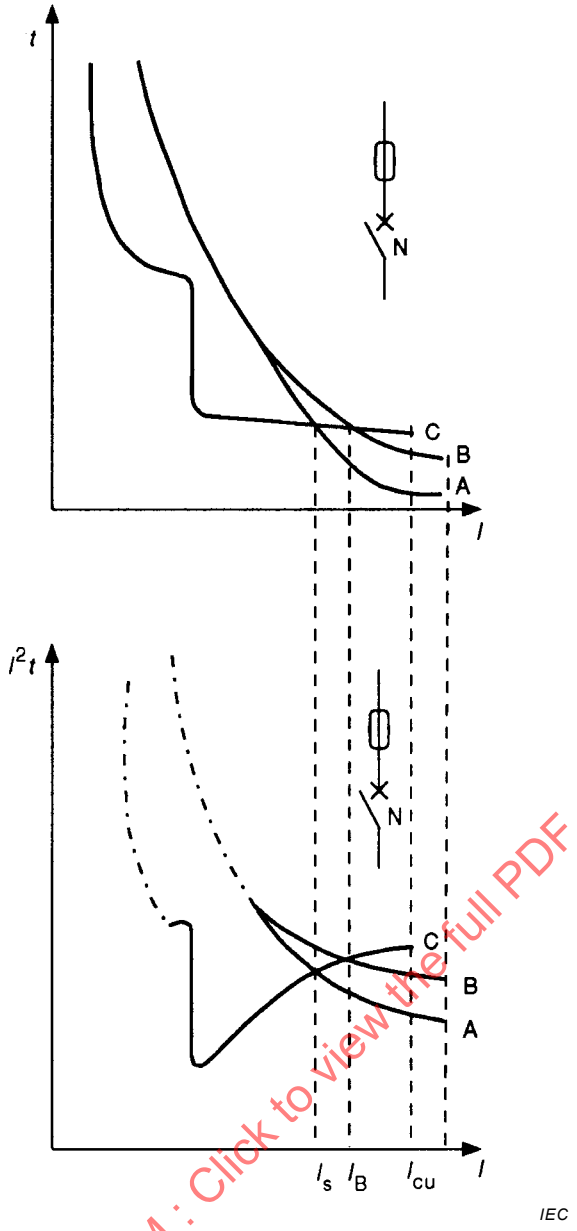
A.6.4 Results to be obtained

Subclause 8.3.4.1.7 of IEC 60947-1:2007 and 8.3.2.6.7 first paragraph of this standard apply, with the following addition:

Following the tests, if C_1 is a circuit-breaker, it shall comply with 8.3.5.4 and 8.3.5.5; if C_1 is a fuse, it shall comply with the applicable requirements of IEC 60269-1.

In addition, if the associated SPCD is a circuit-breaker (C_2), it shall be verified, by manual operation or other appropriate means, that the contacts of C_2 have not welded.

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I = Prospective short-circuit current

I_{cu} = Rated ultimate short-circuit breaking capacity (4.3.6.2.2)

I_s = Selectivity limit current (2.17.4)

I_B = Take-over current (2.17.5)

A = Pre-arcing characteristic of the fuse

B = Operating characteristic of the fuse

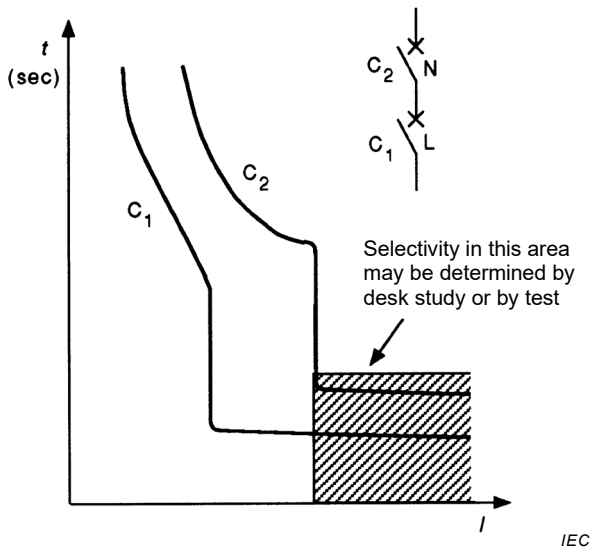
C = Operating characteristic of the circuit-breaker, non-current-limiting (N) (break-time/current and I^2t /current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure A.1 – Over-current co-ordination between a circuit-breaker and a fuse or back-up protection by a fuse: operating characteristics

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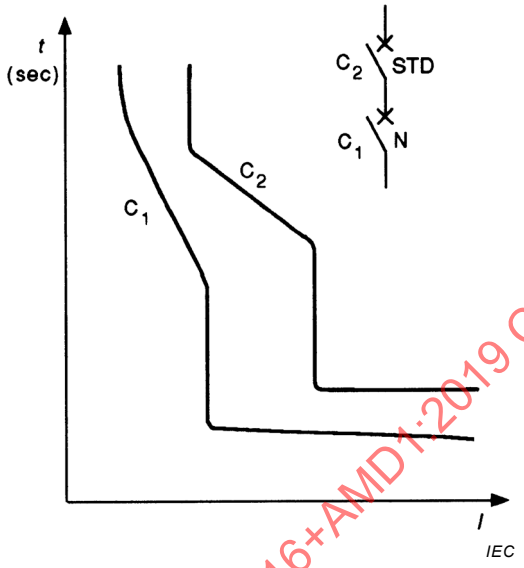


C_1 = Current-limiting circuit-breaker (L) (break-time characteristic)

C_2 = Current-limiting circuit breaker or non current-limiting circuit-breaker (N) (tripping characteristic)

Values of I_{cu} are not shown.

Figure A.2a) – Current-limiting CB downstream



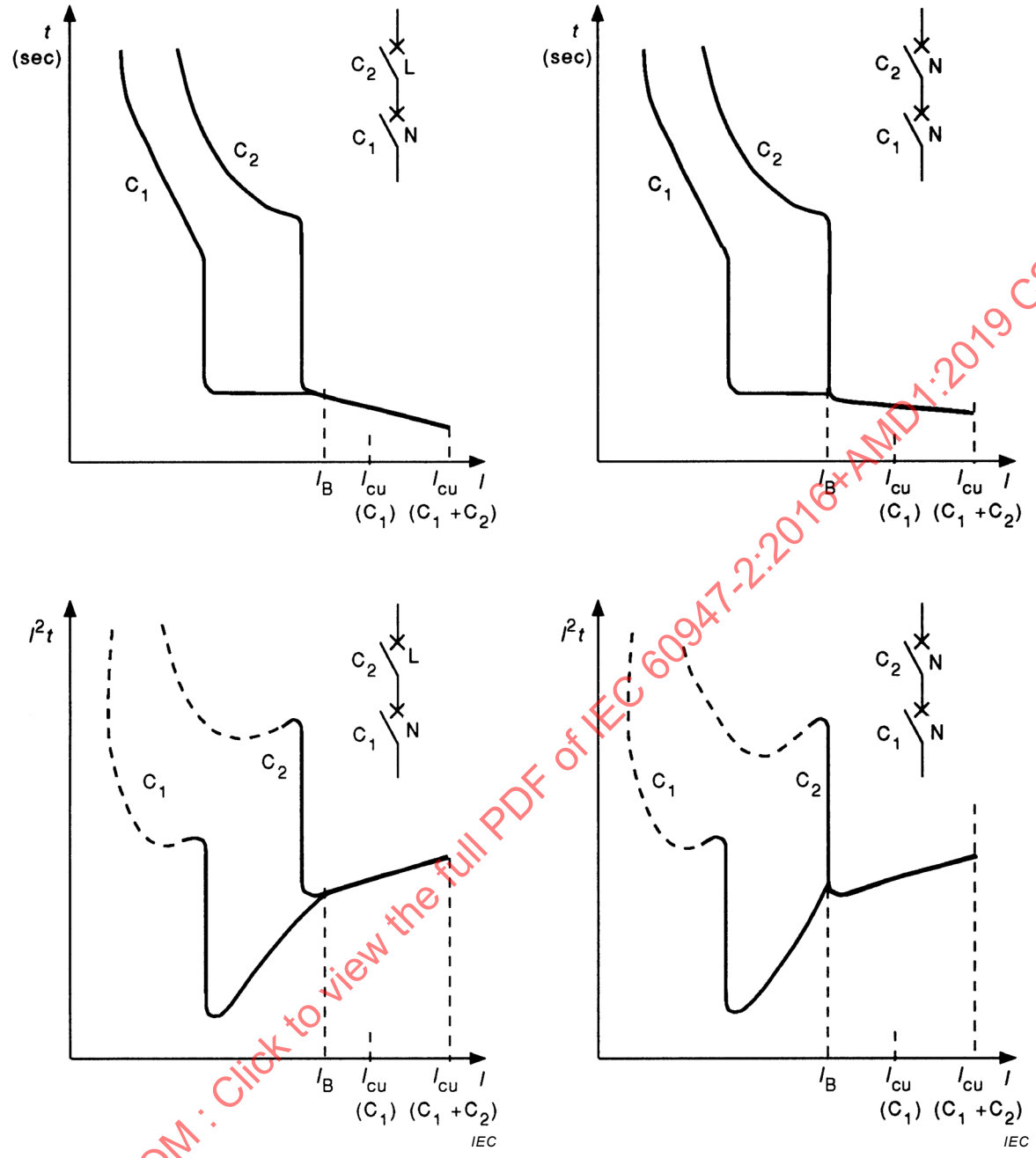
C_1 = Non-current-limiting circuit-breaker (N) (break-time characteristic)

C_2 = Circuit-breaker with intentional short-time delay (STD) (tripping characteristic)

Figure A.2b) – Non current-limiting CB downstream

Figure A.2 – Total selectivity between two circuit-breakers

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C_1 = Non current-limiting circuit-breaker (N)

C_2 = Current-limiting circuit-breaker (L)

Figure A.3a) – Current-limiting CB upstream

C_1, C_2 = Non current-limiting circuit-breaker (N)

Figure A.3b) – Non current-limiting CB upstream

I_B = Take-over current

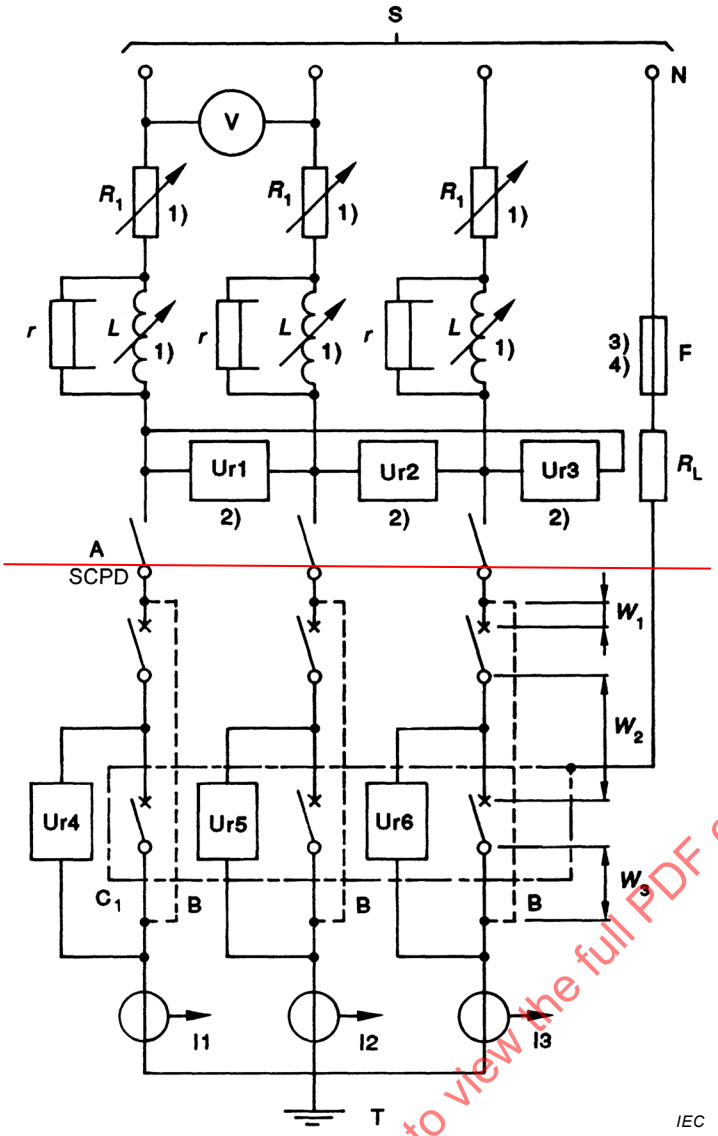
NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 I_{cu} (C_1 + C_2) ≤ I_{cu} (C_2)

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

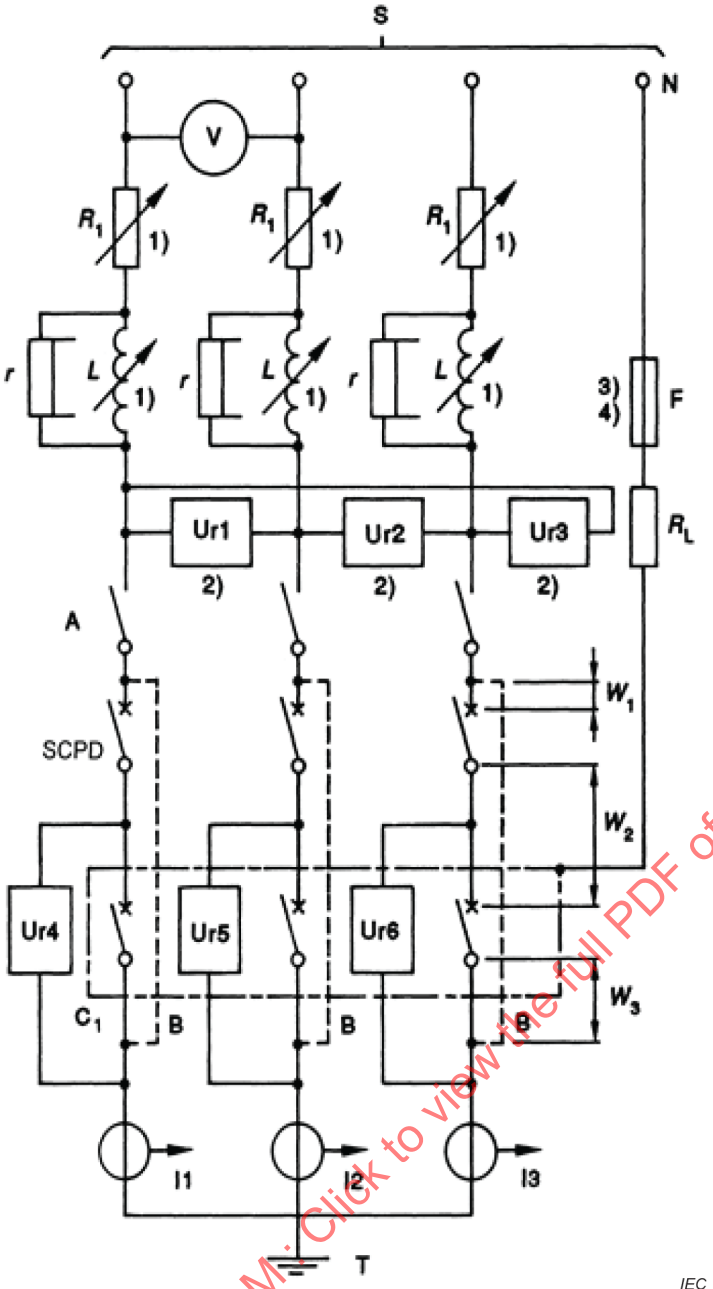
Figure A.3 – Back-up protection by a circuit-breaker – Operating characteristics

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S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for SCPD
W_2	=	50 cm of cable rated for C_1
W_3	=	25 cm of cable rated for C_1
SCPD	=	Circuit-breaker C_2 or set of 3 fuses
C_1	=	Circuit-breaker under test

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S = Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 = Voltage sensors
V = Voltage measuring device
A = Closing device
R_1 = Adjustable resistor
N = Neutral of supply (or artificial neutral)
F = Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L = Adjustable reactors
R_L = Fault current limiting resistor
B = Temporary connections for calibration
I1, I2, I3 = Current sensing devices
T = Earth: one earthing point only (load side or supply side)
r = Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1 = 75 cm of cable rated for SCPD
W_2 = 50 cm of cable rated for C_1
W_3 = 25 cm of cable rated for C_1
SCPD = Circuit-breaker C_2 or set of 3 fuses
C_1 = Circuit-breaker under test

~~Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.~~

Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

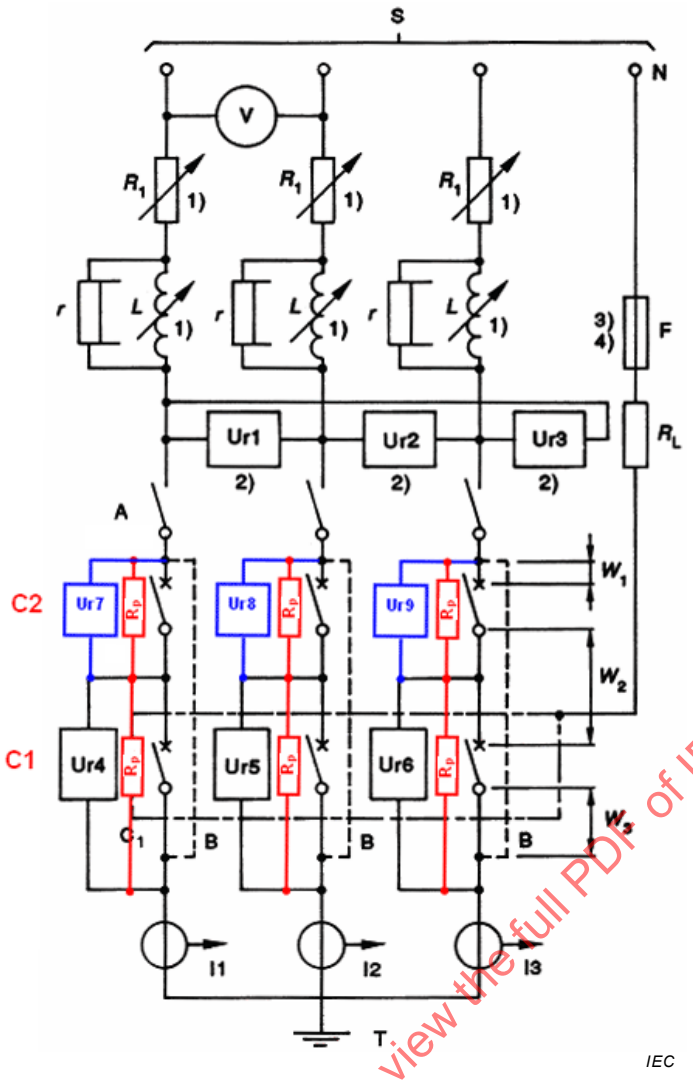
In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

In the USA and Canada (see notes to 4.3.2.1), F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e;
– to the neutral for equipment marked with a twin voltage.

Figure A.4 – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C_1)

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S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 Ur7, Ur8, Ur9	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
R_p	=	Optional polarising resistors
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for C_2
$W_2 + W_3$	=	75 cm of cable rated for C_1 (see A.5.2)
C_1, C_2	=	Circuit-breakers under test

~~Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.~~

Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

NOTE 1 In the USA and Canada (see notes to 4.3.2.1), F is connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

NOTE 2 Polarizing resistors allow determination of contact opening time for the two devices in series, the value being high enough not to influence the devices under test.

Figure A.5 – Example of test circuit for the verification of selectivity

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Annex B
(normative)

Circuit-breakers incorporating residual current protection

B.1 General

B.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of a circuit-breaker to achieve a two-fold goal, i.e.:

– providing protection of installations against overloads and short-circuit currents;

– providing protection of persons against indirect contact, i.e. hazardous increases of ground potential due to defective insulation.

Residual current devices may also provide additional protection against fire and other hazards which may develop as a result of an earth fault of a lasting nature which cannot be detected by the over-current protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in case of failure of the relevant protective means.

The requirements for the installation of such devices are specified in various sections of IEC 60364 series.

This annex is essentially based upon the relevant requirements of IEC 60755, IEC 61008-1 and IEC 61009-1.

B.1.2 Scope and object

This annex applies to circuit-breakers providing residual current protection (CBRs). It covers the requirements for units which concurrently perform residual current detection, compare such measurements with a preset value and cause the protected circuit to be switched off when this value is exceeded.

This annex applies to:

– circuit-breakers according to this standard which incorporate the residual current function as an integrated feature (hereinafter called integral CBRs);

– CBRs consisting of a combination of a residual current device (hereinafter referred to as r.c. units) and a circuit-breaker according to this standard; their combination both mechanically and electrically, may be carried out either at the factory or in the field by the user according to the manufacturer's instructions.

This annex also covers requirements for CBRs concerning electromagnetic compatibility (EMC).

NOTE The neutral current sensing means, if any, can be external to the circuit-breaker or the combination, as the case may be.

This annex applies only to CBRs intended for use in a.c. circuits.

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~~The residual current function of CBRs covered by this annex may or may not be functionally dependent on line voltage. CBRs depending on an alternative supply source are not covered by this annex.~~

~~This annex does not apply to equipment where the current sensing means (except the neutral current sensing means) or the processing device are mounted separately from the circuit-breaker.~~

~~The requirements for such devices are given in Annex M.~~

~~The object of this annex is to state:~~

~~a) the specific features of the residual current function;~~

~~b) the specific requirements which shall be complied with by the CBR~~

~~– under normal circuit conditions;~~

~~– under abnormal circuit conditions, whether of a residual current nature or not;~~

~~c) the tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;~~

~~d) the relevant product information.~~

~~B.2 Terms and definitions~~

~~As a complement to Clause 2 of this standard, the following definitions apply:~~

~~B.2.1 Terms and definitions relating to currents flowing from live parts to earth~~

~~**B.2.1.1**~~
~~**earth fault current**~~
~~current flowing to earth due to an insulation fault~~

~~[SOURCE: IEC 60050-442:1998, 442-01-23]~~

~~**B.2.1.2**~~
~~**earth leakage current**~~
~~current flowing from the live parts of the installation to earth in the absence of an insulation fault~~

~~[SOURCE: IEC 60050-442:1998, 442-01-24]~~

~~B.2.2 Terms and definitions relating to the energization of a CBR~~

~~**B.2.2.1**~~
~~**energizing quantity**~~
~~electrical energizing quantity which, alone or in combination with other such quantities, shall be applied to a CBR to enable it to accomplish its function under specified conditions~~

~~**B.2.2.2**~~
~~**energizing input-quantity**~~
~~energizing quantity by which the CBR is activated when it is applied under specified conditions~~

~~Note 1 to entry: These conditions can involve, e.g., the energizing of certain auxiliary elements.~~

~~[SOURCE: IEC 60050-442:1998, 442-05-58, modified – adapted to CBRs]~~

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B.2.2.3
residual current
I_{Δ}
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

[SOURCE: IEC 60050-442:1998, 442-05-19, modified – adapted to CBRs]

B.2.2.4
residual operating current
$I_{\Delta n}$
value of the residual current which causes the CBR to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – adapted to CBRs]

B.2.2.5
residual non-operating current
$I_{\Delta no}$
value of the residual current at which (and below which) the CBR does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – symbol introduced and adapted to CBRs]

B.2.3 Terms and definitions relating to the operation and the functions of a CBR

B.2.3.1
circuit-breaker incorporating residual current protection
CBR
circuit-breaker (see 2.1) designed to cause the opening of the contacts when the residual current attains a given value under specified conditions

B.2.3.2
CBR functionally independent of line voltage
CBR for which the functions of detection and evaluation, and the actuating means of interruption (see B.2.3.6) do not depend on the line voltage

B.2.3.3
CBR functionally dependent on line voltage
CBR for which the functions of detection and/or evaluation, and/or the actuating means of interruption (see B.2.3.6) depend on the line voltage

Note 1 to entry: It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

B.2.3.4
detection (of a residual current)
function consisting in sensing the presence of a residual current

Note 1 to entry: This function can be performed, for example, by a transformer integrating the vector sum of the currents.

[SOURCE: IEC 60050-442:1998, 442-05-24]

B.2.3.5
evaluation
function consisting in giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

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[SOURCE: IEC 60050-442:1998, 442-05-25, modified – without "(for a residual current)" and adapted to CBRs]

B.2.3.6
interruption
function consisting in bringing automatically the main contacts of the CBR from the closed position into the open position, thereby interrupting the current(s) flowing through them

[SOURCE: IEC 60050-442:1998, 442-05-26, modified – without "(for a residual current device)" and adapted to CBRs]

B.2.3.7
limiting non-actuating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the CBR without bringing it actually to operate

[SOURCE: IEC 60050-442:1998, 442-05-23, modified – addition of "rated" and adapted to CBRs]

B.2.3.8
time-delay CBR
CBR specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

Note 1 to entry: The residual current time-delay characteristic may or may not be of an inverse time/current nature.

[SOURCE: IEC 60050-442:1998, 442-05-05, modified – adapted to CBRs and addition of Note 1 to entry]

B.2.3.9
reset CBR
CBR with an r.c. unit which must be intentionally reset by a means different from the operating means of the CBR, following the occurrence of a residual current, before it can be reclosed

[SOURCE: IEC 60050-442:1998, 442-05-10, modified – adapted to CBRs]

B.2.3.10
test device
device simulating a residual current for checking that the CBR operates

B.2.4 Terms and definitions relating to values and ranges of energizing quantities

B.2.4.1
limiting value of the non-operating over-current in the case of a single-phase load
maximum value of a single-phase over-current which, in the absence of a residual current, can flow through a CBR (whatever the number of poles) without causing it to operate

Note 1 to entry: See B.7.2.7.

B.2.4.2
limiting value of the non-operating current in the case of a balanced load
maximum value of the current which, in the absence of any fault to frame or earth or of any earth leakage current, can flow in the circuit monitored by the CBR with a balanced load (whatever the number of poles) without causing it to operate

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B.2.4.3
residual short-circuit making and breaking capacity
a value of the a.c. component of a residual prospective short-circuit current which a CBR can make, carry for its opening time and break under specified conditions of use and behaviour

B.3 Classification

B.3.1 Classification according to the method of operation of the residual current function

B.3.1.1 CBR functionally independent of line voltage (see B.2.3.2)

B.3.1.2 CBR functionally dependent on line voltage (see B.2.3.3 and B.7.2.11)

B.3.1.2.1 Opening automatically in the case of failure of the line voltage with or without delay.

B.3.1.2.2 Not opening automatically in the case of failure of line voltage.

Not opening automatically in the case of failure of the line voltage, but able to trip under specified conditions in the case of an earth fault arising on failure of the line voltage.

NOTE Classification under this subclause includes CBRs unable to open automatically when no hazardous situation exists.

B.3.2 Classification according to the possibility of adjusting the residual operating current

B.3.2.1 CBR with single rated residual operating current

B.3.2.2 CBR with multiple settings of residual operating current (see note to B.4.1.1)

A CBR may have multiple settings of residual operating current, either by fixed steps or by continuous variation.

B.3.3 Classification according to time-delay of the residual current function

B.3.3.1 CBR without time-delay: non-time-delayed type

B.3.3.2 CBR with time-delay: time-delayed type (see B.2.3.8)

B.3.3.2.1 CBR with non-adjustable time-delay

B.3.3.2.2 CBR with adjustable time-delay

A CBR may have an adjustable time-delay, either by fixed steps or by continuous variation.

B.3.4 Classification according to behaviour in presence of a d.c. component

B.3.4.1 CBRs of type AC (see B.4.4.1)

B.3.4.2 CBRs of type A (see B.4.4.2)

B.4 Characteristics of CBRs concerning their residual current function

B.4.1 Rated values

B.4.1.1 Rated residual operating current ($I_{\Delta n}$)

The r.m.s. value of a sinusoidal residual operating current (see B.2.2.4) assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

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NOTE For a CBR with multiple settings of residual operating current, the highest setting is used to designate its rating. See, however, Clause B.5 concerning marking.

B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The r.m.s. value of sinusoidal residual non-operating current (see B.2.2.5) assigned to the CBR by the manufacturer at which the CBR does not operate under specified conditions.

B.4.1.3 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of the prospective residual short-circuit current (see B.2.4.3) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

B.4.2 Preferred and limiting values

B.4.2.1 Preferred values of rated residual operating current ($I_{\Delta n}$)

Preferred values of rated residual operating current are

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Higher values may be required.

$I_{\Delta n}$ may be expressed as a percentage of the rated current.

B.4.2.2 Minimum value of rated residual non-operating current ($I_{\Delta no}$)

The minimum value of rated residual non-operating current is 0,5 $I_{\Delta n}$.

B.4.2.3 Limiting value of non-operating over-current in the case of a single-phase load

The limiting value of non-operating over-current in the case of a single-phase load shall be in accordance with B.7.2.7.

B.4.2.4 Operating characteristics

B.4.2.4.1 Non-time-delay type

The operating characteristic for a non-time-delay type is given in Table B.1.

Table B.1 – Operating characteristic for non-time-delay type

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Maximum break times s	0,3	0,15	0,04	0,04
[a] For CBRs having $I_{\Delta n} \leq$ 30 mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$. [b] 0,5 A if 0,25 A is used according to footnote a.				

CBRs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type.

B.4.2.4.2 Time-delay type

B.4.2.4.2.1 Limiting non-actuating time (see B.2.3.7)

For a time-delay type, the limiting non-actuating time is defined at 2 $I_{\Delta n}$ and shall be declared by the manufacturer.

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The minimum limiting non-actuating time at 2 $I_{\Delta n}$ is 0,06 s.

Preferred values of limiting non-actuating time at 2 I_{Δ} are

0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s.

B.4.2.4.2.2 Operating characteristic

For CBR's having a limiting non-actuating time higher than 0,06 s, the manufacturer shall declare the maximum break time at $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, and 10 $I_{\Delta n}$.

For CBR's having limiting non-actuating time of 0,06 s the operating characteristic is given in Table B.2.

Table B.2 – Operating characteristic for time-delay type having a limiting non-actuating time of 0,06 s

Residual current	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Maximum break time in s	0,5	0,2	0,15	0,15

In case of a CBR having an inverse current/time characteristic, the manufacturer shall state the residual current/break time characteristic.

B.4.3 Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The minimum value of $I_{\Delta m}$ is 25 % of I_{cu}.

Higher values may be tested and declared by the manufacturer.

B.4.4 Operating characteristics in case of an earth fault current in the presence or absence of a d.c. component

B.4.4.1 CBR of type AC

A CBR for which tripping is ensured for residual sinusoidal alternating currents, in the absence of a d.c. component whether suddenly applied or slowly rising.

B.4.4.2 CBR of type A

A CBR for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents with or without a specified level of superimposed d.c., whether suddenly applied or slowly rising.

B.5 Marking

Each CBR shall be marked in a durable manner:

a) The following data shall be marked on integral CBRs (see B.1.1), in addition to the marking specified in 5.2, and be clearly visible in the installed position:

- rated residual operating current $I_{\Delta n}$;
- settings of residual operating current, when applicable;
- limiting non-actuating time at 2 $I_{\Delta n}$, for time-delay type, by the symbol Δt followed by the limiting non-actuating time in ms; alternatively, where the limiting non-actuating time is 0,06 s, the symbol may be S (S in a square);
- the operating means of the test device by the letter T (see also B.7.2.6);

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– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type AC with the symbol 

for CBRs of type A with the symbol 

b) The following data shall be marked on r.c. units and be clearly visible in the installed position:

– rated voltage(s) if different from the rated voltage(s) of the circuit-breaker;

– value (or range) of the rated frequency if different from that of the circuit-breaker;

– the indication $I_n \leq ...$A (I_n being the maximum current rating of the circuit-breaker with which the r.c. unit may be combined);

– rated residual operating current $I_{\Delta n}$;

– settings of residual operating current, when applicable;

– limiting non-actuating time, as specified in item a);

– the operating means of the test device, as specified in item a);

– operating characteristic in case of residual currents in the presence or absence of a d.c. component:

for CBRs of type A with the symbol 

for CBRs of type AC with the symbol 

c) The following data shall be marked on r.c. units and be visible after assembly with the circuit-breaker:

– manufacturer's name or trade mark;

– type designation or serial number;

– identification of the circuit-breaker(s) with which the r.c. unit may be assembled, unless incorrect assembly (such as to render the protection ineffective) is made impossible by the design;

– IEC 60947-2;

– suitability for use with a 3-phase supply only, with the symbol 

d) The following data shall be marked on integral CBRs or r.c. units, as applicable, or made available in the manufacturer's literature:

– rated residual short-circuit making and breaking capacity $I_{\Delta m}$ if higher than 25 % of I_{cu} (see B.4.3);

– diagram of connections, including those of the test circuit and, if applicable, those to the line, for CBRs dependent on the line voltage;

– value of rated residual non-operating current $I_{\Delta no}$ if greater than 0,5 $I_{\Delta n}$.

e) The following data shall be made available in the manufacturer's literature:

– suitability for use on:

- three-phase systems only, or
- three-phase and single phase systems.

B.6 Normal service, mounting and transport conditions

Clause 6 applies.

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B.7 Design and operating requirements

B.7.1 Design requirements

It shall not be possible to modify the operating characteristic of a CBR except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

CBRs combining a r.c. unit device and a circuit-breaker shall be so designed and built that:

- the coupling system of the r.c. unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that may adversely affect the installation or result in injury to the user;
- the addition of the r.c. unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;
- the r.c. unit does not sustain any permanent damage due to the short-circuit currents during test sequences.

B.7.2 Operating requirements

B.7.2.1 Operation in case of a residual current

The CBR shall open automatically in response to any earth leakage current or earth fault current equal to or exceeding the rated residual operating current for a time exceeding the non-actuating time.

The operation of the CBR shall be in compliance with the time requirements specified in B.4.2.4. Compliance shall be checked by the tests of B.8.1.1.

B.7.2.2 Rated residual current short-circuit making and breaking capacity $I_{\Delta m}$

CBRs shall meet the test requirements of B.8.10.

B.7.2.3 Operational performance capability

CBRs shall comply with the tests of B.8.1.1.1.

B.7.2.4 Effects of environmental conditions

CBRs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the test of B.8.11.

B.7.2.5 Dielectric properties

CBRs shall withstand the tests of B.8.3.

B.7.2.6 Test device

CBRs shall be provided with a test device causing the passing through the detecting device of a current simulating a residual current, in order to allow periodic testing of the ability of the CBRs to operate.

The test device shall satisfy the tests of B.8.4.

The protective conductor, if any, shall not become live when the test device is operated.

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It shall not be possible to energize the protected circuit by operating the test device when the CBR is in the open position.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; a light colour should preferably be used.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

B.7.2.7 Value of the non-operating over-current in the case of a single-phase load

CBRs shall withstand the smaller of the following two over-current values without tripping:

– $6\ I_n$;

– 80 % of the maximum short-circuit release current setting.

Compliance is checked by the test of B.8.5.

However this test is not necessary in the case of CBRs of selectivity category B since the requirements of this subclause are verified during test sequence IV (or the test sequence VI (combined)).

NOTE Tests for polyphase balanced loads are not necessary since they are considered to be covered by the requirements of this subclause.

B.7.2.8 Resistance of CBRs to unwanted tripping due to surge currents resulting from impulse voltages

B.7.2.8.1 Resistance to unwanted tripping in case of loading of the network capacitance

CBRs shall withstand the test of B.8.6.2.

B.7.2.8.2 Resistance to unwanted tripping in case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.3.

B.7.2.9 Behaviour of CBRs of type A in case of an earth fault comprising a d.c. component

The behaviour of CBRs in case of an earth fault current comprising a d.c. component, shall be such that the maximum break times stated in Table B.1 and Table B.2, as applicable, shall also be valid, the test current values specified being, however, increased:

– by the factor 1,4 for CBRs having $I_{\Delta n} > 0{,}015$ A;

– by the factor 2 for CBRs having $I_{\Delta n} \leq 0{,}015$ A (or 0,03 A, whichever is the higher).

Compliance is checked by the tests of B.8.7.

B.7.2.10 Conditions of operation for reset-CBRs

It shall not be possible to reclose reset-CBRs (see B.2.3.9) after tripping due to a residual current, if they have not been reset.

Compliance is checked during the test of 8.3.3.4.4 in accordance with B.8.1.1.1.

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B.7.2.11 Additional requirements for CBRs functionally dependent on line voltage

CBRs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times its rated value.

Compliance is checked by the tests of B.8.2.3.

Where a CBR has more than one rated frequency or a range of rated frequencies, the CBR shall be capable of operating in accordance with this subclause at all frequencies.

Compliance is verified by carrying out the tests of B.8.2 and B.8.4.

According to their classification CBRs functionally dependent on line voltage shall comply with the requirements given in Table B.3.

Table B.3 – Requirements for CBRs functionally dependent on line voltage

Classification of the device according to B.3.1		Behaviour in case of failure of line voltage
CBRs opening automatically in the case of failure of the line voltage (B.3.1.2.1)	Without delay	Opening without delay according to item a) of B.8.8.3
	With delay	Opening with delay according to item b) of B.8.8.3
CBRs not opening automatically in the case of failure of the line voltage but able to open in the case of a hazardous situation arising (B.3.1.2.2)		Operating according to B.8.9

B.7.3 Electromagnetic compatibility

The requirements of Annex J apply.

Additional test specifications are given in B.8.12.

Immunity to voltage variations is covered by the requirements of B.7.2.11.

B.8 Tests

B.8.1 General

This clause specifies tests for CBRs having a rated residual operating current $I_{\Delta n}$ up to and including 30 A.

The applicability of the tests specified in this clause when $I_{\Delta n} > 30$ A is subject to agreement between manufacturer and user.

The instruments for the measurement of the residual current shall be at least class 0,5 (see IEC 60051) and shall show (or permit to determine) the true r.m.s. value.

The instruments for the measurement of time shall have a relative error not greater than 10 % of the measured value.

Tests specified in this annex are supplementary to the tests of Clause 8.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 8. For the dielectric withstand verifications during these test sequences (see 8.3.3.6), the control circuit of residual current devices functionally dependent on line voltage shall be disconnected from the main circuit.

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The tests shall be made with substantially sinusoidal currents.

For CBRs comprising a separate r.c. unit and a circuit-breaker, the assembly shall be performed in compliance with the manufacturer's instructions.

In the case of CBRs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of CBRs with adjustable time-delay (see B.3.3.2.2) the time-delay shall be set at maximum, unless otherwise stated.

In the case of CBRs with adjustable instantaneous tripping, the instantaneous trip shall be set at maximum, unless otherwise stated.

b) Routine tests

Subclause 8.4.5 applies.

B.8.1.1 Tests to be made during the test sequences of Clause 8

B.8.1.1.1 Operational performance capability

During the operating cycles with current (see 8.3.3.4.4) specified in Table 8 (see 7.2.4.2), a third of the breaking operations shall be performed by actuating the test device, and a further third by applying a residual current of value $I_{\Delta n}$ (or, if applicable, of the lowest setting of the residual operating current) to any one pole.

In the case of a reset-CBR, it shall be verified that it is not possible to reclose the CBR after tripping without the intentional resetting action. This verification shall take place at the beginning and at the end of the operational performance capability test with current (8.3.3.4.4).

No failure to trip shall be admitted.

B.8.1.1.2 Verification of the withstand capability to short-circuit currents

B.8.1.1.2.1 Rated service short-circuit breaking capacity (test sequence II)

Following the tests of 8.3.4, verification of the correct operation of the CBR in case of residual current shall be performed in accordance with B.8.2.4.2.

B.8.1.1.2.2 Rated ultimate short-circuit breaking capacity (test sequence III)

For the purpose of verifying the correct operation of the overload releases, the single pole tests specified in 8.3.5.2 and 8.3.5.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.2 and 8.3.5.5 but applicable to two poles.

Following the tests of 8.3.5, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.3 Rated short-time withstand current (test sequence IV or test sequence VI (combined))

The following requirements apply:

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.3 or 8.3.8.3, as applicable.

b) Verification of overload releases

– For test sequence IV

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For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.6.2 and 8.3.6.7, the single pole tests specified in 8.3.5.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

– For the combined test sequence

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.8.2, the single pole test specified in 8.3.5.2 shall be replaced by two-pole tests made on all possible combinations of phase poles in turn.

For the purpose of verifying the correct operation of overload releases in accordance with 8.3.8.7, the test specified in 8.3.3.8 shall be made using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 8.3.6 or 8.3.8, as applicable, verification of the residual current tripping device shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.4 Integrally fused circuit-breakers (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 8.3.7.5 and 8.3.7.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.5 and 8.3.7.9 but applicable to two poles.

Following the tests of 8.3.7, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.1.2.5 Test sequence VI (combined)

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2 Additional test sequences

Additional test sequences shall be performed on CBRs in accordance with Table B.4.

Table B.4 – Additional test sequences

Sequences	Test	Subclause
B I	Operating characteristic	B.8.2
	Dielectric properties	B.8.3
	Operation of the test device at the limits of rated voltage	B.8.4
	Limiting value of the non-operating current under over-current conditions	B.8.5
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Behaviour in the case of an earth fault current comprising a d.c. component	B.8.7
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.1	B.8.8
	Behaviour in the case of failure of line voltage for CBRs classified under B.3.1.2.2.	B.8.9
B II	Residual short-circuit making and breaking capacity ($I_{\Delta m}$)	B.8.10
B III	Effects of environmental conditions	B.8.11
B IV	Immunity tests	B.8.12.1
	Emission tests	B.8.12.2

For CBRs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the

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tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of test sequences B I, B II and B III.

For test sequence B IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Test sequence B I

B.8.2 Verification of the operating characteristic

B.8.2.1 Test circuit

The CBR is installed as in normal use.

The test circuit shall be in accordance with Figure B.1.

B.8.2.2 Test voltage for CBRs functionally independent of line voltage

Tests may be made at any convenient voltage.

B.8.2.3 Test voltage for CBRs functionally dependent on line voltage

Tests shall be made at the following values of voltage applied to the relevant terminals:

– 0,85 times the minimum rated voltage for the tests specified in B.8.2.4 and B.8.2.5.2;

– 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.3.

CBRs with more than one rated frequency or a range of rated frequencies shall be tested in each case at the highest and lowest rated frequency. However, for CBRs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover the requirements.

B.8.2.4 Off-load test at 20 °C ± 5 °C

B.8.2.4.1 General

The connections being as in Figure B.1, the CBR shall perform the tests of B.8.2.4.2, B.8.2.4.3 and B.8.2.4.4 and also, where applicable, B.8.2.4.5, all made on one pole only chosen at random. Each test shall comprise three measurements or verifications, as applicable.

Unless otherwise specified, for CBR's with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the lowest and highest settings, and at one intermediate setting.

B.8.2.4.2 Verification of the correct operation in the case of a steady increase of the residual current

For CBR's with adjustable time-delay, the tests shall be performed at the lowest setting. The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$ so as to attain the value $I_{\Delta n}$ in approximately 30 s, the tripping current being measured each time. The three measured values shall be greater than $I_{\Delta no}$ and less than or equal to $I_{\Delta n}$.

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B.8.2.4.3 Verification of the correct operation in the case of closing on residual current

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or the specific settings of the residual operating current if applicable, see B.8.2.4), and the switches S_1 and S_2 being closed, the CBR is closed onto the circuit so as to simulate service conditions as closely as possible. The break time is measured three times.

No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

B.8.2.4.4 Verification of the correct operation in the case of sudden appearance of residual current

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable, and the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S_2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of I_{Δ}. No value shall exceed the relevant limiting value.

B.8.2.4.5 Verification of the limiting non-actuating time of CBRs of the time-delayed type

The test circuit being calibrated at the value of 2 $I_{\Delta n}$, the test switch S_1 and the CBR being in the closed position, the residual current is established by closing the switch S_2 and applied for a time equal to the limiting non-actuating time declared by the manufacturer, in accordance with B.4.2.4.2.1.

During each of the three verifications the CBR shall not trip. If the CBR has an adjustable residual operating current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of residual operating current and at the maximum setting of time delay.

B.8.2.5 Tests at the temperature limits

B.8.2.5.1 General

NOTE The upper temperature limit can be the reference temperature.

The temperature limits of this subclause may be extended by agreement between manufacturer and user, in which case tests shall be performed at the agreed temperature limits.

B.8.2.5.2 Off-load test at –5 °C

The CBR is placed in a chamber having a stabilized ambient temperature within the limits of –7 °C and –5 °C. After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, if applicable, B.8.2.4.5.

B.8.2.5.3 On-load test at the reference temperature or at +40 °C

The CBR, connected in accordance with Figure B.1, is placed in a chamber having a stabilized ambient temperature equal to the reference temperature (see 4.7.3) or, in the absence of a reference temperature, equal to 40 °C ± 2 °C. A load current equal to I_n (not indicated on Figure B.1) is applied on all phase poles.

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After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, where applicable, B.8.2.4.5.

B.8.3 Verification of dielectric properties

CBRs shall comply with 8.3.3.3.

B.8.4 Verification of the operation of the test device at the limits of rated voltage

The verification consists of the following tests:

a) The CBR being supplied with a voltage equal to 1,1 times the highest rated voltage, the test device is momentarily actuated 25 times at intervals of 5 s, the CBR being closed again before each operation.

b) Test a) is then repeated at 0,85 times the lowest rated voltage, the device being actuated three times.

c) Test a) is then repeated, but only once, the operating means of the test device being held in the closed position for 5 s.

For these tests:

– in the case of CBRs with identified line and load terminals, the supply connections shall be in accordance with the marking;

– in the case of CBRs with unidentified line and load terminals, the supply shall be connected to each set of terminals in turn, or alternatively to both sets of terminals simultaneously.

At each test the CBR shall operate.

For CBRs having an adjustable residual operating current:

– the lowest setting shall be used for tests a) and c);

– the highest setting shall be used for test b).

For CBRs having an adjustable time-delay the test is made at the maximum setting of time-delay.

NOTE The verification of the endurance of the test device is considered to be covered by the tests of B.8.1.1.1.

B.8.5 Verification of the limiting value of the non-operating current under over-current conditions

The test shall be made with a single phase load, the connections being made according to Figure B.2.

The impedance Z is adjusted so as to let a current equal to the lower of the following two values flow in the circuit:

– $6\ I_n$;

– 80 % of the maximum short-circuit release current setting.

NOTE 1 For the purpose of this current adjustment, the CBR D (see Figure B.2) can be replaced by connections of negligible impedance.

For CBRs with an adjustable residual current setting the test is made at the lowest setting.

CBRs functionally independent of line voltage are tested at any convenient voltage.

CBRs functionally dependent on line voltage are supplied on the line side with their rated voltage (or, if relevant, with a voltage having any value within the range of rated voltages).

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The test is made at a power factor of 0,5.

The switch S_1, being open, is closed and reopened after 2 s. The test is repeated three times for each possible combination of the current paths, the interval between successive closing operations being at least 1 min.

The CBR shall not trip.

NOTE 2 The time of 2 s can be reduced (but to not less than the minimum break time) to avoid the risk of tripping by action of the overload release(s) of the CBR.

B.8.6 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

B.8.6.1 General

For CBRs with adjustable time delay (see B.3.3.2.2) the time-delay shall be set at minimum.

B.8.6.2 Verification of resistance to unwanted tripping in case of loading of the network capacitance

The CBR is tested using a surge current generator capable of delivering a damped oscillatory current as shown in Figure B.4.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.5.

One pole of the CBR chosen at random shall be subjected to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be approximately 30 s. The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 200 A $^{+10}_{0}$ %;

– virtual front time: 0,5 µs ± 30 %;

– period of the following oscillatory wave: 10 µs ± 20 %;

– each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

B.8.6.3 Verification of resistance to unwanted tripping in case of flashover without follow-on current

The CBR is tested using a surge current generator capable of delivering an 8/20 µs surge current wave, without reverse polarity, as shown in Figure B.6.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.7.

One pole of the CBR, chosen at random, shall be submitted to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive operations shall be approximately 30 s.

The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 250 A $^{+10}_{0}$ %;

– virtual front time (T_1): 8 µs ± 10 %;

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– virtual time to half value (T_2): 20 µs ± 10 %.

During the tests the CBR shall not trip.

B.8.7 Verification of the behaviour of CBRs of type A in the case of an earth fault current comprising a d.c. component

B.8.7.1 Test conditions

The test conditions of B.8 and B.8.2.1, B.8.2.2 and B.8.2.3 apply, except that the test circuits shall be those shown in Figure B.8 and Figure B.9, as applicable.

B.8.7.2 Verifications

B.8.7.2.1 Verification of the correct operation in case of a continuous rise of residual pulsating direct current

The test circuit shall be according to Figure B.8. In the case of a CBR with adjustable time delay (see B.3.3.2.2), the time-delay shall be set to minimum.

The auxiliary switches S_1 and S_2 and the CBR D shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the CBR shall be tested at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S_3.

At every test, the current, starting from zero, shall be steadily increased at an approximate rate of:

$\frac{1{,}4\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} > 0{,}015$ A;

$\frac{2\ I_{\Delta n}}{30}$ A/s for CBRs of $I_{\Delta n} \leq 0{,}015$ A.

The tripping current shall be in accordance with Table B.5.

Table B.5 – Tripping current range for CBRs in case of an earth fault comprising a d.c. component

Angle α	Tripping current A	
	Lower limit	Upper limit
0°	0,35 $I_{\Delta n}$	0,03 A for $I_{\Delta n} \leq 0{,}015$ A or 1,4 $I_{\Delta n}$ for $I_{\Delta n} > 0{,}015$ A
90°	0,25 $I_{\Delta n}$	
135°	0,11 $I_{\Delta n}$	

B.8.7.2.2 Verification of the correct operation in case of a suddenly appearing residual pulsating direct current

The test shall be performed according to Figure B.8.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the CBR being in the closed position, the residual current is suddenly established by the closing switch S_2.

NOTE In the case of CBR's functionally dependent on line voltage, classified according to B.3.1.2.2, the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time

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necessary to energize the CBR. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the CBR under test and S_2 being previously closed.

Four measurements are made at each value of test current at a current delay angle α = 0°, two with the auxiliary switch in position I and two in position II.

For CBRs with $I_{\Delta n}$ > 0,015 A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 1,4.

For CBRs with $I_{\Delta n}$ ≤ 0,015 A, the test shall be made at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 2 (or at 0,03 A, whichever is the higher).

No value shall exceed the specified limiting values (see B.7.2.9).

B.8.7.2.3 Verification of the correct operation with load at the reference temperature

The tests of B.8.7.2.1 and B.8.7.2.2 are repeated, the pole under test and one other pole of the CBR being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure B.8.

B.8.7.2.4 Verification of the correct operation in case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

The CBR shall be tested according to Figure B.9, with a half-wave rectified residual current (current delay angle α = 0°) superimposed by a smooth direct current of 0,006 A.

Each pole of the CBR is tested in turn, twice at each of positions I and II.

For CBRs of $I_{\Delta n}$ > 0,015 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 1,4 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 1,4 $I_{\Delta n}$ + 0,006 A.

For CBRs of $I_{\Delta n}$ ≤ 0,015 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 2 $I_{\Delta n}$ / 30 A/s, tripping shall occur before the current reaches a value not exceeding 0,03 A + 0,006 A.

B.8.8 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

B.8.8.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs with an adjustable time-delay, the test is made at any one of the time-delay settings.

B.8.8.2 Determination of the limiting value of the line voltage

A voltage equal to the rated voltage is applied to the line terminals of the CBR and is then progressively lowered to zero over a time period corresponding to the longer of the two values given hereinafter until automatic opening occurs:

- about 30 s;
- a period long enough with respect to the delayed opening of the CBR, if any (see B.7.2.11).

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The corresponding voltage is measured.

Three measurements are made. All the values shall be less than 0,85 times the minimum rated voltage of the CBR.

Following these measurements it shall be verified that the CBR trips when a residual current equal to $I_{\Delta n}$ is applied, the applied voltage being just above the highest value measured.

It shall then be verified that, for any value of voltage less than the lowest value measured, it is not be possible to close the CBR by manual operating means.

B.8.8.3 Verification of the automatic opening in the case of failure of the line voltage

The CBR being closed, a voltage equal to its rated voltage, or, in the case of a range of rated voltages, any one of the rated voltages is applied to its line terminals. The voltage is then switched off. The CBR shall trip. The time interval between the switching off and the opening of the main contacts is measured.

Three measurements are made:

a) for CBRs opening without delay (see B.7.2.11), no value shall exceed 0,2 s;

b) for CBRs opening with delay the maximum and minimum values shall be situated within the range indicated by the manufacturer.

B.8.9 Verification of the behaviour of CBRs functionally dependent on line voltage as classified under B.3.1.2.2 in the case of failure of line voltage

B.8.9.1 General

For CBRs having an adjustable residual operating current, the test is made at the lowest setting.

For CBRs having an adjustable time delay the test is made at any one of the time-delay settings.

B.8.9.2 Case of loss of one phase in a 3-phase system (for 3-pole and 4-pole CBRs)

The CBR is connected according to Figure B.3 and is supplied on the line side at 0,85 times the rated voltage, or, in the case of a range of rated voltages, at 0,85 times the lowest value of rated voltage.

One phase is then switched off by opening switch S_4; the CBR is then submitted to the test of B.8.2.4.4. The switch S_4 being closed again, a further test is made by opening switch S_5; the CBR is then submitted to the test of B.8.2.4.4.

This test procedure is repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

B.8.9.3 Case of voltage drop due to an overcurrent resulting from a low impedance fault to earth

The CBR is connected according to Figure B.3 and is supplied on the line side with the rated voltage or, in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_1. The CBR shall not trip.

S_1 is then reclosed and the voltage is reduced as follows:

a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

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b) for CBRs for use with a single phase supply: to 85 V applied as follows:

– for single-pole and two-pole CBRs: between poles;

– for three-pole and four-pole CBRs, declared as suitable for use with a single-phase supply (see B.5 e)): between each combination of two poles, connected according to the manufacturer's specification.

NOTE For the purpose of this annex, a single-pole CBR is a device with one overcurrent protected pole and an uninterrupted neutral (two current paths).

A current of value $I_{\Delta n}$ is then applied to a) and/or b), as applicable. The CBR shall trip.

Test sequence B II

B.8.10 Verification of the residual short-circuit making and breaking capacity

B.8.10.1 General

This test is intended to verify the ability of the CBR to make, to carry for a specified time and to break residual short-circuit currents.

B.8.10.2 Test conditions

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using Figure 9 of IEC 60947-1:2007/AMD1:2010, but connected in such a manner that the short-circuit current is a residual current.

The test is carried out at phase to neutral voltage on one pole only which shall not be the neutral pole. The current paths which do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

Where applicable, the CBR is adjusted at the lowest setting of residual operating current and at the maximum setting of time-delay.

If the CBR has more than one value of I_{cu}, each one having a corresponding value of $I_{\Delta m}$, the test is made at the maximum value of $I_{\Delta m}$, at the corresponding phase-to-neutral voltage.

B.8.10.3 Test procedure

The sequence of operations to be performed is

O – *t* – CO

B.8.10.4 Conditions of the CBR after test

B.8.10.4.1 Following the test of B.8.10.3 the CBR shall show no damage likely to impair its further use and shall be capable, without maintenance, of:

– withstanding a voltage equal to twice its maximum rated operational voltage, under the conditions of 8.3.3.4.1 item 4) of IEC 60947-1:2007. For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests;

– making and breaking its rated current at its maximum rated operational voltage.

B.8.10.4.2 The CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.4, but at a value of 1,25 $I_{\Delta n}$ and without measurement of break time. The test is made on any one pole, taken at random.

If the CBR has an adjustable residual operating current, the test is made at the lowest setting, at a current of a value of 1,25 times that setting.

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B.8.10.4.3 Where applicable the CBR shall also be submitted to the test of B.8.2.4.5.

B.8.10.4.4 CBRs functionally dependent on line voltage shall also satisfy the tests of B.8.8 or B.8.9, as applicable.

Test sequence B III

B.8.11 Verification of the effects of environmental conditions

The test is carried out according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be

– 6 for $I_{\Delta n}$ > 1 A,

– 28 for $I_{\Delta n}$ ≤ 1 A.

The 28 cycle test shall be applied to CBRs having multiple settings of residual operating current when one of the possible settings is ≤ 1 A.

At the end of the cycles the CBR shall be capable of complying with the tests of B.8.2.4.4, but with a residual operating current of 1,25 $I_{\Delta n}$ and without measurement of break time. Only one verification need to be made.

Where applicable the CBR shall also comply with the test of B.8.2.4.5. Only one verification need to be made.

B.8.12 Verification of electromagnetic compatibility

B.8.12.1 Immunity tests

B.8.12.1.1 General

Annex J applies with the following additional requirements.

For CBRs with adjustable settings of residual operating current and/or time-delay, the tests shall be made at the lowest of these settings.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

The tests are performed without load current but with the residual current, when specified.

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1, with the following specifications:

Performance criterion A:

For step 1, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, shall correctly indicate the status.

For step 2, the CBR shall trip at each test frequency, when loaded at 1,25 $I_{\Delta n}$; the dwell time at each frequency shall be not less than the maximum break time specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2, as applicable.

Following these tests, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

Performance criterion B:

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During the test, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, may be temporarily affected. Following the test, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

B.8.12.1.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

The test set-up shall be in accordance with Figure J.1 and Figure J.3.

Performance criterion B of B.8.12.1.1 applies except that during the test the CBR may trip. If this is the case a further test shall be made at the immediate lower level, and the CBR shall not trip.

B.8.12.1.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test set-up shall be in accordance with Figure J.4.

The test connections shall be in accordance with Figure 5 or Figure 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer's instructions for installation. The type of cable used shall be stated in the test report.

Performance criterion A of B.8.12.1.1 applies.

B.8.12.1.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figure 4 of IEC 61000-4-4:2012.

The test set-up shall be in accordance with Figure J.5 for testing power lines and with Figure J.6 for testing signal lines, taking into consideration the manufacturer's instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.5 Surges

Annex J applies, in particular J.2.5.

The test conditions of 7.2 of IEC 61000-4-5:2014 apply.

For convenience, the mounting specified in B.8.12.1.4 may be used but the use of the ground reference plane is optional.

The test connections shall be in accordance with Figures 6, 7, 8 or 9 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B of B.8.12.1.1 applies.

B.8.12.1.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

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~~Performance criterion A of B.8.12.1.1 applies.~~

~~**B.8.12.2 Emission tests**~~

~~**B.8.12.2.1 General**~~

~~Annex J applies with the following additional requirements.~~

~~The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.~~

~~Tests shall be made without load current and without residual current.~~

~~**B.8.12.2.2 Conducted RF disturbances (150 kHz to 30 MHz)**~~

~~Annex J applies, in particular J.3.2.~~

~~**B.8.12.2.3 Radiated RF disturbances (30 MHz to 1 000 MHz)**~~

~~Annex J applies, in particular J.3.3.~~

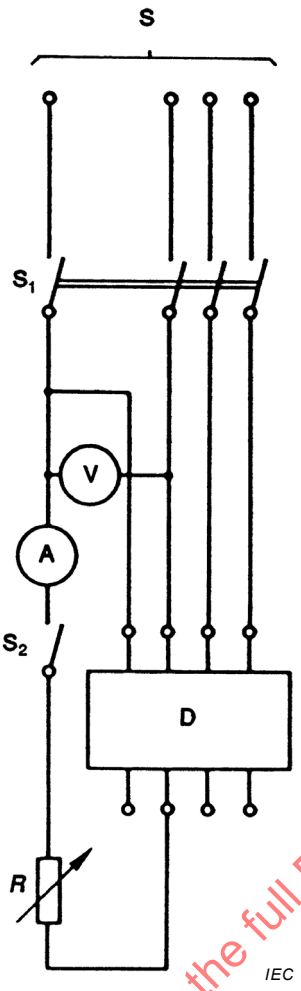
~~**B.8.13 Test for variations or interruptions of voltage and for voltage dips**~~

~~NOTE For definition of voltage dips, see IEC 61000-4-11.~~

~~The relevant tests of B.8.8 and B.8.9 are considered adequate to cover the EMC requirements.~~

~~No additional tests are therefore required.~~

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~~S = Supply~~

~~V = Voltmeter~~

~~A = Ammeter~~

~~S_1 = All-pole switch~~

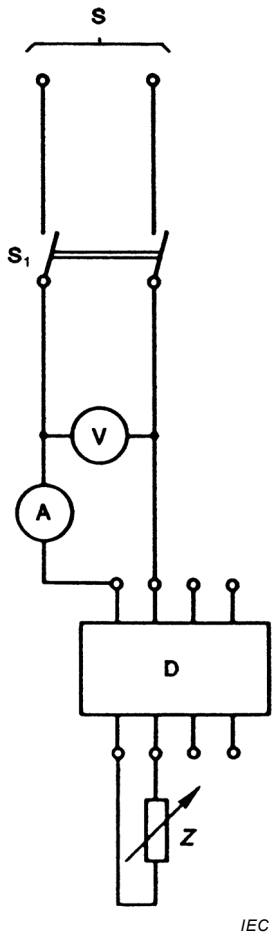
~~S_2 = Single-pole switch~~

~~D = CBR under test~~

~~*R* = Adjustable resistor~~

~~Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)~~

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~~S = Supply~~

~~S_1 = Two-pole switch~~

~~V = Voltmeter~~

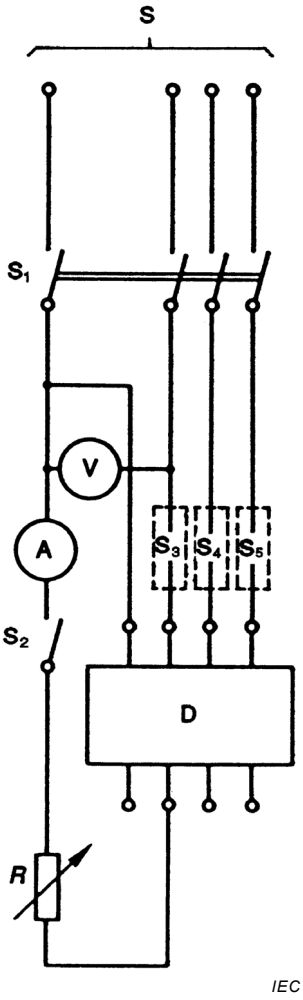
~~A = Ammeter~~

~~D = CBR under test~~

~~Z = Adjustable impedance~~

~~Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)~~

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S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
S_3, S_4, S_5 = Single-pole switches opening one phase in turn
D = CBR under test
R = Adjustable resistor

Figure B.3 – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.9)

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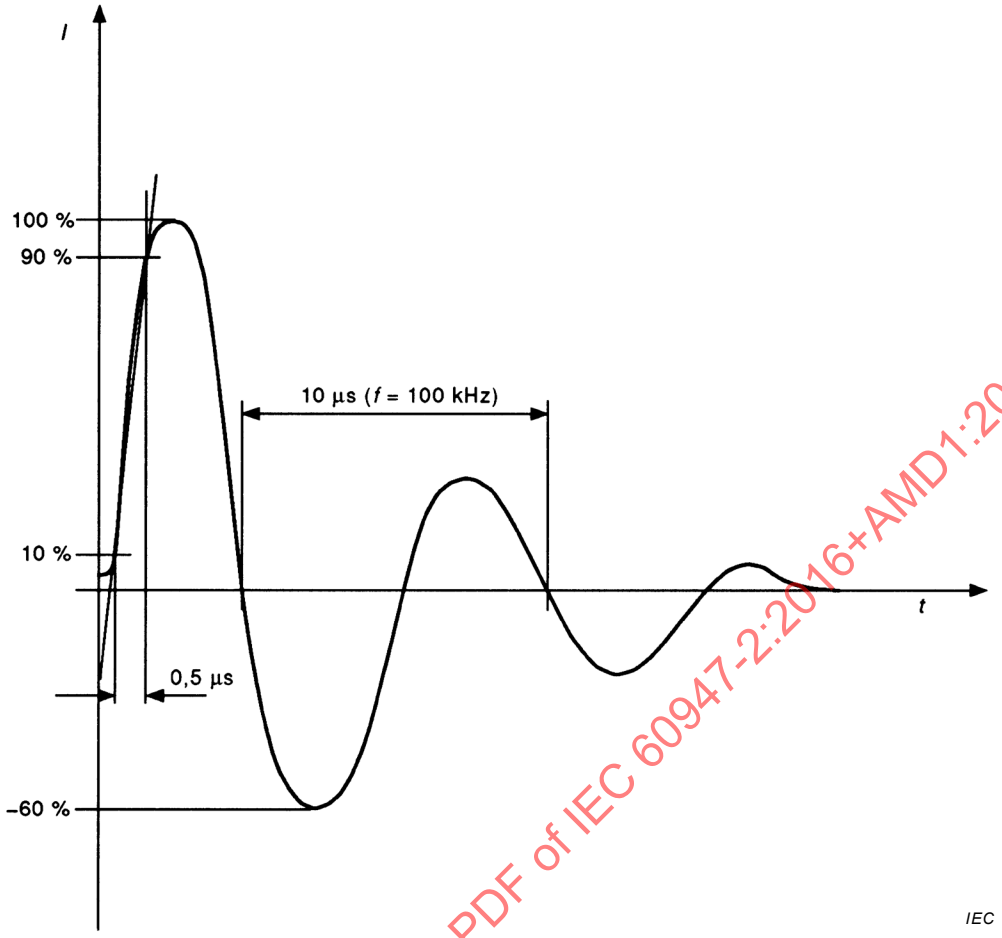
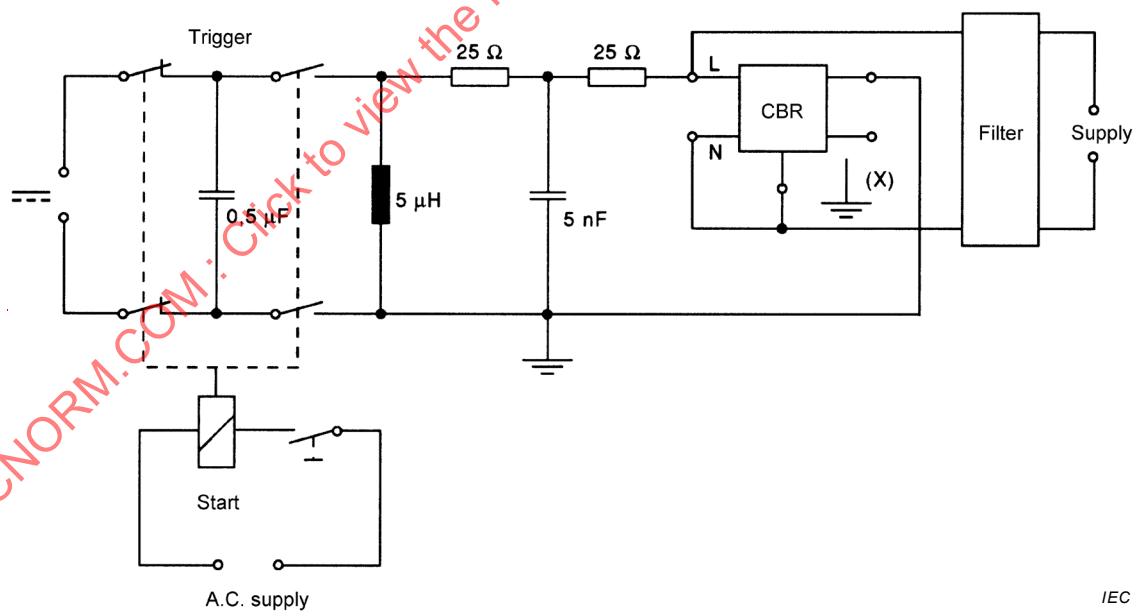


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

NOTE The circuit component values are given for guidance only and may require adjustment to comply with the wave shape requirements of Figure B.4.

Figure B.5 – Example of test circuit for the verification of resistance to unwanted tripping

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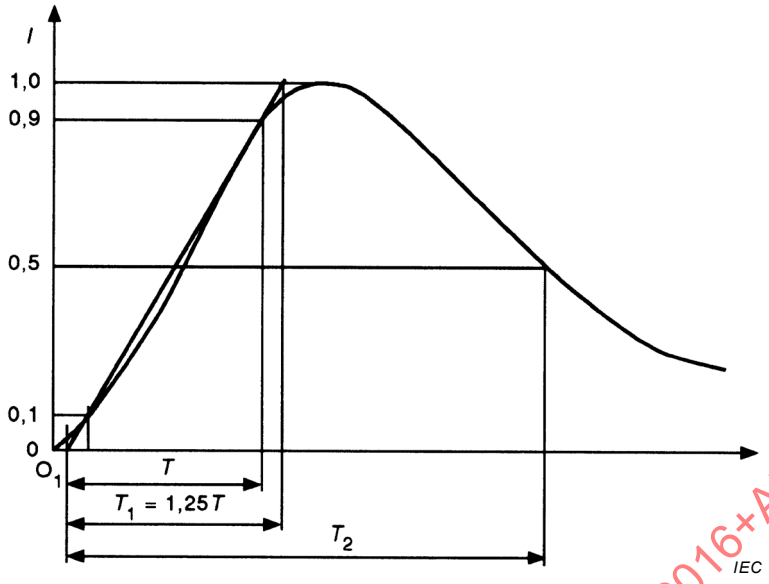
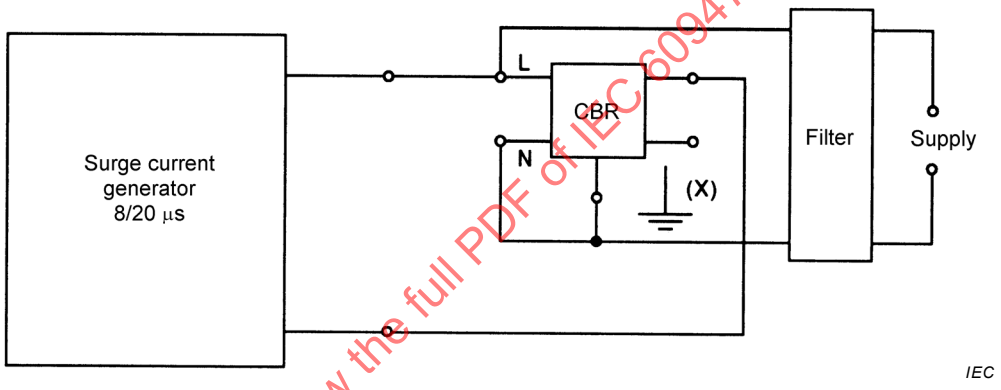


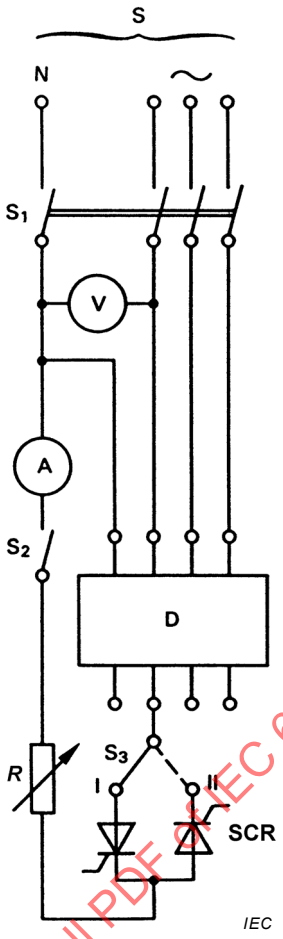
Figure B.6 – Surge current wave 8/20 µs



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in case of flashover without follow-on current (B.8.6.3)

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S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

R = Variable resistor

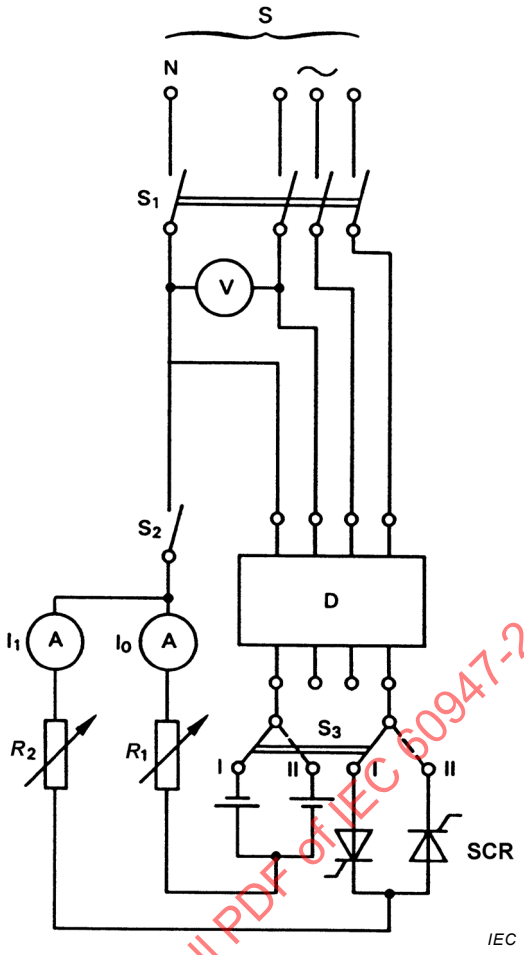
S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents (see B.8.7.2.1, B.8.7.2.2 and B.8.7.2.3)

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S = Supply

V = Voltmeter

A = Ammeter (measuring r.m.s values)

D = CBR under test

SCR = Thyristors

R_1, R_2 = Variable resistor

S_1 = All-pole switch

S_2 = Single pole switch

S_3 = Two-way switch

Figure B.9 – Test circuit for the verification of the correct operation of CBRs, in the case of a residual pulsating direct current superimposed by a smooth direct residual current (see B.8.7.2.4)

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B.1 General

B.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of a circuit-breaker to achieve a two-fold goal, i.e.:

– providing protection of installations against overloads and short-circuit currents;

– providing protection of persons against indirect contact, i.e. hazardous increases of ground potential due to defective insulation.

NOTE 1 In IEC 61140:2016, the term “protection of persons against indirect contact” is replaced by “fault protection”.

Residual current devices may also provide additional protection against fire and other hazards, which may develop as a result of an earth fault of a lasting nature that cannot be detected by the over-current protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in the event of failure of the relevant protective means.

NOTE 2 In IEC 61140:2016, the term “protection of persons against direct contact” is replaced by “basic protection”.

The requirements for the installation of such devices are specified in various sections of IEC 60364 series.

This annex includes definitions, additional requirements and tests for circuit-breakers incorporating residual current protection of type B to cover the use of new electronic technology in equipment which can result in particular residual currents not covered by the characteristics of type AC or type A.

NOTE 3 This annex complies with the relevant requirements of IEC 60755.

B.1.2 Scope and object

This annex applies to circuit-breakers providing residual current protection (CBRs). It covers the requirements for units that concurrently perform residual current detection, compare such measurements with a preset value and cause the protected circuit to be switched off when this value is exceeded.

This annex applies to:

- circuit-breakers in accordance with this document, which incorporate the residual current function as an integrated feature (hereinafter called integral CBRs);
- CBRs consisting of a combination of a residual current device (hereinafter referred to as r.c. units) and a circuit-breaker in accordance with this document; their combination both mechanically and electrically, may be carried out either at the factory or in the field by the user in accordance with the manufacturer's instructions.

This annex covers CBRs of type AC, type A and type B (see B.4.4).

This annex applies only to CBRs intended for use in a.c. circuits.

NOTE The neutral current sensing means, if any, can be external to the circuit-breaker or the combination, depending on the case.

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The residual current function of CBRs covered by this annex may or may not be functionally dependent on line voltage. CBRs depending on an alternative supply source are not covered by this annex.

This annex does not apply to equipment where the current sensing means (except the neutral current sensing means) or the processing device are mounted separately from the circuit-breaker. The requirements for such devices are given in Annex M.

The object of this annex is to state:

a) the specific features of the residual current function;

b) the specific requirements that shall be complied with by the CBR
   – under normal circuit conditions;
   – under abnormal circuit conditions, whether of a residual current nature or not;

c) the tests that shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures, including tests for electromagnetic compatibility;

d) the relevant product information.

B.2 Terms and definitions

As a complement to Clause 2 of this document, the following terms and definitions apply:

B.2.1 Terms and definitions relating to currents flowing from live parts to earth

B.2.1.1
earth fault current
current flowing to earth due to an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
earth leakage current
current flowing from the live parts of the installation to earth in the absence of an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Terms and definitions relating to the energization of a CBR

B.2.2.1
energizing quantity
electrical energizing quantity that, alone or in combination with other such quantities, shall be applied to a CBR to enable it to accomplish its function under specified conditions

B.2.2.2
energizing input-quantity
energizing quantity by which the CBR is activated when it is applied under specified conditions

Note 1 to entry: These conditions can involve, e.g., the energizing of certain auxiliary elements.

[SOURCE: IEC 60050-442:1998, 442-05-58, modified – In the definition, "residual current device" has been replaced with "CBR".]

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B.2.2.3
residual current
I_{Δ}
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

[SOURCE: IEC 60050-442:1998, 442-05-19, modified – The definition has been adapted to apply to CBRs.]

B.2.2.4
residual operating current
$I_{\Delta n}$
value of the residual current which causes the CBR to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – In the definition, "residual current device" has been replaced with "CBR".]

B.2.2.5
residual non-operating current
$I_{\Delta no}$
value of the residual current at which (and below which) the CBR does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – Symbol introduced and, in the definition, "residual current device" has been replaced with "CBR".]

B.2.3 Terms and definitions relating to the operation and the functions of a CBR

B.2.3.1
circuit-breaker incorporating residual current protection
CBR
circuit-breaker (see 2.1) designed to cause the opening of the contacts when the residual current attains a given value under specified conditions

B.2.3.2
CBR functionally independent of line voltage
CBR for which the functions of detection and evaluation, and the actuating means of interruption (see B.2.3.6) do not depend on the line voltage

B.2.3.3
CBR functionally dependent on line voltage
CBR for which the functions of detection and/or evaluation, and/or the actuating means of interruption (see B.2.3.6) depend on the line voltage

Note 1 to entry: It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

B.2.3.4
detection (of a residual current)
function consisting in sensing the presence of a residual current

Note 1 to entry: This function can be performed, for example, by a transformer integrating the vector sum of the currents.

[SOURCE: IEC 60050-442:1998, 442-05-24]

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B.2.3.5
evaluation
function consisting in giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

[SOURCE: IEC 60050-442:1998, 442-05-25, modified – In the term, "(for a residual current)" has been deleted and in the definition, "residual current device" has been replaced with "CBR".]

B.2.3.6
interruption
function consisting in bringing automatically the main contacts of the CBR from the closed position into the open position, thereby interrupting the current(s) flowing through them

[SOURCE: IEC 60050-442:1998, 442-05-26, modified – In the term, "(for a residual current device)" has been deleted and in the definition, "residual current device" has been replaced with "CBR".]

B.2.3.7
limiting non-actuating time
maximum delay during which a value of residual current higher than the rated residual non-operating current can be applied to the CBR without bringing it actually to operate

[SOURCE: IEC 60050-442:1998, 442-05-23, modified – In the definition, "residual current device" has been replaced with "CBR" and "rated" has been added.]

B.2.3.8
time-delay CBR
CBR specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

[SOURCE: IEC 60050-442:1998, 442-05-05, modified – In the definition and the term, "residual current device" has been replaced with "CBR".]

B.2.3.9
reset-CBR
CBR with an r.c. unit that shall be intentionally reset by a means different from the operating means of the CBR, following the occurrence of a residual current, before it can be reclosed

B.2.3.10
test device
device simulating a residual current for checking that the CBR operates

B.2.4 Terms and definitions relating to values and ranges of energizing quantities

B.2.4.1
limiting value of the non-operating over-current in the case of a single-phase load
maximum value of a single-phase over-current which, in the absence of a residual current, can flow through a CBR (whatever the number of poles) without causing it to operate

Note 1 to entry: See B.7.2.7.

B.2.4.2
residual short-circuit making and breaking capacity
value of the a.c. component of a residual prospective short-circuit current which a CBR can make, carry for its opening time and break under specified conditions of use and behaviour

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B.3 Classification

B.3.1 Classification according to the method of operation of the residual current function

B.3.1.1 CBR functionally independent of line voltage (see B.2.3.2)

B.3.1.2 CBR functionally dependent on line voltage (see B.2.3.3 and B.7.2.12)

B.3.1.2.1 Opening automatically in the case of failure of the line voltage with or without delay

B.3.1.2.2 Not opening automatically in the case of failure of line voltage

Not opening automatically in the case of failure of the line voltage, but able to trip under specified conditions in the case of an earth fault arising on failure of the line voltage.

NOTE Classification under this subclause includes CBRs unable to open automatically when no hazardous situation exists.

B.3.2 Classification according to the possibility of adjusting the residual operating current

B.3.2.1 CBR with single rated residual operating current

B.3.2.2 CBR with multiple settings of residual operating current

– by fixed steps;

– by continuous variation.

B.3.3 Classification according to time delay of the residual current function

B.3.3.1 CBR without time-delay; non-time-delayed type

B.3.3.2 CBR with time-delay; time-delayed type (see B.2.3.8)

B.3.3.2.1 CBR with non-adjustable time delay

B.3.3.2.2 CBR with adjustable time delay

– by fixed steps;

– by continuous variation.

B.3.4 Classification according to behaviour in presence of a d.c. component

B.3.4.1 CBRs of type AC (see B.4.4.1)

B.3.4.2 CBRs of type A (see B.4.4.2)

B.3.4.3 CBRs of type B (see B.4.4.3)

B.4 Characteristics of CBRs concerning their residual current function

B.4.1 Rated values

B.4.1.1 Rated residual operating current ($I_{\Delta n}$)

The r.m.s. value of a sinusoidal residual operating current (see B.2.2.4) assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

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For a CBR with multiple settings of residual operating current, the highest setting is used to designate its rating. See, however, Clause B.5 concerning marking.

B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The r.m.s. value of sinusoidal residual non-operating current (see B.2.2.5) assigned to the CBR by the manufacturer at which the CBR does not operate under specified conditions.

B.4.1.3 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of the prospective residual short-circuit current (see B.2.4.2) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

B.4.2 Preferred and limiting values

B.4.2.1 Preferred values of rated residual operating current ($I_{\Delta n}$)

Preferred values of rated residual operating current are

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Higher values may be required.

$I_{\Delta n}$ may be expressed as a percentage of the rated current.

B.4.2.2 Minimum value of rated residual non-operating current ($I_{\Delta no}$)

The minimum value of rated residual non-operating current is 0,5 $I_{\Delta n}$.

B.4.2.3 Limiting value of non-operating over-current in the case of a single-phase load

The limiting value of non-operating over-current in the case of a single-phase load shall be in accordance with B.7.2.7.

B.4.2.4 Operating characteristics

B.4.2.4.1 Non-time-delay type

The operating characteristic for a non-time-delay type is given in Table B.1.

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Table B.1 – Operating characteristic in the case of sinusoidal residual current for non-time-delay type

Residual current [c]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Maximum break times s	0,3	0,15	0,04	0,04
NOTE These values are derived from IEC 60479-1 and are valid for both 50 Hz and 60 Hz.				
[a] For CBRs having $I_{\Delta n} \leq 30$ mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.				
[b] For CBRs having $I_{\Delta n} \leq 30$ mA, 0,5 A may be used as an alternative to 10 $I_{\Delta n}$.				
[c] For CBRs of types A and B, multiplying factors may apply – see B.8.7 and B.8.8.				

CBRs having $I_{\Delta n} \leq 30$ mA shall be of the non-time-delay type.

B.4.2.4.2 Time-delay type

B.4.2.4.2.1 Limiting non-actuating time (see B.2.3.7)

For a time-delay type, the limiting non-actuating time is defined at 2 $I_{\Delta n}$ and shall be declared by the manufacturer.

The minimum limiting non-actuating time is 0,06 s.

The preferred values of limiting non-actuating time are

0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s

B.4.2.4.2.2 Operating characteristics

For CBRs having a limiting non-actuating time of 0,06 s, the operating characteristics is given in Table B.2.

Table B.2 – Operating characteristics in the case of sinusoidal residual currents, for time-delay type having a limiting non-actuating time of 0,06 s

Residual current [a]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Maximum break time s	0,5	0,2	0,15	0,15
Limiting non actuating time s	-	0,06	-	-
NOTE These values are derived from IEC 60479-1 and are valid for both 50 Hz and 60 Hz.				
[a] For CBRs of types A and B, multiplying factors may apply – see B.8.7 and B.8.8				

For CBRs having a limiting non-actuating time higher than 0,06 s, the manufacturer shall declare the maximum break time at $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, and 10 $I_{\Delta n}$.

In the case of a CBR having an inverse current/time characteristic, the manufacturer shall state the residual current/break time characteristic.

B.4.3 Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The minimum value of $I_{\Delta m}$ is 25 % of I_{cu}.

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Higher values may be tested and declared by the manufacturer.

B.4.4 Operating characteristics in the case of an earth fault current in the presence or absence of a d.c. component

B.4.4.1 CBR of type AC

A CBR for which tripping is ensured for residual sinusoidal alternating currents, in the absence of a d.c. component whether suddenly applied or slowly rising.

B.4.4.2 CBR of type A

A CBR for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents with or without a specified level of superimposed d.c. (± 6 mA), whether suddenly applied or slowly rising.

B.4.4.3 CBR of type B

A CBR for which tripping is ensured as for type A, and in addition:

– for residual sinusoidal alternating currents up to 1 000 Hz,
– for composite residual currents, whether suddenly applied or slowly rising intended for circuits supplied between phase and neutral or phase and earthed middle conductor,
– for residual alternating currents superimposed by a smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value,
– for residual pulsating direct currents superimposed by a smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value,
– for residual direct currents which can result from rectifying circuits, i.e.:
  - two-pulse bridge connection line to line for 2-, 3- and 4-pole CBRs,
  - three-pulse star connection or six-pulse bridge connection for 3- and 4-pole CBRs,
– for residual smooth direct currents.

B.5 Marking

Each CBR shall be marked as specified in 5.2 and, in addition, in accordance with Table B.3

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Table B.3 – Product information

Item	Information	Marking location	
		Integral CBR	r. c. unit
B1.1	the operating means of the test device by the letter T (see also B.7.2.6)	Visible	Visible
B1.2	operating characteristic in the case of residual currents in the presence or absence of a d.c. component: – for CBRs of type AC with the symbol  (IEC 60417-6148:2012-01) – for CBRs of type A with the symbol  (IEC 60417-6149:2012-01) – for CBRs of type B with the symbol  (IEC 60417-6398:2017-12) or  (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	Visible
B1.3	rated residual operating current $I_{\Delta n}$	Visible	Visible
B2.1	settings of residual operating current, when applicable	Marked	Marked
B2.2	limiting non-actuating time at 2 $I_{\Delta n}$, for time-delay type, by the symbol Δt followed by the limiting non-actuating time	Marked	Marked
B2.3	suitability for use with a 3-phase supply only, with the symbol  (IEC 60417-6364:2016-07)	Marked	Marked
B2.4	rated voltage(s) if different from the rated voltage(s) of the circuit-breaker	-	Marked
B2.5	value (or range) of the rated frequency if different from that of the circuit-breaker	-	Marked
B2.6	the indication I_n ≤ ...A (I_n being the maximum current rating of the circuit-breaker with which the r.c. unit may be combined)	-	Marked
B2.7	manufacturer's name or trade mark	-	Marked
B2.8	type designation or catalog reference	-	Marked
B2.9	identification of the circuit-breaker(s) with which the r.c. unit may be assembled unless incorrect assembly (such as to render the protection ineffective) is made impossible by the design;	-	Marked
B2.10	IEC 60947-2	-	Marked
B3.1	rated residual short-circuit making and breaking capacity $I_{\Delta m}$ if higher than 25 % of I_{cu} (see B.4.3)	Literature	Literature
B3.2	diagram of connections, including those of the test circuit and, if applicable, those to the line, for CBRs dependent on the line voltage	Literature	Literature
B3.3	value of rated residual non-operating current $I_{\Delta no}$ if greater than 0,5 $I_{\Delta n}$	Literature	Literature
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked:marked on the product Literature:provided in the manufacturer's literature			

B.6 Normal service, mounting and transport conditions

Clause 6 applies.

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B.7 Design and operating requirements

B.7.1 Design requirements

It shall not be possible to modify the operating characteristic of a CBR except by means which are specifically provided for setting the rated residual operating current or the definite time delay.

Changing from one setting to another shall only be possible through a deliberate action, such as the use of a tool, a password or equivalent means.

CBRs combining an r.c. unit device and a circuit-breaker shall be so designed and built that:

– the coupling system of the r.c. unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that may adversely affect the installation or result in injury to the user;
– the addition of the r.c. unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;
– the r.c. unit does not sustain any permanent damage due to the short-circuit currents during test sequences.

B.7.2 Operating requirements

B.7.2.1 Operation in the case of a residual current

CBRs shall open automatically in response to any earth leakage current or earth fault current equal to or exceeding the rated residual operating current for a time exceeding the non-actuating time.

The operation of CBRs shall be in compliance with the time requirements specified in B.4.2.4. Compliance shall be checked by the tests of B.8.1.2.

B.7.2.2 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

CBRs shall meet the test requirements of B.8.11.

B.7.2.3 Operational performance capability

CBRs shall comply with the tests of B.8.1.2.1.

B.7.2.4 Effects of environmental conditions

CBRs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the test of B.8.12.

B.7.2.5 Dielectric properties

CBRs shall withstand the tests of B.8.3.

B.7.2.6 Test device

CBRs shall be provided with a test device causing the passing through the detecting device of a current simulating a residual current, in order to allow periodic testing of the ability of the CBRs to operate.

The test device shall satisfy the tests of B.8.4.

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The protective conductor, if any, shall not become live when the test device is operated.

It shall not be possible to energize the protected circuit by operating the test device when the CBR is in the open position.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; a light colour should preferably be used.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

B.7.2.7 Value of the non-operating over-current in the case of a single-phase load

CBRs shall withstand the smaller of the following two over-current values without tripping:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

Compliance is checked by the test of B.8.5.

However this test is not necessary in the case of CBRs of selectivity category B since the requirements of this subclause are verified during test sequence IV (or test sequence VI).

NOTE Polyphase balanced load tests are considered to be covered by the requirements of this subclause.

B.7.2.8 Resistance of CBRs to unwanted tripping due to surge currents resulting from impulse voltages

B.7.2.8.1 Resistance to unwanted tripping in the case of loading of the network capacitance

CBRs shall withstand the test of B.8.6.2.

B.7.2.8.2 Resistance to unwanted tripping in the case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.3.

B.7.2.9 Behaviour of CBRs of type A in the case of an earth fault comprising a d.c. component

The behaviour of CBRs in the case of an earth fault current comprising a d.c. component shall be such that the maximum break times stated in Table B.1 and Table B.2, as applicable, shall also be valid, the test current values specified being, however, increased:

– by the factor 1,4 for CBRs having $I_{\Delta n} \geq 0{,}030$ A;
– by the factor 2 for CBRs having $I_{\Delta n} < 0{,}030$ A.

Compliance is checked by the tests of B.8.7.

B.7.2.10 Behaviour of CBRs of type B in response to the type of residual current

B.7.2.10.1 Composite residual currents

Type B RCDs shall operate in response to a steady increase of composite residual currents, including a 10 Hz component and a 1 kHz component, as defined in Table B.7.

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The residual operating current shall be within the limits given in Table B.8.

Compliance is checked by the tests of B.8.8.1.

Type B CBRs shall operate in response to a sudden appearance of a composite residual current equal to 7 $I_{\Delta n}$, within the maximum break-time specified in B.4.2.4 for 5 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.2.

B.7.2.10.2 Residual sinusoidal alternating currents up to 1 000 Hz

Type B RCDs shall operate in response to residual currents of any frequency up to 1 000 Hz, in accordance with Table B.9.

Compliance is checked by the tests of B.8.8.3.

B.7.2.10.3 Residual alternating current superimposed by a residual smooth direct current

Type B CBRs shall operate in the case of residual alternating currents of the rated frequency superimposed by a residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value.

The alternating tripping current shall be equal or lower than $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.4.

B.7.2.10.4 Residual pulsating direct current superimposed by a residual smooth direct current

Type B CBRs shall operate in the case of residual pulsating direct currents superimposed by a residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value.

The tripping current shall not be higher than 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ > 0,01 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≤ 0,01 A.

NOTE The tripping current 1,4 $I_{\Delta n}$ or 2 $I_{\Delta n}$, as applicable, is the RMS value due to the half-wave pulsating direct current.

Compliance is checked by the tests of B.8.8.5.

B.7.2.10.5 Residual pulsating direct currents that can result from rectifying circuits supplied from two phases

Type B CBRs shall operate in response to a steady increase of residual pulsating direct currents resulting from rectifying circuits within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.6 a).

Type B CBRs shall operate in response to a sudden appearance of residual pulsating direct currents resulting from rectifying circuits according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.6 b).

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B.7.2.10.6 Residual pulsating direct currents that can result from rectifying circuits supplied from three phases

Type B CBRs shall operate in response to a steady increase of residual pulsating direct currents resulting from rectifying circuits within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.7 a).

Type B CBRs shall operate in response to a sudden appearance of residual pulsating direct currents resulting from rectifying circuits according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.7 b).

B.7.2.10.7 Residual smooth direct current

Type B CBRs shall operate in response to a steady increase of a smooth direct residual current within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.8.1 a) and B.8.8.8.2.

Type B CBRs shall operate in response to a sudden appearance of a smooth direct residual current according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.8.1 b).

B.7.2.11 Conditions of operation for reset-CBRs

It shall not be possible to reclose reset-CBRs (see B.2.3.9) after tripping due to a residual current, if they have not been reset.

Compliance is checked during the test of 8.3.3.4.4 in accordance with B.8.1.2.1.

B.7.2.12 Additional requirements for CBRs functionally dependent on line voltage

CBRs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times its rated value.

Compliance is checked by the tests of B.8.2.3.

Where a CBR has more than one rated frequency or a range of rated frequencies, the CBR shall be capable of operating in accordance with this subclause at all frequencies.

Compliance is verified by carrying out the tests of B.8.2 and B.8.4.

According to their classification CBRs functionally dependent on line voltage shall comply with the requirements given in Table B.4.

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Table B.4 – Requirements for CBRs functionally dependent on line voltage

Classification of the device according to B.3.1		Behaviour in the case of failure of line voltage
CBRs opening automatically in the case of failure of the line voltage (B.3.1.2.1)	Without delay	Opening without delay according to item a) of B.8.9.3
	With delay	Opening with delay according to item b) of B.8.9.3
CBRs not opening automatically in the case of failure of the line voltage but able to open in the case of a hazardous situation arising (B.3.1.2.2)		Operating according to B.8.10

B.7.3 Electromagnetic compatibility

The requirements of Annex J apply.

Additional test specifications are given in B.8.13.

Immunity to voltage variations is covered by the requirements of B.7.2.12.

B.8 Tests

B.8.1 Test sequences

B.8.1.1 General

This clause specifies tests for CBRs having a rated residual operating current $I_{\Delta n}$ up to and including 30 A.

The applicability of the tests specified in this clause when $I_{\Delta n} > 30$ A is subject to agreement between manufacturer and user.

The instruments for the measurement of the residual current shall show (or permit to determine) the true r.m.s. value.

Tests specified in this annex are supplementary to the tests of Clause 8.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 8. For the dielectric withstand verifications during these test sequences (see 8.3.3.6), the control circuit of residual current devices functionally dependent on line voltage shall be disconnected from the main circuit.

The tests shall be carried out with substantially sinusoidal currents.

For CBRs comprising a separate r.c. unit and a circuit-breaker, the assembly shall be performed in compliance with the manufacturer's instructions.

In the case of CBRs with multiple settings of residual operating current, the tests shall be carried out at the lowest setting, unless otherwise stated.

In the case of CBRs with adjustable time delays (see B.3.3.2.2), the time delay shall be set at maximum, unless otherwise stated.

In the case of CBRs with adjustable instantaneous tripping, the instantaneous trip shall be set at maximum, unless otherwise stated.

b) Routine tests

Subclause 8.4.5 applies.

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B.8.1.2 Tests to be carried out during the test sequences of Clause 8

B.8.1.2.1 General performance characteristics (test sequence I)

To avoid unintentional operation of the residual current function, the verification of tripping limits and characteristics (8.3.3.2) shall be amended as follows:

– for the verification of the short-circuit releases of electronic overcurrent releases, the pole under test shall be tested in series with one other pole chosen at random; for the verification of the short-circuit releases of electromagnetic overcurrent releases, the additional verification in single pole need not be carried out; for the verification of the overload release of the neutral pole, this pole shall be tested in series with 2 other poles connected in parallel;

– alternatively, when feasible and with the agreement of the manufacturer, the residual current function may be rendered inoperative;

– the test conditions shall be stated in the test report.

During the operating cycles with current (see 8.3.3.4.4) specified in Table 8 (see 7.2.4.2), a third of the breaking operations shall be performed by actuating the test device, and a further third by applying a residual current of value $I_{\Delta n}$ (or, if applicable, of the lowest setting of the residual operating current) to any one pole.

In the case of a reset-CBR, it shall be verified that it is not possible to reclose the CBR after tripping without the intentional resetting action. This verification shall take place at the beginning and at the end of the operational performance capability test with current (8.3.3.4.4).

No failure to trip shall be admitted.

B.8.1.2.2 Verification of the withstand capability to short-circuit currents

B.8.1.2.2.1 Rated service short-circuit breaking capacity (test sequence II)

Following the tests of 8.3.4, verification of the correct operation of the CBR in the case of residual current shall be performed in accordance with B.8.2.4.2.

B.8.1.2.2.2 Rated ultimate short-circuit breaking capacity (test sequence III)

For the purpose of verifying the correct operation of the overload releases, the single pole tests specified in 8.3.5.2 and 8.3.5.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.2 and 8.3.5.5 but applicable to two poles.

Following the tests of 8.3.5, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.3 Rated short-time withstand current (test sequence IV or test sequence VI (combined))

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.3 or 8.3.8.3, as applicable.

b) Verification of overload releases

– for test sequence IV

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.6.2 and 8.3.6.7, the single pole tests specified in 8.3.5.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

– for the combined test sequence

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For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.8.2, the single pole test specified in 8.3.5.2 shall be replaced by two-pole tests made on all possible combinations of phase poles in turn.

For the purpose of verifying the correct operation of overload releases in accordance with 8.3.8.7, the test specified in 8.3.3.8 shall be carried out using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 8.3.6 or 8.3.8, as applicable, verification of the residual current tripping device shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.4 Integrally fused circuit-breakers (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 8.3.7.5 and 8.3.7.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.5 and 8.3.7.9 but applicable to two poles.

Following the tests of 8.3.7, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.5 Test sequence VI (combined)

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.3 Additional test sequences

Additional test sequences shall be performed on CBRs in accordance with Table B.5.

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Table B.5 – Additional test sequences

Sequences	Test	Subclause
B I	Verification of the operating characteristics	B.8.2
	Verification of dielectric properties	B.8.3
	Verification of the operation of the test device at the limits of rated voltage	B.8.4
	Verification of the limiting value of the non-operating current under over-current conditions	B.8.5
	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Additional verifications for CBRs of types A and B	B.8.7
	Additional verifications for CBRs of type B	B.8.8
	Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1	B.8.9
	Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.2	B.8.10
B II	Verification of the residual short-circuit making and breaking capacity ($I_{\Delta m}$)	B.8.11
B III	Verification of the effects of environmental conditions	B.8.12
B IV	Verification of electromagnetic compatibility	B.8.13
	Immunity tests	B.8.13.1
	Emission tests	B.8.13.2

For CBRs having variants with different number of poles, tests shall be carried out on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants' construction is not identical to the variant tested, then those variants shall also be tested.

One sample shall be tested for each of the test sequences B I, B II and B III.

For test sequence B IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

B.8.2 Verification of the operating characteristics

B.8.2.1 Test circuit

The CBR shall be installed as in normal use.

The test circuit shall be in accordance with Figure B.1.

B.8.2.2 Test voltage for CBRs functionally independent of line voltage

Tests may be carried out at any convenient voltage.

B.8.2.3 Test voltage for CBRs functionally dependent on line voltage

Tests shall be carried out at the following values of voltage applied to the relevant terminals:

– 0,85 times the minimum rated voltage for the tests specified in B.8.2.4 and B.8.2.5.2;
– 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.3.

For CBRs having functions which do not depend on line voltage, tests of those functions may be carried out at any convenient voltage.

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CBRs with more than one rated frequency or a range of rated frequencies shall be tested in each case at the highest and lowest rated frequency. However, for CBRs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover the requirements.

For tests where the poles are loaded with rated current or above (see for example B.8.2.5.3, B.8.7.2.3, B.8.8.8.2 and B.8.8.9), for practical reasons, it is acceptable to use a sample where the voltage pick-up conductors have been separated from the phase poles, to allow the use of a low-power source for the loading with current. The details of the modification shall be agreed between the manufacturer and the testing station, and shall be stated in the test report.

B.8.2.4 Off-load test at 20 °C ± 5 °C

B.8.2.4.1 General

The connections being as in Figure B.1, the CBR shall perform the tests of B.8.2.4.2, B.8.2.4.3 and B.8.2.4.4 and also, where applicable, B.8.2.4.5, all made on one pole only chosen at random. Each test shall comprise three measurements or verifications, as applicable.

Unless otherwise specified, for CBRs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the lowest and highest settings, and at one intermediate setting.

B.8.2.4.2 Verification of the correct operation in the case of a steady increase of the residual current

For CBRs with adjustable time delays, the tests shall be performed at the lowest setting. The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$ so as to attain the value $I_{\Delta n}$ in approximately 30 s, the tripping current being measured each time. The three measured values shall be greater than $I_{\Delta no}$ and less than or equal to $I_{\Delta n}$.

B.8.2.4.3 Verification of the correct operation in the case of closing on residual current

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or the specific settings of the residual operating current if applicable, see B.8.2.4), and the switches S_1 and S_2 being closed, the CBR is closed onto the circuit so as to simulate service conditions as closely as possible. The break time measurement test shall be repeated three times.

No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

B.8.2.4.4 Verification of the correct operation in the case of sudden appearance of residual current

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable, and the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S_2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of I_{Δ}. No value shall exceed the relevant limiting value.

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B.8.2.4.5 Verification of the limiting non-actuating time of CBRs of the time-delayed type

The test circuit being calibrated at the value of 2 $I_{\Delta n}$, the switch S_1 and the CBR being in the closed position, the residual current is established by closing the switch S_2 and applied for a time equal to the limiting non-actuating time declared by the manufacturer, in accordance with B.4.2.4.2.1.

During each of the three verifications, the CBR shall not trip. If the CBR has an adjustable residual operating current setting and/or an adjustable time delay, the test shall be made, as applicable, at the lowest setting of residual operating current and at the maximum setting of time delay.

B.8.2.5 Tests at the temperature limits

B.8.2.5.1 General

NOTE The upper temperature limit can be the reference temperature.

The temperature limits of this subclause may be extended by agreement between manufacturer and user, in which case tests shall be performed at the agreed temperature limits.

B.8.2.5.2 Off-load test at –5 °C

The CBR shall be placed in a chamber having a stabilized internal temperature within the limits of –7 °C and –5 °C. After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, if applicable, B.8.2.4.5.

B.8.2.5.3 On-load test at the reference temperature or at +40 °C

The CBR, connected in accordance with Figure B.1, shall be placed in a chamber having a stabilized internal temperature equal to the reference temperature (see 4.7.3) or, in the absence of a reference temperature, equal to 40 °C ± 2 °C. A load current equal to I_n (not indicated on Figure B.1) shall be applied on all phase poles.

After reaching thermal steady-state conditions, the CBR shall be submitted to the tests of B.8.2.4.4 and, where applicable, B.8.2.4.5.

B.8.3 Verification of dielectric properties

CBRs shall comply with 8.3.3.3.

B.8.4 Verification of the operation of the test device at the limits of rated voltage

The verification consists of the following tests:

a) The CBR being supplied with a voltage equal to 1,1 times the highest rated voltage, the test device shall be momentarily actuated 25 times, the CBR being closed again before each operation.

b) Test a) shall be then repeated at 0,85 times the lowest rated voltage, the test device being actuated 3 times instead of 25 times.

c) The CBR being in the closed position and supplied with a voltage equal to 1,1 times the highest rated voltage, the test device shall be actuated and held in the actuated position for 5 s.

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For these tests:

– in the case of CBRs with identified line and load terminals, the supply connections shall be in accordance with the marking;
– in the case of CBRs with unidentified line and load terminals, the supply shall be connected to each set of terminals in turn, or alternatively to both sets of terminals simultaneously.

At each test, the CBR shall operate.

For CBRs having an adjustable residual operating current:

– the lowest setting shall be used for tests a) and c);
– the highest setting shall be used for test b).

For CBRs having an adjustable time delay, the test shall be made at the maximum setting of the time-delay.

NOTE The verification of the endurance of the test device is considered to be covered by the tests of B.8.1.2.1.

B.8.5 Verification of the limiting value of the non-operating current under over-current conditions

The test shall be carried out with a single-phase load, the connections being made in accordance with Figure B.2.

The impedance *Z* shall be adjusted so as to let a current equal to the lower of the following two values flow in the circuit:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

NOTE 1 For the purpose of this current adjustment, the CBR D (see Figure B.2) can be replaced by connections of negligible impedance.

For CBRs with an adjustable residual current setting, the test shall be made at the lowest setting.

CBRs functionally independent of line voltage are tested at any convenient voltage.

CBRs functionally dependent on line voltage are supplied on the line side with their rated voltage (or, if relevant, with a voltage having any value within the range of rated voltages).

The test shall be made at a power factor of 0,5.

The switch S_1, being open, shall be closed and reopened after 2 s. The test shall be repeated three times for each possible combination of the current paths, the interval between successive closing operations being at least 1 min.

The CBR shall not trip.

NOTE 2 The time of 2 s can be reduced (but to not less than the minimum break time) to avoid the risk of tripping by action of the overload release(s) of the CBR.

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B.8.6 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

B.8.6.1 General

For CBRs with adjustable time delays (see B.3.3.2.2), the time delay shall be set at minimum.

B.8.6.2 Verification of resistance to unwanted tripping in the case of loading of the network capacitance

The CBR shall be tested using a surge current generator capable of delivering a damped oscillatory current as shown in Figure B.4.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.5.

One pole of the CBR chosen at random shall be subjected to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be approximately 30 s. The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

- peak value: 200 A $^{+10}_{0}$ %;
- virtual front time: 0,5 µs ± 30 %;
- period of the following oscillatory wave: 10 µs ± 20 %;
- each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

B.8.6.3 Verification of resistance to unwanted tripping in the case of flashover without follow-on current

The CBR shall be tested using a surge current generator capable of delivering an 8/20 µs surge current wave, without reverse polarity, as shown in Figure B.6.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.7

One pole of the CBR, chosen at random, shall be submitted to 10 applications of each of the surge currents listed below. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications of surge current shall be approximately 30 s.

The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 250 A $^{+10}_{0}$ %, with no tripping and

– 3 000 A $^{+10}_{0}$ %, with tripping allowed;

– virtual front time (T_1): 8 µs ± 10 %;

– virtual time to half value (T_2): 20 µs ± 10 %.

B.8.6.4 Verification after the tests

After the tests of B.8.6.2 and B.8.6.3, the operation of the CBR shall be verified in accordance with B.8.2.4.4, with one measurement of break time, at $I_{\Delta n}$ only.

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B.8.7 Additional verifications for CBRs of types A and B

B.8.7.1 Test conditions

The test conditions of B.8 and B.8.2.1, B.8.2.2 and B.8.2.3 apply, except that the test circuits shall be those shown in Figure B.8 and Figure B.9, as applicable.

B.8.7.2 Verifications

B.8.7.2.1 Verification of the correct operation in the case of a continuous rise of residual pulsating direct current

The test circuit shall be according to Figure B.8. In the case of a CBR with an adjustable time delay (see B.3.3.2.2), the time delay shall be set to minimum.

The auxiliary switches S_1 and S_2 and the CBR D shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the CBR shall be tested at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S_3.

At every test, the current, starting from zero, shall be steadily increased at an approximate rate of:

– 1,4 $I_{\Delta n}$ / 30 s for CBRs of $I_{\Delta n} \geq$ 0,030 A;
– 2 $I_{\Delta n}$ / 30 s for CBRs of $I_{\Delta n}$ < 0,030 A.

The tripping current shall be in accordance with Table B.6.

Table B.6 – Tripping current range for CBRs in the case of an earth fault comprising a d.c. component

Angle α	Tripping current A	
	Lower limit	Upper limit
0°	0,35 $I_{\Delta n}$	2 $I_{\Delta n}$ for $I_{\Delta n}$ < 0,030 A
90°	0,25 $I_{\Delta n}$	or
135°	0,11 $I_{\Delta n}$	1,4 $I_{\Delta n}$ for $I_{\Delta n} \geq$ 0,030 A

B.8.7.2.2 Verification of the correct operation in the case of a suddenly appearing residual pulsating direct current

The test shall be performed according to Figure B.8.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the CBR being in the closed position, the residual current is suddenly established by the closing switch S_2.

NOTE In the case of a CBR functionally dependent on line voltage, classified according to B.3.1.2.2, the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the CBR. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the CBR under test and S_2 being previously closed.

Four measurements are made at each value of test current at a current delay angle α = 0°, two with the auxiliary switch in position I and two in position II.

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For CBRs with $I_{\Delta n}$ ≥ 0,030 A, the test shall be carried out at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 1,4.

For CBRs with $I_{\Delta n}$ < 0,030 A, the test shall be carried out at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 2.

No value shall exceed the specified limiting values (see B.7.2.9).

B.8.7.2.3 Verification of the correct operation with load at the reference temperature

The tests of B.8.7.2.1 and B.8.7.2.2 shall be repeated, the pole under test and one other pole of the CBR being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure B.8.

B.8.7.2.4 Verification of the correct operation in the case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

This test need not be applied to CBRs of type B since it is covered by the test of B.8.8.5.

The CBR shall be tested according to Figure B.9, with a half-wave rectified residual current (current delay angle α = 0°) superimposed by a smooth direct current of 0,006 A.

Each pole of the CBR shall be tested in turn, twice at each of the positions I and II.

For CBRs of $I_{\Delta n}$ ≥ 0,030 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 1,4 $I_{\Delta n}$ / 30 s, tripping shall occur before the current exceeds a value of 1,4 $I_{\Delta n}$ + 0,006 A.

For CBRs of $I_{\Delta n}$ < 0,030 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 2 $I_{\Delta n}$ / 30 s, tripping shall occur before the current exceeds a value of 2 $I_{\Delta n}$ + 0,006 A.

B.8.8 Additional verifications for CBRs of type B

B.8.8.1 Verification of the correct operation in the case of a steady increase of composite residual current

The operation of the CBR shall be verified with a composite residual current in accordance with Table B.7. The test set up shall comply with Figure B.14.

The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from the value given in Table B.7, so as to attain the upper limit of residual operating current given in Table B.8 within approximately 30 s.

The ratio of the different frequencies shall be maintained from the initial value up to the operating value.

The test shall be repeated three times through one pole chosen at random. Operating values shall be within the limits of Table B.8.

The test frequency has a tolerance of ± 2 %.

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Table B.7 – Composite test current definition and starting current value

Frequency component values of composite starting current			Resulting composite current starting value (r.m.s.)
$I_{\text{at rated frequency}}$	$I_{\text{1 kHz}}$	$I_{\text{F motor (10 Hz)}}$	I_{Δ}
0,138 $I_{\Delta n}$	0,138 $I_{\Delta n}$	0,035 $I_{\Delta n}$	0,2 $I_{\Delta n}$
NOTE 1 $I_{\Delta n}$ corresponds to the rated residual operating current of the device at the rated frequency. NOTE 2 For the test purposes, the values of 10 Hz and 1 kHz have been used for the output and clock frequency, respectively, representing the most severe condition.			

Table B.8 – Operating current range for composite residual current

Operating current (r.m.s.)	
Lower limit	Upper limit
0,5 $I_{\Delta n}$	1,4 $I_{\Delta n}$

B.8.8.2 Verification of the correct operation in the case of sudden appearance of composite residual current

Tests are carried out to verify the break time of the CBR, the test current being calibrated at 5 times the upper limit value given in Table B.8.

The test shall be performed according to Figure B.14.

The switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

Three measurements of the break time are made.

For non-time-delayed type CBRs, the break times shall be less than 0,04 s.

For time-delayed type the break time shall comply with Table B.2 or the value declared by the manufacturer for 5 $I_{\Delta n}$, as applicable.

Time-delayed CBRs shall additionally be tested to verify the non-actuating time, the test current being suddenly established by closing the switch S_2 for a duration of 0,06 s or the value of the non-actuating time declared by the manufacturer, as applicable, with a tolerance of $^{0}_{-5}$ %.

Three tests are made, at an interval of at least 1 min. The CBR shall not trip during any of the tests.

B.8.8.3 Verification of the correct operation in the case of residual sinusoidal alternating currents up to 1 000 Hz

The test shall be performed according to Figure B.14.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value

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of residual operating current given in Table B.9 within approximately 30 s, the tripping current being measured.

The test shall be carried out on one pole taken at random at each frequency given in Table B.9 and repeated five times; the tripping values shall be in compliance with Table B.9.

b) The test circuit being calibrated at the residual operating current corresponding to 1 000 Hz according to Table B.9, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

Two measurements of the break time are made on one pole chosen at random.

For the non-time-delay type, the maximum break time shall not exceed 0,3 s.

For the time delayed type, the maximum break time shall not exceed 0,5 s or the value declared by the manufacturer for $I_{\Delta n}$, as applicable.

Table B.9 – Operating limits for residual sinusoidal alternating currents up to 1 000 Hz

Frequency Hz	Residual non-operating current	Residual operating current
150	0,5 $I_{\Delta n}$	2,4 $I_{\Delta n}$ [a]
400	0,5 $I_{\Delta n}$	6 $I_{\Delta n}$ [a]
1 000	$I_{\Delta n}$	14 $I_{\Delta n}$ [a b]

[a] These values are derived from ventricular fibrillation protection according to IEC 60479-1 in combination with the frequency factor for ventricular fibrillation according to IEC 60479-2.

[b] IEC 60479-2 gives no factors for frequencies above 1 kHz.

B.8.8.4 Verification of the correct operation in the case of a residual alternating current superimposed by a residual smooth direct current

The test shall be performed according to Figure B.10.

The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current shall be applied through one pole chosen at random and shall be adjusted to 0,4 $I_{\Delta n}$ or 10 mA, whichever is the highest value.

The residual alternating current of the rated frequency shall be applied to another pole chosen at random and is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

The CBR shall be tested twice at each of the positions I and II of S_3.

The alternating tripping current shall be equal or lower than $I_{\Delta n}$.

B.8.8.5 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a residual smooth direct current

The test shall be performed in accordance with Figure B.9.

The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current shall be applied through one pole chosen at random and shall be adjusted to 0,4 $I_{\Delta n}$ or 10 mA whichever is the highest value.

The residual pulsating direct current shall be applied to another pole chosen at random with a current delay angle α of 0° and is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n} \geq 0{,}030$ A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n} < 0{,}030$ A within approximately 30 s, the tripping current being measured.

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The CBR shall be tested twice at each of the positions I and II of S_3.

The CBR shall trip before the residual pulsating direct current exceeds a value of 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≥ 0,030 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ < 0,030 A.

B.8.8.6 Verification of the correct operation in the case of residual direct currents that can result from rectifying circuits supplied from two phases

The test shall be performed in accordance with Figure B.11.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 2 $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

   The CBR shall be connected to the test circuit at two line terminals chosen at random.

   The CBR shall be tested five times at each of the positions I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

   With the CBR connected at two line terminals chosen at random, five measurements of the break time are made at each of these values of residual current given in Table B.1 at each position I and II of S_3.

   The break times shall be in compliance with B.4.2.4.

B.8.8.7 Verification of the correct operation in the case of residual direct currents that can result from rectifying circuits supplied from three phases

This test does not apply to 2-pole type B CBRs.

The test shall be performed in accordance with Figure B.12.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 2 $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

   The CBR shall be tested five times at each of the positions I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

   Five measurements of the break time are made at each of these values of residual current at each position I and II of S_3.

   The break times shall be in compliance with B.4.2.4.

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B.8.8.8 Verification of the correct operation in the case of residual smooth direct current

B.8.8.8.1 Verification of the correct operation in the case of residual smooth direct current without load

The test shall be performed according to Figure B.13.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, trying to attain the value of 2 $I_{\Delta n}$ within 30 s, the tripping current being measured.

   One pole of the CBR, chosen at random and exemplified in Figure B.14, shall be tested twice at each position I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each residual operating current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2. The switch S_3 shall be in position I or II chosen at random.

   Two measurements of the break time are made on one pole chosen at random at each test current.

   The break times shall be in compliance with B.4.2.4.

B.8.8.8.2 Verification of the correct operation in the case of residual smooth direct current with load

The test of B.8.8.8.1 a) shall be repeated, the CBR being loaded with the rated current as in normal service for a sufficient time so as to reach thermal steady-state conditions.

NOTE The loading with rated current is not shown in Figure B.13.

B.8.8.9 Tests at the temperature limits

The CBR shall perform the tests specified in B.8.8.6 b), B.8.8.7 b) and B.8.8.8.1 b) under the following conditions, successively:

a) ambient air temperature: −5 °C, without load;

b) ambient air temperature: +40 °C, the CBR having been previously loaded with the rated current, until it has attained thermal steady-state conditions. In practice these conditions are reached when the variation of temperature-rise, measured at one of the main terminals, does not exceed 1 K per hour. The loading of the main circuit may be carried out at reduced voltage but the power supply of the residual current function, for a CBR functionally dependent on line voltage, shall be connected to its maximum rated voltage – see also B.8.2.3.

In the case of CBRs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

B.8.8.10 Test of three- and four-pole CBRs supplied between two phase poles only

Additionally, the tests of B.8.8.3 and B.8.8.8.1 are repeated, the CBR being supplied between two phase poles chosen at random.

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B.8.9 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

B.8.9.1 General

For CBRs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For CBRs with an adjustable time delay, the test shall be carried out at any one of the time-delay settings.

B.8.9.2 Determination of the limiting value of the line voltage

A voltage equal to the rated voltage shall be applied to the line terminals of the CBR and shall be then progressively lowered to zero over a time period corresponding to the longer of the two values given hereinafter until automatic opening occurs:

– about 30 s;

– a period long enough with respect to the delayed opening of the CBR, if any (see B.7.2.12).

The corresponding voltage is measured.

Three measurements are made. All the values shall be less than 0,85 times the minimum rated voltage of the CBR.

Following these measurements, it shall be verified that the CBR trips when a residual current equal to $I_{\Delta n}$ is applied, the applied voltage being just above the highest value measured.

It shall then be verified that, for any value of voltage less than the lowest value measured, it is not possible to close the CBR by manual operating means.

B.8.9.3 Verification of the automatic opening in the case of failure of the line voltage

The CBR being closed, a voltage equal to its rated voltage, or, in the case of a range of rated voltages, any one of the rated voltages shall be applied to its line terminals. The voltage is then switched off. The CBR shall trip. The time interval between the switching off and the opening of the main contacts is measured.

Three measurements are made:

a) for CBRs opening without a delay (see B.7.2.12), no value shall exceed 0,2 s;

b) for CBRs opening with a delay, the maximum and minimum values shall be situated within the range stated by the manufacturer.

B.8.10 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.2

B.8.10.1 General

For CBRs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For CBRs having an adjustable time-delay, the test shall be carried out at any one of the time-delay settings.

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B.8.10.2 Case of loss of one phase in a 3-phase system (for 3-pole and 4-pole CBRs)

The CBR shall be connected according to Figure B.3 and shall be supplied on the line side at 0,85 times the rated voltage, or, in the case of a range of rated voltages, at 0,85 times the lowest value of rated voltage.

One phase is then switched off by opening switch S_4; the CBR shall be then submitted to the test of B.8.2.4.4. The switch S_4 being closed again, a further test shall be made by opening switch S_5; the CBR shall be then submitted to the test of B.8.2.4.4.

This test procedure shall be repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

B.8.10.3 Case of voltage drop due to an overcurrent resulting from a low-impedance fault to earth

The CBR shall be connected in accordance with Figure B.3 and shall be supplied on the line side with the rated voltage or, in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_1. The CBR shall not trip.

S_1 is then reclosed and the voltage is reduced as follows:

a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

b) for CBRs for use with a single-phase supply: to 85 V applied as follows:
   - for single-pole and two-pole CBRs: between poles;
   - for three-pole and four-pole CBRs, declared as suitable for use with a single-phase supply (see B.5): between each combination of two poles, connected according to the manufacturer's specifications.

NOTE For the purpose of this annex, a single-pole CBR is a device with one overcurrent protected pole and an uninterrupted neutral (two current paths).

A current of value $I_{\Delta n}$ shall be then applied to a) and/or b), as applicable. The CBR shall trip.

B.8.11 Verification of the residual short-circuit making and breaking capacity

B.8.11.1 General

This test is intended to verify the ability of the CBR to make, to carry for a specified time and to break residual short-circuit currents.

B.8.11.2 Test conditions

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using Figure 9 of IEC 60947-1:2007/AMD1:2010, but connected in such a manner that the short-circuit current is a residual current.

The test shall be carried out at phase to neutral voltage on one pole only which shall not be the neutral pole. The current paths that do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

Where applicable, the CBR shall be adjusted at the lowest setting of residual operating current and at the maximum setting of the time delay.

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If the CBR has more than one value of I_{cu}, each one having a corresponding value of $I_{\Delta m}$, the test shall be made at the maximum value of $I_{\Delta m}$, at the corresponding phase-to-neutral voltage.

B.8.11.3 Test procedure

The sequence of operations to be performed is:

O – *t* – CO

B.8.11.4 Conditions of the CBR after test

Following the test of B.8.11.3, the CBR shall comply with the following requirements:

a) the CBR shall show no damage likely to impair its further use and shall be capable, without maintenance, of:
   - withstanding a voltage equal to twice its maximum rated operational voltage, under the conditions of 8.3.3.4.1 item 4) of IEC 60947-1:2007. For the purposes of this document, circuits incorporating solid-state devices shall be disconnected for the tests;
   - making and breaking its rated current at its maximum rated operational voltage.

b) the CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.4, but at a value of 1,25 $I_{\Delta n}$ and without measurement of break time. The test shall be made on any one pole, taken at random.

   If the CBR has an adjustable residual operating current, the test shall be made at the lowest setting, at a current of a value of 1,25 times that setting.

c) where applicable, the CBR shall also be submitted to the test of B.8.2.4.5.

d) CBRs functionally dependent on line voltage shall also satisfy the tests of B.8.9 or B.8.10, as applicable.

e) CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

B.8.12 Verification of the effects of environmental conditions

The test shall be carried out in accordance with IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be:

– 6 for $I_{\Delta n} > 1$ A;
– 28 for $I_{\Delta n} \leq 1$ A.

The 28 cycles test shall be applied to CBRs having multiple settings of residual operating current when one of the possible settings is ≤ 1 A.

At the end of the cycles, the CBR shall be capable of complying with the tests of B.8.2.4.4, but with a residual test current of 1,25 $I_{\Delta n}$ and without measurement of break time. Only one verification needs to be carried out.

Where applicable, the CBR shall also comply with the test of B.8.2.4.5. Only one verification needs to be carried out.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

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B.8.13 Verification of electromagnetic compatibility

B.8.13.1 Immunity tests

B.8.13.1.1 General

Annex J applies with the following additional requirements.

For CBRs with adjustable settings of residual operating current and/or time delay, the tests shall be carried out at the lowest of these settings.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

The tests are performed without load current but with the residual current, when specified.

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1, with the following specifications:

Performance criterion A:

For step 1, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, shall correctly indicate the status.

For step 2, the CBR shall trip at each test frequency, when loaded at 1,25 $I_{\Delta n}$; the dwell time at each frequency shall be not less than the maximum break time specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2, as applicable.

Following these tests, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, in accordance with B.8.2.4.4, but at $I_{\Delta n}$ only.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

Performance criterion B:

During the test, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, may be temporarily affected.

Following the test, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

B.8.13.1.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

The test set-up shall be in accordance with Figure J.1 and Figure J.3.

Performance criterion B applies except that during the test, the CBR can trip. If this is the case, a further test shall be carried out at the immediate lower level, and the CBR shall not trip.

B.8.13.1.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test set-up shall be in accordance with Figure J.4.

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The test connections shall be in accordance with Figure 5 or Figure 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer's instructions for installation. The type of cable used shall be stated in the test report.

Performance criterion A applies.

B.8.13.1.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figure 4 of IEC 61000-4-4:2012.

The test set-up shall be in accordance with Figure J.5 for testing power lines and with Figure J.6 for testing signal lines, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

B.8.13.1.5 Surges

Annex J applies, in particular J.2.5.

The test conditions of 7.2 of IEC 61000-4-5:2014 apply.

For convenience, the mounting specified in B.8.13.1.4 may be used but the use of the ground reference plane is optional.

The test connections shall be in accordance with Figures 6, 7, 8 or 9 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

B.8.13.1.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

Performance criterion A applies.

B.8.13.2 Emission tests

B.8.13.2.1 General

Annex J applies with the following additional requirements.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

Tests shall be carried out without load current and without residual current.

B.8.13.2.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

B.8.13.2.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

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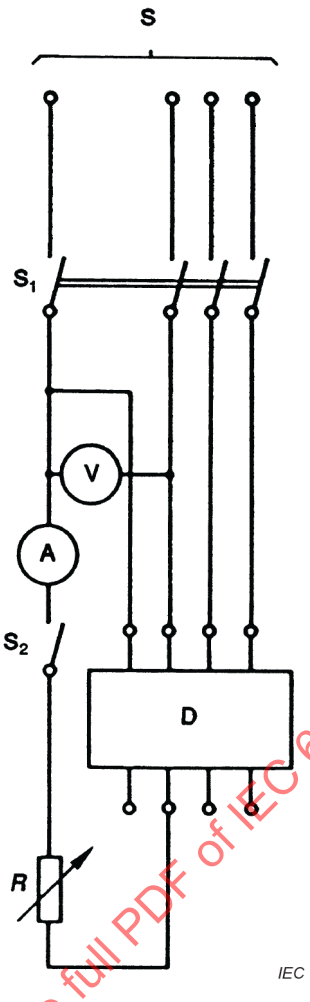
B.8.14 Test for variations or interruptions of voltage and for voltage dips

NOTE For definition of voltage dips, see IEC 61000-4-11.

The relevant tests of B.8.8 and B.8.10 are considered adequate to cover the EMC requirements.

No additional tests are therefore required.

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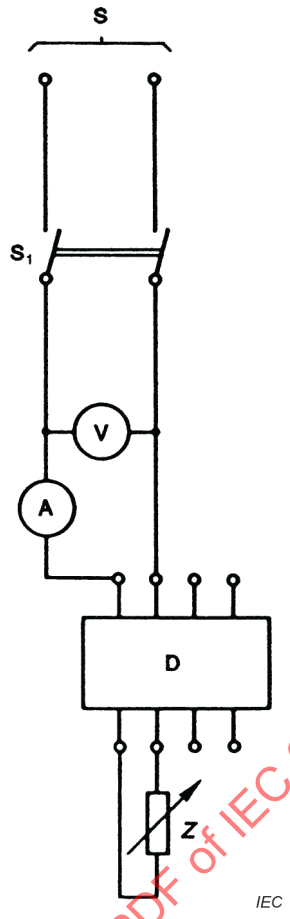


Key

S supply
V voltmeter
A ammeter
S_1 multi-pole switch
S_2 single-pole switch
D CBR under test
R adjustable resistor

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)

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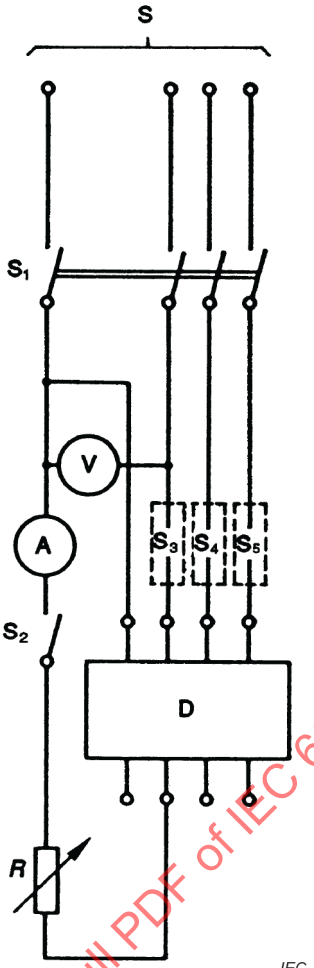


Key

S	supply	D	CBR under test
V	voltmeter	*Z*	adjustable impedance
A	ammeter	S_1	two-pole switch

Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)

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Key

S	supply	S_2	single-pole switch
V	voltmeter	S_3, S_4, S_5	single-pole switches opening one phase in turn
A	ammeter	D	CBR under test
S_1	multi-pole switch	*R*	adjustable resistor

Figure B.3 – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.10)

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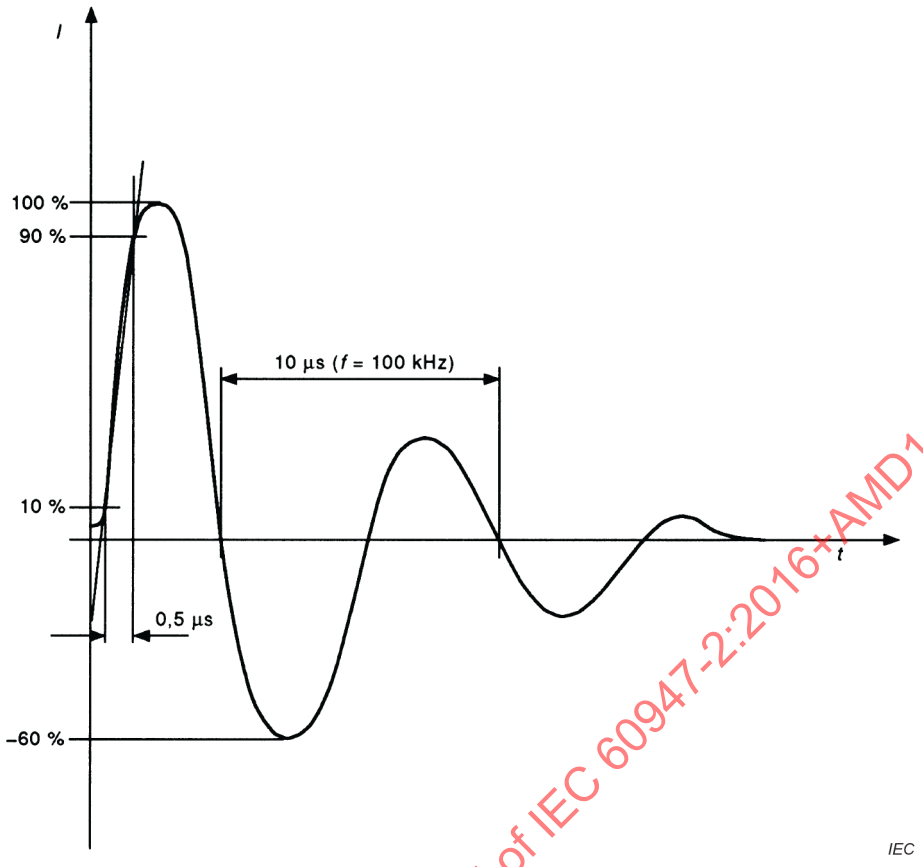
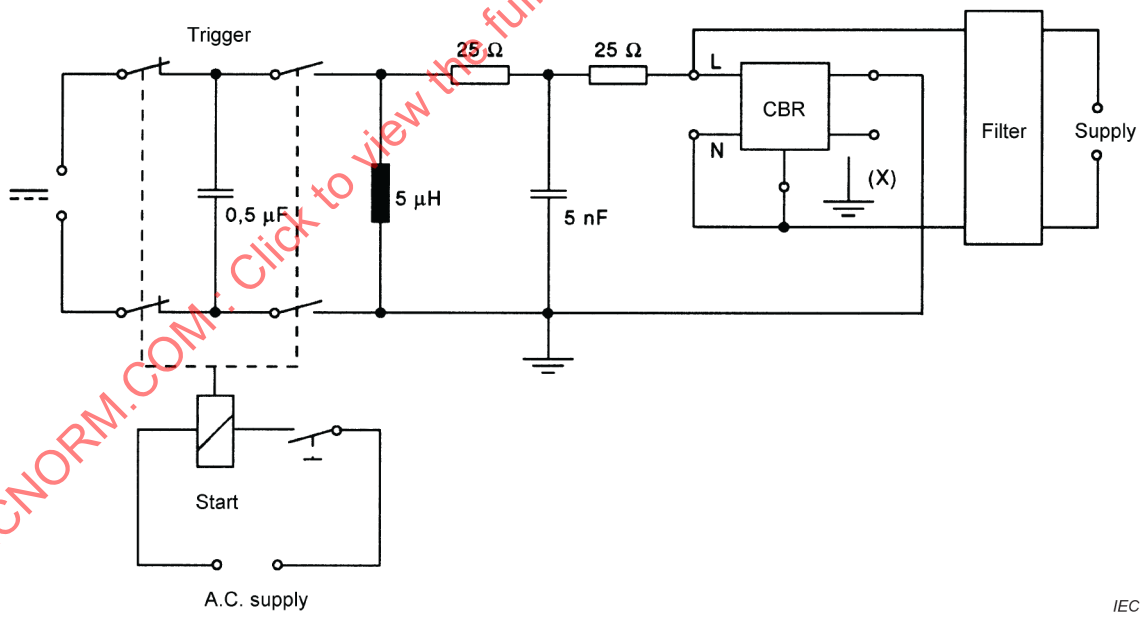


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

The circuit component values are given for guidance only and may require adjustment to comply with the wave shape requirements of Figure B.4.

Figure B.5 – Example of a test circuit for the verification of resistance to unwanted tripping

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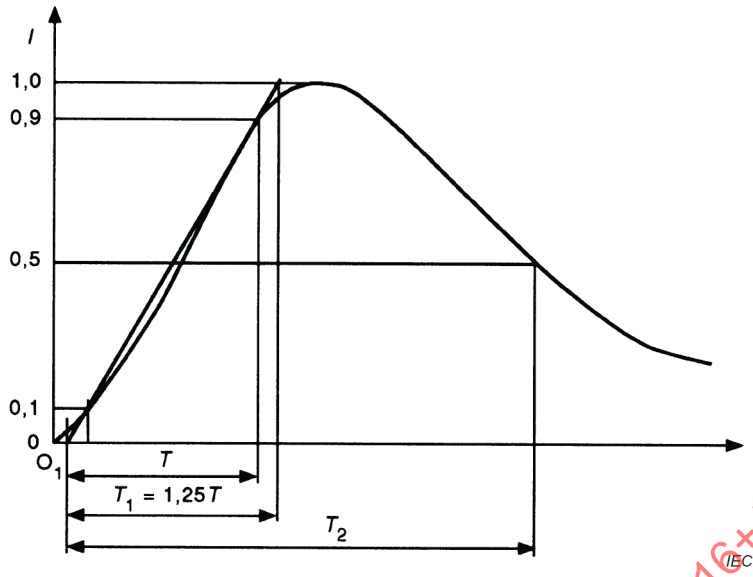
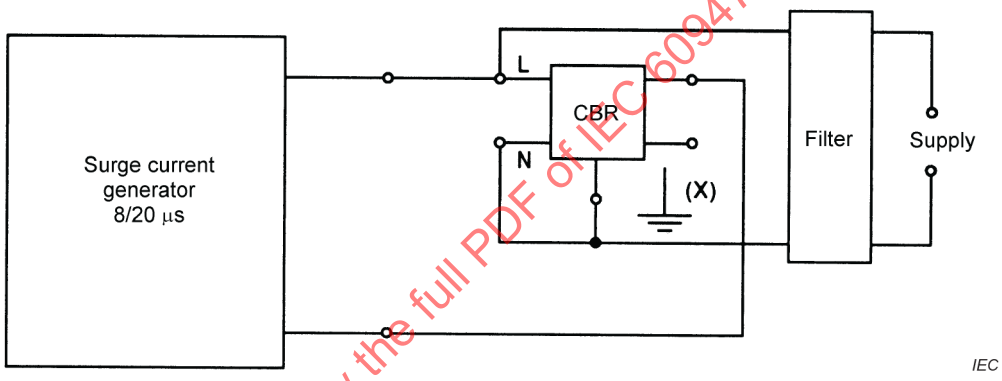


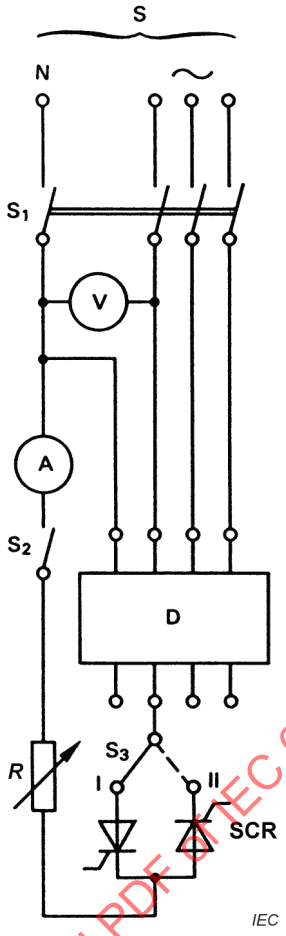
Figure B.6 – Surge current wave 8/20 µs



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in the case of flashover without follow-on current

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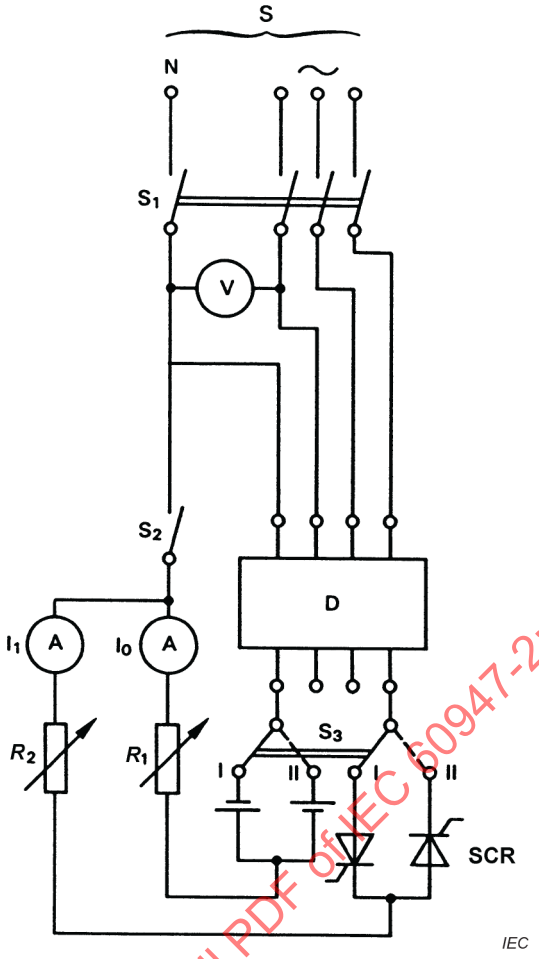


Key

S supply
V voltmeter
A ammeter
D CBR under test
SCR thyristors
R adjustable resistor
S_1 multi-pole switch
S_2 single-pole switch
S_3 two-way switch

Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents

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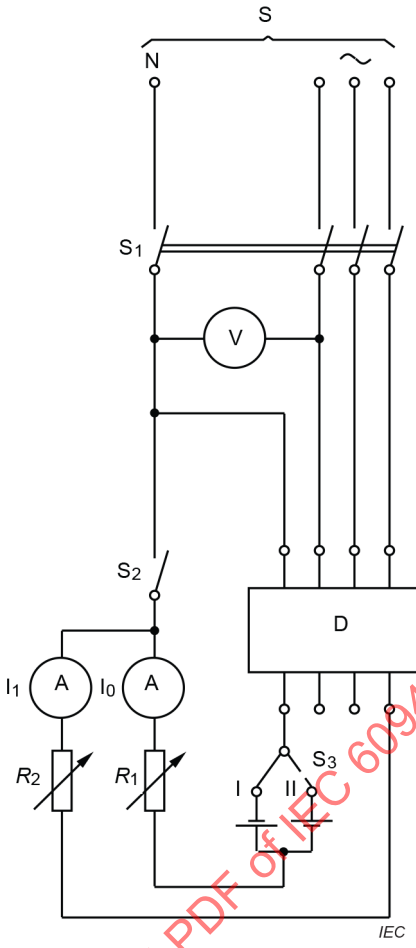


Key

S	supply	R_1, R_2	adjustable resistors
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch
SCR	thyristors		

Figure B.9 – Test circuit for residual pulsating direct current superimposed by a smooth direct current

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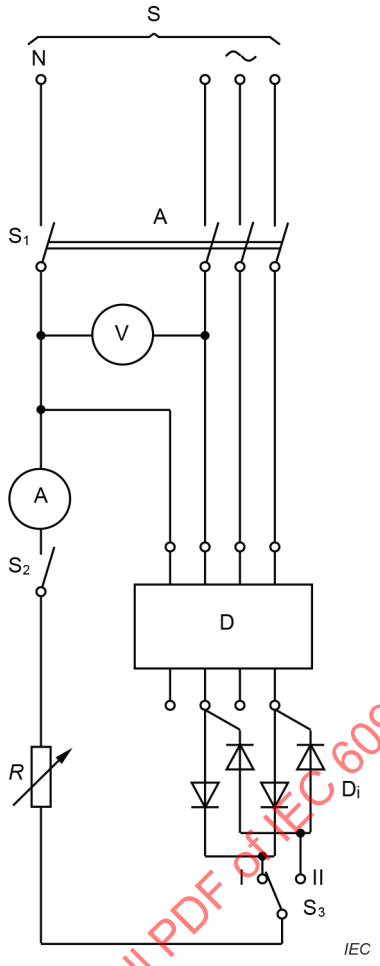


Key

S	supply	R_1, R_2	adjustable resistors
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch

Figure B.10 – Test circuit for residual alternating currents superimposed by a smooth direct current

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Key

Point A supply by 2 phases chosen at random

S supply

V voltmeter

A ammeter

D CBR under test

D_i diodes

R adjustable resistor

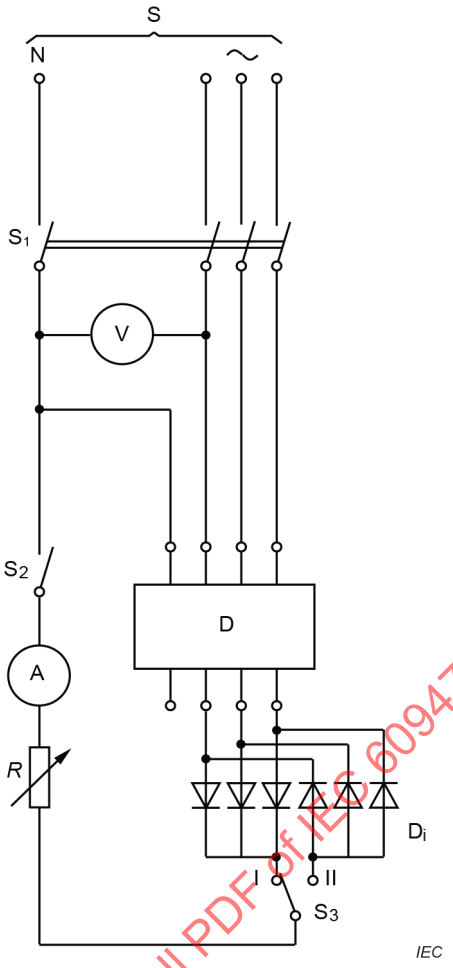
S_1 multi-pole switch

S_2 single-pole switch

S_3 two-way switch

Figure B.11 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from two phases

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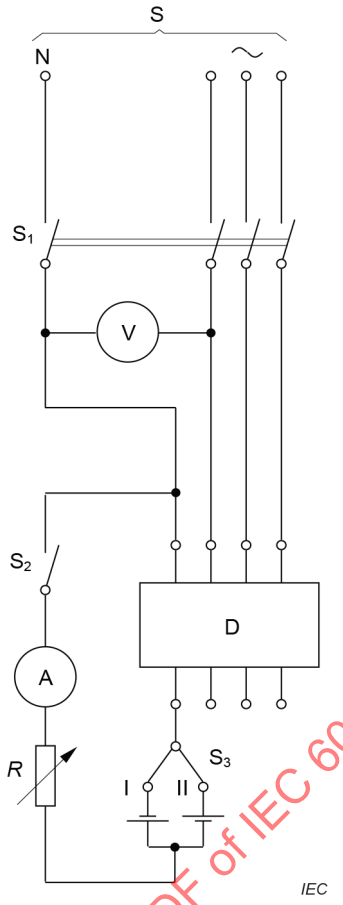


Key

S supply
V voltmeter
A ammeter
D CBR under test
D_i diodes
R adjustable resistors
S_1 multi-pole switch
S_2 single-pole switch
S_3 two-way switch

Figure B.12 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from three phases

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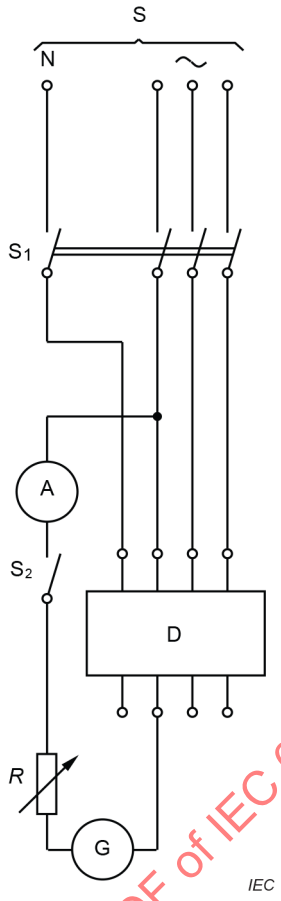


Key

S	supply	*R*	adjustable resistor
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch

Figure B.13 – Test circuit for residual smooth direct current

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Key

S supply
A ammeter
D CBR under test
G generator
R adjustable resistor
S_1 multi-pole switch
S_2 single-pole switch

Figure B.14 – Test circuit for composite residual currents, and residual sinusoidal alternating current up to 1 000 Hz

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Annex C
(normative)

Individual pole short-circuit test sequence

C.1 General

This test sequence applies to multipole circuit-breakers intended for use on phase-earthed systems and identified in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit breaking capacity (I_{su})	C.2
Verification of dielectric withstand	C.3
Verification of overload releases	C.4

C.2 Test of individual pole short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{su} equal to 25 % of the ultimate rated short-circuit breaking capacity I_{cu}.

NOTE Values higher than 25 % of I_{cu} can be tested and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on phase-earthed systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with
Table 10. The power factor shall be according to Table 11, appropriate to the test current.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

$$O - t - CO$$

and shall be made on each pole separately, in turn.

C.3 Verification of dielectric withstand

Following the test according to Clause C.2, the dielectric withstand shall be verified according to 8.3.5.4.

C.4 Verification of overload releases

Following the test according to Clause C.3, the operation of the overload releases shall be verified in accordance with 8.3.5.5.

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Annex D
(normative)

~~Vacant~~

Additional requirements for circuit-breakers intended for connection of aluminium conductors

D.1 General

The purpose of this annex is to address the need of connecting aluminium conductors, as an alternative to copper, by specifying appropriate tests and other requirements while maintaining safety and performance.

This annex specifies the requirements for use of solid and stranded aluminium conductors and aluminium busbars with circuit-breakers within the scope of this document, as follows:

a) aluminium test conductors that are equivalent to, and can be used as an alternative to, the copper conductors given in Tables 9, 10 and 11 of IEC 60947-1:2007 for terminals as depicted in Figures D.1, D.2, D.3, D.4, D.5 (including busbars) and D.6 of IEC 60947-1:2007/AMD1:2010 or similar clamping units;

b) method for verifying the means of connecting aluminium conductors, as used in normal service for terminals as depicted in Figures D.1, D.2, D.3, D.4 and D.6 of IEC 60947-1:2007/AMD1:2010 or similar clamping units. Testing of lug terminals depicted in Figure D.5 of IEC 60947-1:2007/AMD1:2010 is covered by IEC 61238-1 (all parts).

Terminals covered by this annex may be an integral part of the circuit-breaker or may be provided as an accessory.

NOTE The term “terminal” used in this annex is equivalent to the term “clamping unit” used in IEC 60947-1.

Screwless terminals as depicted in Figure D.7 of IEC 60947-1:2007/AMD1:2010 and connection of flexible aluminium conductors are not covered by this annex. Terminating aluminium and copper conductors in one clamping unit at the same time is not covered by this annex.

D.2 Terms and definitions

Clause 2 applies with the following additions:

D.2.1
reference conductor
continuous length of the same type and size conductor as that used in the terminal unit under test and connected in the same series circuit to enable the reference temperature and, if required, reference resistance to be determined

D.2.2
equalizer
arrangement used in the test loop to ensure an equipotential point and a uniform current density in a stranded conductor, without adversely affecting the temperature of the conductor(s)

D.2.3
stability factor
Sf
measure of temperature stability of a terminal unit during the current cycling test

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Note 1 to entry: Definitions for different types of terminals can be found in Annex D of IEC 60947-1:2007/AMD1:2010.

D.3 Classification

Clause 3 applies with the following additions:

According to the conductor connection:

– for use with copper only, or
– for use with either copper or aluminium, or
– for use with aluminium only.

D.4 Characteristics

Clause 4 applies.

D.5 Product information

D.5.1 Nature of information

Subclause 5.1 applies.

D.5.2 Marking

Subclause 5.2 applies with the following addition:

The suitability of the terminal for use with aluminium conductors only (Al) or copper and aluminium conductors (Cu/Al) shall be marked on the circuit-breaker or the circuit-breaker terminals, or in the manufacturer's literature, as appropriate. When the marking is on the circuit-breaker or terminals, the abbreviations ‘AL’ and ‘CU/AL’ may also be used.

If the rated current of the terminals is lower than the rated current of the circuit-breaker, it shall be marked on the circuit-breaker or the circuit-breaker terminals, or in the manufacturer literature, as appropriate.

D.5.3 Instructions for installation, operation and maintenance

Subclause 5.3 applies with the following addition:

Manufacturer’s literature may include recommended installation practices, such as:

(i) after removal of the conductor insulation and prior to termination, the aluminium conductor shall be cleaned by wire brushing the aluminium followed by application of an anti-oxidant compound to limit oxidization of the aluminium;

(ii) treatment of the busbar at the termination points, by wire brushing the aluminium followed by the application of an anti-oxidant compound or by use of an electrically conductive coating such as tin.;

(iii) use of specific hardware for termination.

D.6 Normal service, mounting and transport conditions

Clause 6 applies.

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D.7 Constructional and performance requirements

Clause 7 applies with the following addition:

Clamping units intended for use with aluminum conductor(s) shall be treated with an electrically conductive coating such as tin, or alternative means that will inhibit corrosion due to difference in electrochemical series.

The manufacturer shall specify whether the terminals are suitable for stranded, solid or both types of conductors. Performance tests shall be carried out with all conductor types specified by the manufacturer.

Aluminium conductor sizes for different currents given in Table D.7 and in Table D.8 correspond to copper conductor sizes given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007.

NOTE The conductor sizes have been derived from IEC 60898-1, UL 486E and IS 1394761.

D.8 Tests

D.8.1 General

The tests shall be performed with aluminium conductors having a cross-section as given in Table D.7, corresponding to the lower of either the rated current of the device or the rated current of the terminals.

The aluminium cable to be used shall be single core, with black insulation, with electrical and mechanical properties complying with IEC 60228.

Class A aluminium alloy grade 1350, as referred to in IEC 61545, shall be used for testing purposes.

NOTE 1 Grade 1350 aluminium is generally considered to be the worst case and its use for testing is consistent with UL 486 standards.

NOTE 2 Requirements for terminals acceptable for use with sector-shaped conductors are under consideration.

The following tests shall be carried out on either the product or the terminal specimen to be used in the final product as specified in Table D.1 below. Each specimen comprises a pair of terminals and a conductor part.

Table D.1 – List of tests for terminal connections[a] with aluminium cables

Test		Subclause	Tested on	Number of units
Current cycling test		D.8.2	Terminal specimen	4 specimens
Mechanical properties of terminals	Flexion test	D.8.3.1	Circuit-breaker	As per 8.2.4.3 of IEC 60947-1: 2007/AMD1:2010
	Pull-out test	D.8.3.2		As per 8.2.4.4 of IEC 60947-1: 2007/AMD1:2010
Insertion test		D.8.4	Circuit-breaker	As per 8.2.4.5 of IEC 60947-1: 2007/AMD1:2010

[a] Type of connection limited to clamping unit types of Figure D.1, D.2, D.3, D.4 and D.6 as per Annex D of IEC 60947-1:2007/AMD1:2010.

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D.8.2 Current cycling test

D.8.2.1 General

The intent of this test is to verify the stability of the terminal by comparing the temperature performance with that of the reference conductor under current cycling conditions. This test shall be carried out on terminals alone, not on the circuit-breaker.

D.8.2.2 Preparation

The test shall be performed on four specimens, each one made by a couple of terminals, assembled in a manner which represents the use of the terminals in the circuit-breaker. The terminals that have been removed from the product shall be attached to conducting parts of the same cross-section, shape, metal and finish as those on which they are mounted on the product. The conducting part shall not exceed:

(i) three times the length of the terminal,

(ii) the width of the terminal

as shown in Figure D.2. The terminals shall be fixed to the conductor part(s) in the same manner (position, torque, etc.) as on the product.

To avoid excessive oxidation of the conductor and ensure proper connection, a sufficient length of insulation shall be removed immediately prior (without any intentional delay) to installation.

The wire shall be positioned so that 6 mm to 13 mm of the bare conductor is exposed between the wire-entry face of the terminal and the beginning of the insulation. There shall be no mechanical removal or chemical treatment of any oxide on the surface of the conductor entering the terminal, unless it is explicitly required by the manufacturer's instructions, in which case it shall be stated in the test report.

D.8.2.3 Test arrangement

The general arrangement of the samples shall be as shown in Figure D.1.

The test shall be carried out with conductors in accordance with Table D.7, specifying the equivalent cross-section of aluminium conductors.

The length of the test conductor from the point of entry to the terminal specimens to the equalizer shall be as in Table D.2.

Test conductors shall be connected in series with a reference conductor of the same cross-section. The length of the reference conductor shall be approximately twice the length of the test conductor.

90 % of the value of torque stated by the manufacturer or, if not stated, selected in Table 4 of IEC 60947-1:2007/AMD2:2014, shall be used to connect the aluminium cables to the terminal specimens.

Each free-end of the test and reference conductor(s) not connected to a terminal specimen shall be welded or brazed to a short length of equalizer of cross section not greater than that given in Table D.3. All strands of the conductor shall be welded or brazed to make an electrical connection with the equalizer. As an alternative, tool-applied compression type terminations without welding or brazing may be used for the equalizer if acceptable to the manufacturer.

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For a wiring terminal of a piece of equipment intended for paralleling conductors, the hole spacing pattern in the equalizer shall be identical to the hole spacing pattern of the wiring terminal of the piece of equipment.

The distance between the test and reference conductors shall be at least 150 mm.

The test specimen shall be suspended either horizontally or vertically in free air by supporting the equalizer by non-conductive supports so as to minimize the tensile load on the terminals. Thermal barriers shall be installed mid- way between the conductors and shall extend 25 mm ± 5 mm widthways and 150 mm ± 10 mm lengthways beyond the terminals (see Figure D.1). Thermal barriers are not required provided the specimens are separated by at least 450 mm. The specimens shall be located at least 600 mm from the floor, wall or ceiling.

The test specimens shall be located in a substantially vibration-free and draught-free environment and at an ambient air temperature between 15 °C and 35 °C. Once the test is started, the maximum permissible variation is ± 4 K provided the range limitation is not exceeded.

D.8.2.4 Temperature measurements

Temperature measurements are made by means of thermocouples. Positioning of the thermocouples shall not damage the terminal or the reference conductor.

NOTE 1 Drilling of a small hole and subsequent fastening of the thermocouple is an acceptable method, provided that the performance is not affected and that it is agreed by the manufacturer.

For the measurement of the terminal temperature, the thermocouple shall be located on the conductor entry side of the terminal, close to the contact interface.

For the measurement of the temperature of the reference conductor, the thermocouple shall be located midway between the ends of the conductor, and under its insulation.

The ambient air temperature shall be measured with two thermocouples in such a manner as to achieve an average and stable reading in the vicinity of the test loop without undue external influence. The thermocouples shall be located in a horizontal plane intersecting the specimens, at a minimum distance of 600 mm from them.

NOTE 2 A satisfactory method for achieving a stable measurement is, for example, to attach the thermocouple to unplated copper plates of approximately 50 mm × 50 mm, having a thickness of between 6 mm and 10 mm.

D.8.2.5 Test method

The test loop shall be subjected to 500 cycles; each cycle consists of an on-period and an off-period as specified, starting at the test current value given in Table D.4.

The on-time shall be the time it takes for the test specimen terminal to reach stable temperatures. The off-time shall be the time it takes to reach room temperature. These times shall be determined in the first 25 cycles of operation. A test specimen terminal has attained a stable temperature when three readings, taken at not less than 10-minutes intervals, show no more than a 2 °C variation between any two of the readings. The time to temperature stabilization is the first of three readings indicating stable temperature.

Forced-air cooling may be employed to reduce the off-time, if acceptable to the manufacturer. In that case, it shall be applied to the entire test loop and the resulting temperature of the forced air shall not be lower than the ambient air temperature.

Alternatively, for terminals with single conductors, the on- and/or off-times in Table D.4 may be used.

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Near the end of each on-period of the first 24 cycles, the temperature of each terminal shall have attained a minimum of 105 °C. When necessary, the current shall be adjusted to achieve this condition.

If the manufacturer demonstrates that the maximum temperature-rise of the terminals is less than 70 K, the 105 °C temperature may be reduced to this temperature-rise plus 35 °C.This shall be demonstrated by means of a temperature-rise test, in accordance with the general conditions of 8.3.3.3.4 of IEC 60947-1:2007, carried out on the device at the lower of either the rated current of the device or the rated current of the terminals. This test shall be carried out on a new device equipped with the terminals under consideration and the aluminium conductors as specified in Table D.7. The maximum temperature-rise of all terminals shall be used for determining the target temperature for the current cycling test.

At the 25th cycle, the test current shall be adjusted for the last time and the corresponding temperature, when stabilized at the final load current,shall be recorded as the first measurement. There shall be no further adjustment of the test current for the remainder of the test.

Temperatures shall additionally be recorded after approximately 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles. The temperature shall be measured during the last 5 min of the on-period. If the size of the set of test specimens or the speed of the data acquisition system is such that not all measurements can be completed within 5 min, the on-period shall be extended as necessary to complete all the measurements.

D.8.2.6 Acceptance criteria

The evaluation of the performance is based on both the limit of terminal temperature-rise and the temperature variation (stability factor) during the test.

The stability factor *S*f for each of the 11 temperature measurements shall be determined as follows:

– calculate the temperature deviation *d* for the 11 individual temperature measurements by subtracting the associated reference conductor temperature from the terminal temperature;
– calculate the average temperature deviation *D* from the 11 values of *d*;
– calculate *S*f = *d* − *D* for each value of *d*.

See example of stability factor calculation in Table D.5.

NOTE The value of *d* is positive if the terminal temperature is higher than that of the reference conductor and negative if it is lower.

For each terminal:

– the temperature-rise shall not exceed 125 K, and
– the stability factor *S*f shall not exceed ±10 K.

As this is an accelerated aging test, the insulation can be damaged owing to high temperatures, but this is not considered as a failure of the test.

D.8.3 Mechanical properties of terminals

D.8.3.1 Flexion test

Subclause 8.2.4.3 of IEC 60947-1:2007/AMD1:2010 applies with the following modification:

The test values shall be in accordance with Table D.6.

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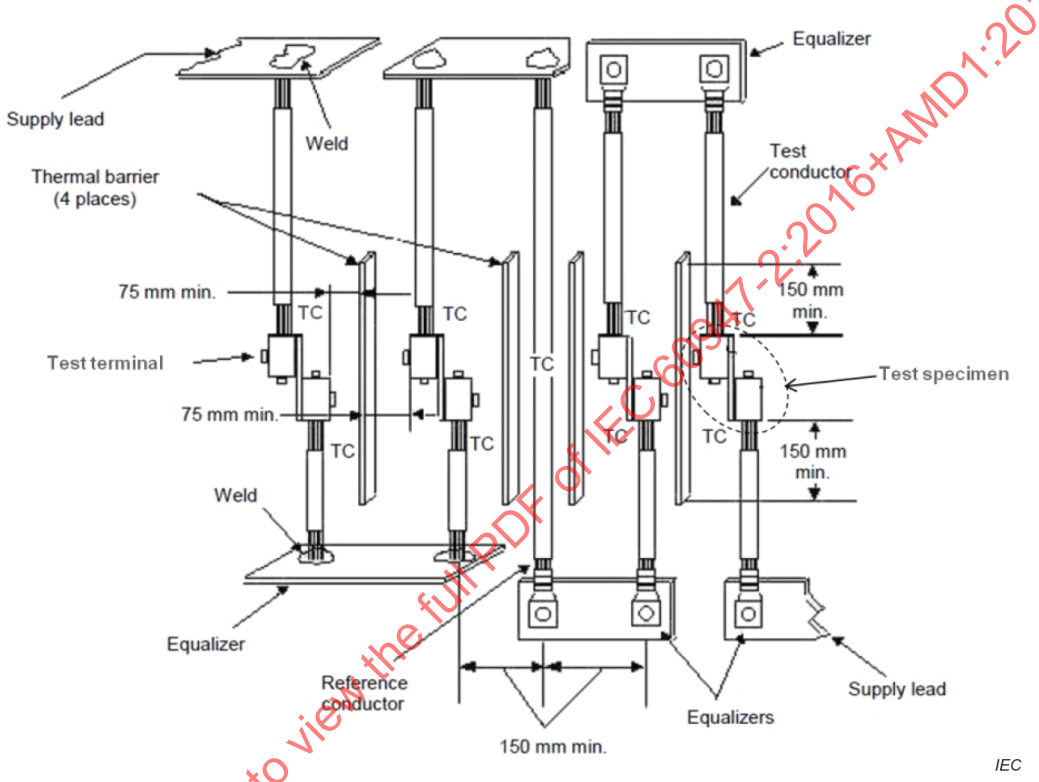
D.8.3.2 Pull-out test

Subclause 8.2.4.4 of IEC 60947-1:2007/AMD1:2010 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.4 Test for insertability of unprepared round aluminium conductors having the maximum cross-section

Subclause 8.2.4.5 of IEC 60947-1:2007/AMD1:2010 applies. Table 7 of IEC 60947-1:2007 applies, except the column relating to flexible conductors.



Key

TC thermocouple

Figure D.1 – General test arrangement

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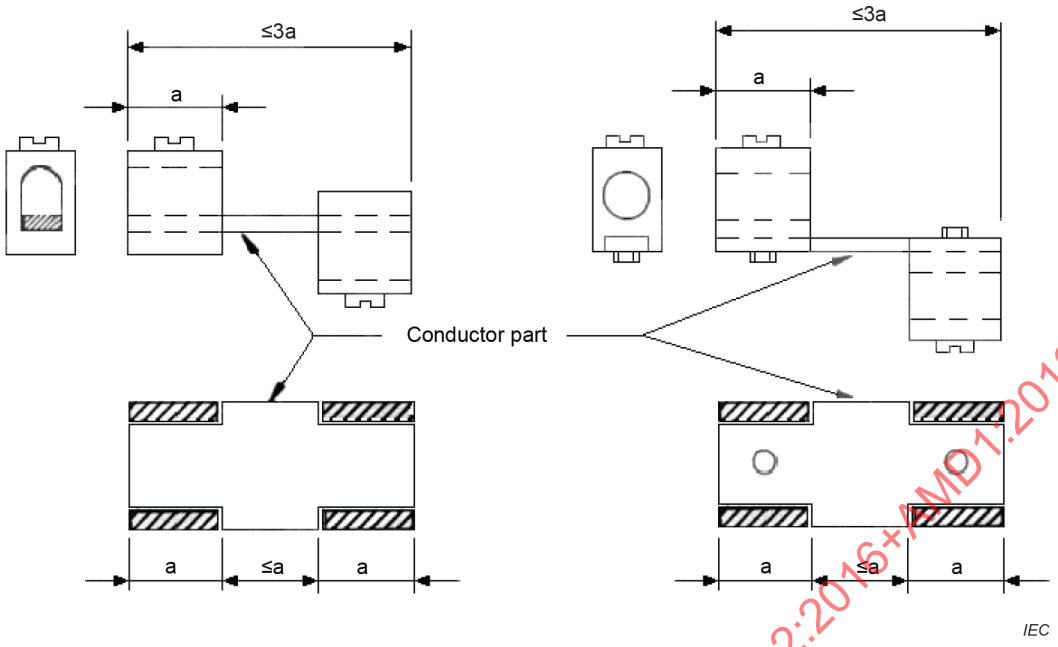


Figure D.2 – Mounting of terminals for the current cycling test

Table D.2 – Conductor length for the current cycling test as per conductor cross-section

Conductor cross-section		Minimum conductor length
mm^2	AWG/kcmil	mm
0 to 10	30 to 8	200
16 to 25	6 to 3	300
35 to 240	2 to 500	460
Larger than 240	Larger than 500	660

Table D.3 – Equalizer dimensions

Range of test current A		Maximum dimensions[a] (thickness × width)			
		Copper		Aluminium	
>	≤	mm	in	mm	in
0	50	3,2 × 12,7	1/8 × 1/2	3,2 × 12,7	1/8 × 1/2
50	125	3,2 × 25	1/8 × 1	3,2 × 32	1/8 × 1-1/4
125	225	3,2 × 48	1/8 × 1-7/8	3,2 × 57	1/8 × 2-1/4
225	400	6,4 × 38	1/4 × 1-1/2	6,4 × 50	1/4 × 2
400	600	6,4 × 50	1/4 × 2	6,4 × 76	1/4 × 3
600	800	6,4 × 76	1/4 × 3	6,4 × 102	1/4 × 4
800	1 000	6,4 × 102	1/4 × 4	9,5 × 89	3/8 × 3-1/2
1 000	1 400	12,7 × 76	1/2 × 3	12,7 × 89	1/2 × 3-1/2
1 400	2 000	12,7 × 102	1/2 × 4	12,7 × 127	1/2 × 5

[a] The equivalence between mm and inches is only approximative; it is acceptable for the equalizer to comply with either millimeters or inches columns. Other dimensions may be used provided the current density for the upper limit of the test current (2nd column) exceeds 1,16 A/mm^2 (750 A/in^2) for an aluminium equalizer or 1,55 A/mm^2 (1 000 A/in^2) for a copper equalizer.

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Table D.4 – Starting test current for the current cycling test

Cable(s) size			Test current	Duration of on- and off-periods
Number	mm^2	AWG/kcmil	A	hours
1	4	12	33	1
1	6	10	45	1
1	10	8	60	1
1	16	6	85	1
1	25	4	110	1
1	35	2	150	1
1	50	0	200	1
1	70	00	230	1
1	95	000	270	1
1	120	250 kcmil	350	1,5
1	150	300 kcmil	390	1,5
1	185	350 kcmil	435	1,5
1	240	500 kcmil	540	2
2	120	250 kcmil	460	-
2	150	300 kcmil	510	-
2	240	500 kcmil	707	-
2	300	600 kcmil	907	-
3	240	500 kcmil	1 060	-

Table D.5 – Example of stability factor calculation

Temperature measurement	Cycle Number	Temperatures		Temperature deviation d = a) – b)	Stability factor $S_f = d - D$ [a]
		a) Terminal [b]	b) Reference conductor		
		°C	°C	K	K
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	-0,82
4	100	76	77	-1	-1,82
5	125	77	77	0	-0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	-1	-1,82
10	425	77	79	-2	-2,82
11	500	81	78	3	2,18

[a] Average temperature deviation $D = \frac{\sum d}{\text{number of measurements}} = \frac{9}{11} = 0,82$.

[b] Example applies to a cable terminal with a maximum temperature of 75 °C.

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Table D.6 – Test values for flexion and pull-out test for cables

Conductor cross-section		Diameter of the bushing hole [a, b]	Height H[a]	Mass	Pulling force
mm^2	AWG/kcmil	mm	mm	kg	N
4	12	9,5	280	0,7	44
6	10	9,5	280	0,7	44
10	8	9,5	280	1,4	44
16	6	12,7	300	4	124
25	4	12,7	300	4,5	160
-	3	14,3	320	5,9	187
35	2	14,3	320	6,8	222
-	1	15,8	343	8,6	271
50	0	15,8	343	9,5	320
70	00	19,1	368	10,4	347
95	000	19,1	368	13,6	432
-	0000	19,1	368	13,6	516
120	250 kcmil	22,2	406	13,6	516
150	300 kcmil	22,2	406	15,4	516
185	350 kcmil	25,4	432	17,2	574
-	400 kcmil	25,4	432	17,2	574
240	500 kcmil	28,6	464	20,4	685
300	600 kcmil	28,6	464	20,4	685

NOTE Table D.6 is based on UL 486E.

[a] Tolerances for height *H* is ± 15 mm, tolerance for diameter of the bushing hole is ± 2 mm.

[b] If the bushing hole diameter is not large enough to accommodate the conductor without binding, a bushing having the next larger hole size may be used.

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Table D.7 – Test aluminium cables for test currents up to 800 A[a,d]

Range of test current A		Cable size		
>	≤	Number	mm²	AWG/kcmil
0	8	1	c	c
8	12	1	c	c
12	15	1	4[b]	12[b]
15	20	1	4[b]	12[b]
20	25	1	6[b]	10[b]
25	32	1	10	8
32	50	1	16	6
50	65	1	25	4
65	85	1	35	2
85	100	1	50	0
100	115	1	50	0
115	130	1	70	00
130	150	1	95	000
150	175	1	120	250 kcmil
175	200	1	150	300 kcmil
200	225	1	150	300 kcmil
225	250	1	185	350 kcmil
250	275	1	240	500 kcmil
275	300	2	120	250 kcmil
300	350	2	120	250 kcmil
350	400	2	150	300 kcmil
400	500	2	240	500 kcmil
500	630	2	300	600 kcmil
630	800	3	240	500 kcmil

[a] See 8.3.3.3.4 of IEC 60947-1:2007.

[b] National regulations may require larger sizes. Aluminium cables with cross-sections lower than 10 mm² are not recommended per IEC 60364-5-52.

[c] Aluminium cables with cross-sections lower than 4 mm² are not recommended.

[d] Test cables for currents above 800 A are under consideration.

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Table D.8 – Test aluminium bars for test currents above 400 A[g] and up to 3 150 A[a, f]

Range of test current A		Aluminium bars[b c d]	
>	≤	Number	Dimensions (mm)
400	500	2	25 × 10
500	630	2	30 × 12
630	800	2	40 × 10
800	1 000	2	50 × 10
1 000	1 250	2	80 × 10
1 250	1 600	2	100 × 10
1 600	2 000	3	100 × 10
2 000	2 500	4	100 × 10
2 500	3 150	4	150 × 10[e]

[a] See 8.3.3.3.4 of IEC 60947-1:2007.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] Bars are assumed to be arranged with their long faces vertically. Arrangements with long faces horizontally may be used if specified by the manufacturer.

[d] Where four bars are used they shall be in two sets of two bars with not more than 100 mm between pair centres.

[e] Dimensions given are recommendations only. Different sizes can be used upon agreement between manufacturer and user.

[f] For rated currents greater than 3 150 A, agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc. This information shall form part of the test report.

[g] Aluminium bars for test currents below or equal to 400 A are under consideration.

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Annex E
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex

– "agreement" is used in a very wide sense;

– "user" includes testing stations.

Annex J of IEC 60947-1:2007 applies with regard to clauses and subclauses of this standard, with the following additions:

Clause or subclause number of this standard	Item
4.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 2
7.2.1.2.1	Automatic opening operation other than trip-free operation and by stored energy
Table 10	Setting of overload releases at intermediate values for short-circuit tests
8.3.3.5	Method of temperature-rise tests for four-pole circuit-breakers having a conventional thermal current higher than 63 A
8.3.2.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
8.3.3.2.3, item b)	Test current value for the verification of inverse time/current characteristics
8.3.3.5	To increase the severity of the conditions for testing overload performance
8.3.3.8 8.3.4.6	Permissible delay between the verification of temperature-rise and that of overload relays in test sequences I and II
8.4.3	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
8.5	Special tests – Damp heat, salt mist, vibration and shock
B.8	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.5	Extension of the test ambient temperature limits

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Annex F
(normative)

Additional tests for circuit-breakers with electronic over-current protection

F.1 General

This annex applies to circuit-breakers intended to be installed on a.c. circuits and providing over-current protection by electronic means, incorporated in the circuit-breaker and independent of the line voltage or any auxiliary supply.

The tests verify the performance of the circuit-breaker under the environmental conditions stated in this annex.

Specific tests for electronic means intended for functions other than over-current protection are not covered by this annex. However, the tests of this annex shall be performed to ensure that these electronic means do not impair the performance of the over-current protective functions.

F.2 List of tests

F.2.1 General

Tests specified in this annex are type tests and are supplementary to the tests of Clause 8.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this standard, if relevant.

F.2.2 Electromagnetic compatibility (EMC) tests

F.2.2.1 General

Circuit-breakers with electronic overcurrent protection shall be tested according to Table J.1 and Figure J.3.

F.2.2.2 Performance criteria

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1 with the following specifications:

Performance criterion A:

For step 1, the circuit-breaker when loaded at 0,9 times the current setting shall not trip and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

For step 2, when loaded at 2,0 times the current setting, the circuit-breaker shall trip within 0,9 times the minimum value and 1,1 times the maximum value of the manufacturer's time current characteristic, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

Performance criterion B:

During the test, the circuit-breaker when loaded at 0,9 times the current setting shall not trip. After the test, the circuit-breaker shall comply with the manufacturer's time current characteristic when loaded at 2,0 times the current setting and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

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F.2.3 Suitability for multiple frequencies

The test shall be performed in accordance with F.6.

F.2.4 Dry heat test

The test shall be performed in accordance with F.7.

F.2.5 Damp heat test

The test shall be performed in accordance with F.8.

F.2.6 Temperature variation cycles at a specified rate of change

The test shall be performed in accordance with F.9.

F.3 General test conditions

F.3.1 General

Tests according to this annex may be performed separately from the tests of Clause 8.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

F.3.2 Electromagnetic compatibility tests

For immunity tests (F.4) one circuit-breaker per frame size and per type of current sensor design shall be tested; a change of winding turns is not considered as a different design in this context. In the case of withdrawable circuit-breaker, the device shall be mounted inside the enclosure in accordance with the manufacturer's instructions, the test set-up being modified accordingly.

The current setting I_r shall be adjusted to the minimum value.

Short-time and instantaneous release settings shall each, if applicable, be adjusted to the minimum value but to not less than 2,5 times I_r.

The tests shall be performed with the appropriate test circuit, as specified in the following subclauses, taking into account any phase-loss sensitive features.

For circuit-breakers having electronic overcurrent protection, it may be assumed that the tripping characteristics are the same, whether tests are performed:

– on individual poles of multipole circuit-breakers;
– on two or three phase poles in series;
– by three-phase connection.

NOTE This enables comparisons to be made between test results obtained on different phase pole combinations as required by the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M):

– in the cases of F.4.4, F.4.5 and F.4.6, tests are made on pairs of phase poles for multipole circuit-breakers, to avoid unintentional tripping by residual current;
– in the cases of F.4.1 and F.4.7, tests may be made on any combination of phase poles, as long as unintentional tripping by residual current is avoided.

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F.4 Immunity tests

F.4.1 Harmonic currents

F.4.1.1 General

These tests apply to circuit-breakers for which the electronic current sensing means are stated by the manufacturer to be r.m.s. responsive.

This shall be indicated either by marking “r.m.s.” on the circuit-breaker or given in the manufacturer's literature, or both.

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including the dimensions of the enclosure shall be stated in the test report.

Where applicable, the tests shall be performed at the rated frequency.

NOTE The test currents can be generated by a source of power based on the use of thyristors (see Figure F.1), saturated cores, programmable power supplies, or other appropriate sources.

F.4.1.2 Test currents

The test current waveform shall consist of one of the following two options:

– option a): two waveforms applied successively:
  - a waveform consisting of a fundamental and a third harmonic component;
  - a waveform consisting of a fundamental and a fifth harmonic component.
– option b): a waveform consisting of a fundamental and a third, fifth and seventh harmonic component.

Test currents shall be

– for option a):

  test of the third harmonic and peak factor
  - 72 % of fundamental component ≤ third harmonic ≤ 88 % of fundamental component;
  - peak factor: 2,0 ± 0,2;

  test of the fifth harmonic and peak factor
  - 45 % of fundamental component ≤ fifth harmonic ≤ 55 % of fundamental component;
  - peak factor: 1,9 ± 0,2;
– for option b):

  the test current, for each period, consists of two equal opposite half-waves defined as follows:
  - current conduction time, for each half-wave is ≤ 21 % of the period;
  - peak factor: ≥ 2,1.

NOTE 1 The peak factor is the peak value of the current divided by the r.m.s. value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 This test current for option b) has at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;
– fifth harmonic > 14 %;
– seventh harmonic > 7 %;
– twenty-first harmonic > 1 %.

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Other harmonics can also be present.

NOTE 3 The test current waveform for option b) can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 4 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the r.m.s. values of the composite waveforms.

F.4.1.3 Test procedure

The tests shall be performed on two-phase poles, chosen at random in accordance with item b) of 7.2.1.2.4 carrying the test current at any convenient voltage, connections being in accordance with Figure F.2. For releases with a phase loss sensitive feature, connections shall be made in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The duration of the test to verify the immunity to unwanted tripping (at 0,9 times the current setting) shall be 10 times the tripping time, which corresponds to twice the current setting.

F.4.1.4 Test results

Performance criterion A of F.2.2.2 shall apply.

F.4.2 Electrostatic discharges

Annex J, in particular J.2.2, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure J.3.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The busbar routing shown in Figure F.2, Figure F.3 and Figure F.4 may be varied providing the 0,1 m distances, with a tolerance of $^{+10}_{0}$ %, to the enclosure are maintained. The actual configuration used shall be shown in the test report.

Performance criterion B of F.2.2.2 applies.

F.4.3 Radiated RF electromagnetic fields

Annex J, in particular J.2.3, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.17.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.4 Electrical fast transient/burst (EFT/B)

Annex J, in particular J.2.4, applies with the following additions.

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The test set-up shall be in accordance with Figure F.16 and Figure F.18 for testing power lines and with Figure F.16 and Figure F.19 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.6.

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.7 for the three phase poles in series connection or as shown in Figure F.8 on a phase pole chosen at random for the three-phase connection.

Performance criterion A of F.2.2.2 applies. However, temporary changes to the monitoring functions (e.g. unwanted LED illumination) during the tests are acceptable, in which case the correct functioning of the monitoring shall be verified after the tests. For step 2, the disturbance shall be applied until the circuit-breaker trips.

F.4.5 Surges

Annex J, in particular J.2.5, applies with the following additions.

On a.c. mains ports, the disturbance shall be applied on one phase pole chosen at random, the EUT being supplied from the other two phase poles, in accordance with Figure F.9 (line-to-earth) and Figure F.12 (line-to-line).

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.10 (line-to-earth) and Figure F.13 (line-to-line) for the three phase poles in series connection or as shown in Figure F.11 (line-to-earth) and Figure F.14 (line-to-line) on a phase pole chosen at random for the three-phase connection.

Performance criterion B of F.2.2.2 applies.

F.4.6 Conducted disturbances induced by RF fields (common mode)

Annex J, in particular J.2.6, applies with the following additions.

The test set-up shall be in accordance with Figure F.16, Figure F.20 and Figure F.21, Figure F.22 or Figure F.23 for testing power lines and with Figure F.16 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.2.

For releases which have a phase-loss sensitive feature the test circuit shall be in accordance with Figure F.3 or Figure F.4 as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.7 Current dips

F.4.7.1 Test procedure

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

The test circuit shall be in accordance with Figure F.2 on two-phase poles chosen at random. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

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The tests shall be performed with a sinusoidal current at any convenient voltage. The current applied shall be according to Figure F.5 and to Table F.1 below where I_r is the setting current, I_D is the dip test current and T is the period of the sinusoidal current.

The duration of each test shall be between three and four times the maximum tripping time corresponding to twice the current setting or 10 min, whichever is the lower.

Table F.1 – Test parameters for current dips and interruptions

Test No.	I_D	Δt
1	0	0,5 T
2		1 T
3		5 T
4		25 T
5		50 T
6	0,4 I_r	10 T
7		25 T
8		50 T
9	0,7 I_r	10 T
10		25 T
11		50 T

F.4.7.2 Test results

Performance criterion B of F.2.2.2 shall apply, except that the after-test verification is not required.

F.5 Emission tests

F.5.1 Harmonics

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.2 Voltage fluctuations

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.3 Conducted RF disturbances (150 kHz to 30 MHz)

Circuit-breakers covered by this annex are independent of line voltage or of any auxiliary supply. Electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to 1 GHz)

Annex J, in particular J.3.3, applies with the following additions.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

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Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The limits of Table J.3 apply.

F.6 Suitability for multiple frequencies

F.6.1 General

The test verifies the tripping characteristics of circuit-breakers declared as suitable for multiple frequencies. It does not apply to circuit-breakers rated at 50 Hz to 60 Hz only.

F.6.2 Test conditions

The tests shall be performed at each rated frequency or, when a range of rated frequencies is declared, at the lowest and the highest rated frequencies.

F.6.3 Test procedure

Tests shall be performed on any pair of phase-poles chosen at random at any convenient voltage.

The test circuit shall be in accordance with Figure F.2. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Under-voltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The short-time and instantaneous trip current settings shall each, if relevant, be adjusted to 2,5 times the current setting. If this setting is not available, the next closest higher setting shall be used.

Tests shall be performed as follows:

a) A current of 0,95 times the conventional non-tripping current (see Table 6) is applied for a time equal to 10 times the tripping time which corresponds to 2,0 times the current setting.

b) Immediately following the test of a), a current of 1,05 times the conventional tripping current (see Table 6) is applied.

c) A further test starting from the cold state is made at 2,0 times the current setting.

F.6.4 Test results

For each test frequency, the overload tripping characteristics shall comply with the following requirements:

– for test a) no tripping shall occur;

– for test b) tripping shall occur within the conventional time (see Table 6);

– for test c) tripping shall occur within 1,1 times the maximum and 0,9 times the minimum values of the manufacturer's stated time-current characteristic.

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F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 7.2.2 at the maximum rated current for a given frame size, on all phase poles, at an ambient temperature of 40 °C. The duration of the test, once temperature equilibrium is reached, shall be 168 h.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see ~~5.2 e)~~ Table 13, item 3.11).

As an alternative, the test may be performed as follows:

– measure and record the highest temperature rise of the air surrounding the electronic components, during the temperature rise verification of test sequence I;
– install the electronic controls in the test chamber;
– supply the electronic controls with their input energizing value;
– adjust the temperature of the test chamber to a value of 40 K above the temperature rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

F.7.2 Test results

The circuit-breaker and the electronic controls shall meet the following requirements:

– no tripping of the circuit-breaker shall occur;
– no operation of the electronic controls which would cause the circuit-breaker to trip shall occur.

F.7.3 Verification of overload releases

Following the test of F.7.1, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.8 Damp heat test

F.8.1 Test procedure

The test shall be performed according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be six.

The test may be performed with only the electronic controls in the test chamber.

F.8.2 Verification of overload releases

Following the test of F.8.1 the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.9 Temperature variation cycles at a specified rate of change

F.9.1 Test conditions

Each design of electronic controls shall be submitted to temperature variation cycles in accordance with Figure F.15.

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The rise and fall of temperature during the rate of variation shall be 1 K/min ± 0,2 K/min. The temperature, once reached, shall be maintained for at least 2 h.

The number of cycles shall be 28.

F.9.2 Test procedure

The test shall be carried out according to IEC 60068-2-14.

For these tests, the electronic controls may be mounted inside the circuit-breaker or separately.

The electronic controls shall be energized to simulate service conditions.

Where the electronic controls are mounted inside the circuit-breaker, the main circuit shall not be energized.

F.9.3 Test results

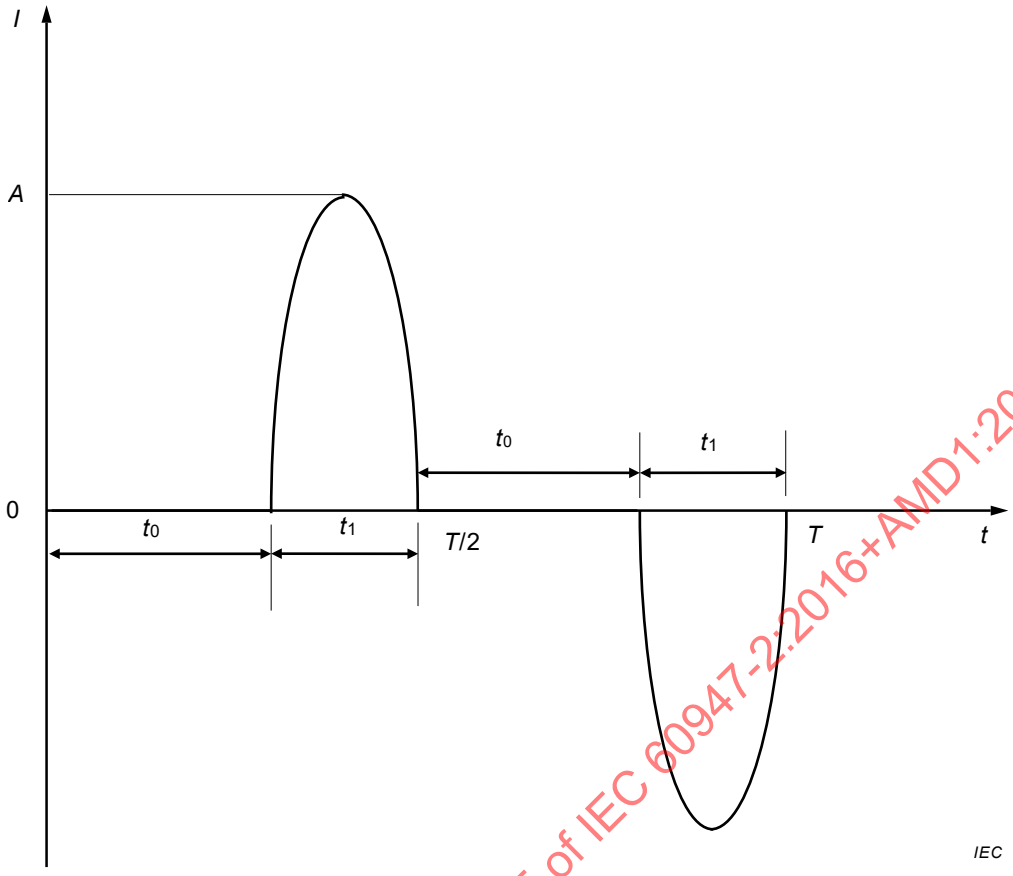
The electronic controls shall meet the following requirement.

No operation of the electronic controls which would cause the circuit-breaker to trip during the 28 cycles shall occur.

F.9.4 Verification of overload releases

Following the test of F.9.2, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

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Key

A peak current

T period

t_1 conducting time during each half-cycle

t_0 delay time

$$\text{Peak factor} = \frac{A}{\sqrt{\frac{2}{T}\int_0^{T/2} i^2(t)\,dt}}$$

Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1

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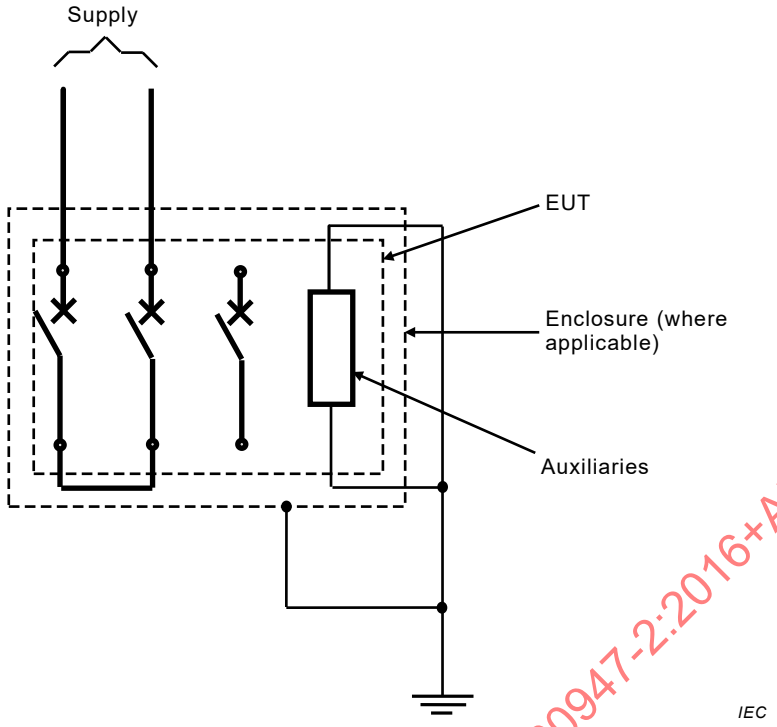


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

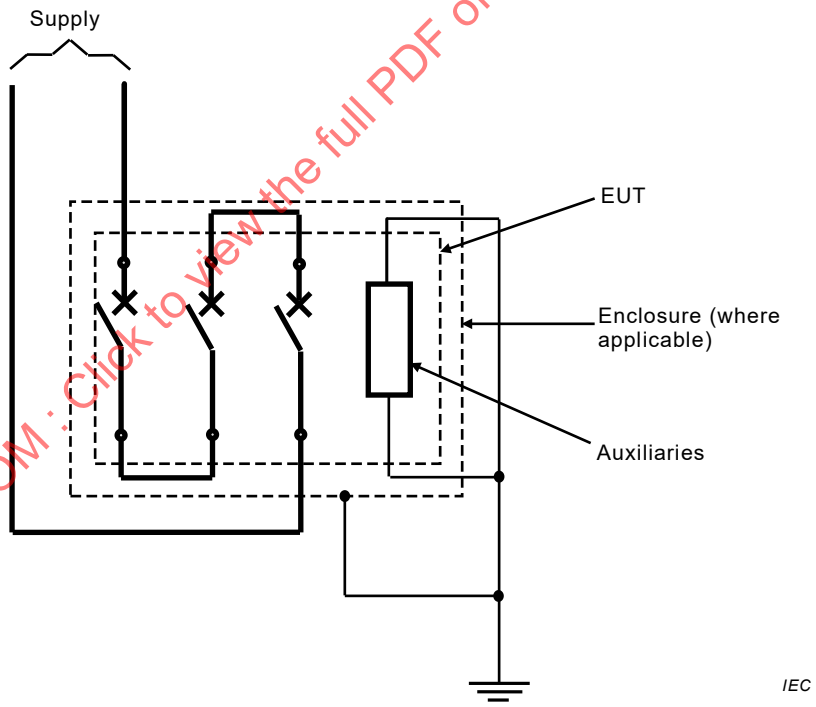
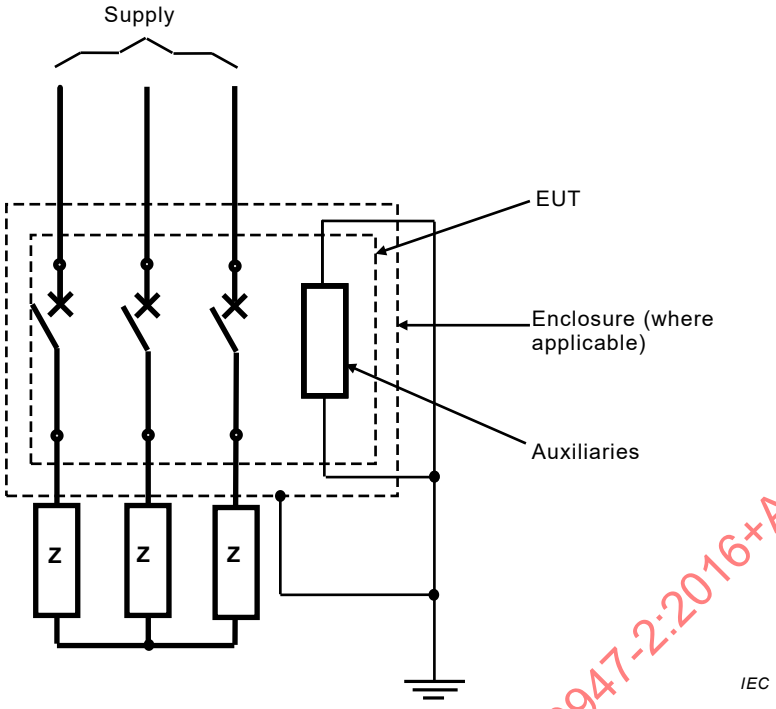


Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series

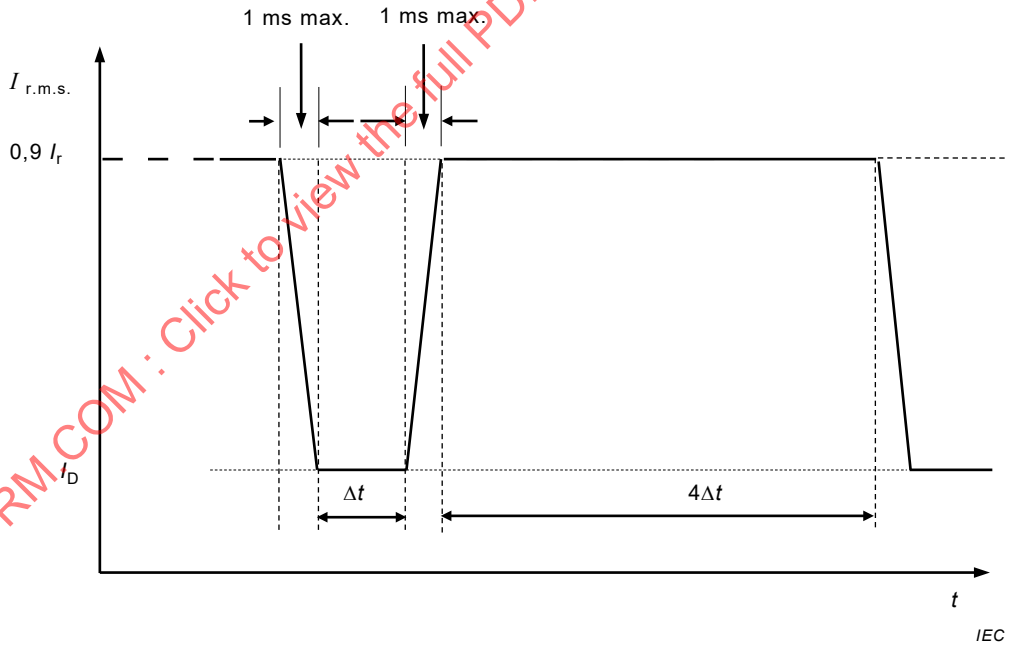
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Key

Z impedance for adjusting the current (where required)

Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection



Key

I_r setting current

I_D dip test current

Δt dip time

$4\Delta t$ dwell time

Figure F.5 – Test current for the verification of the influence of the current dips and interruptions in accordance with F.4.7.1

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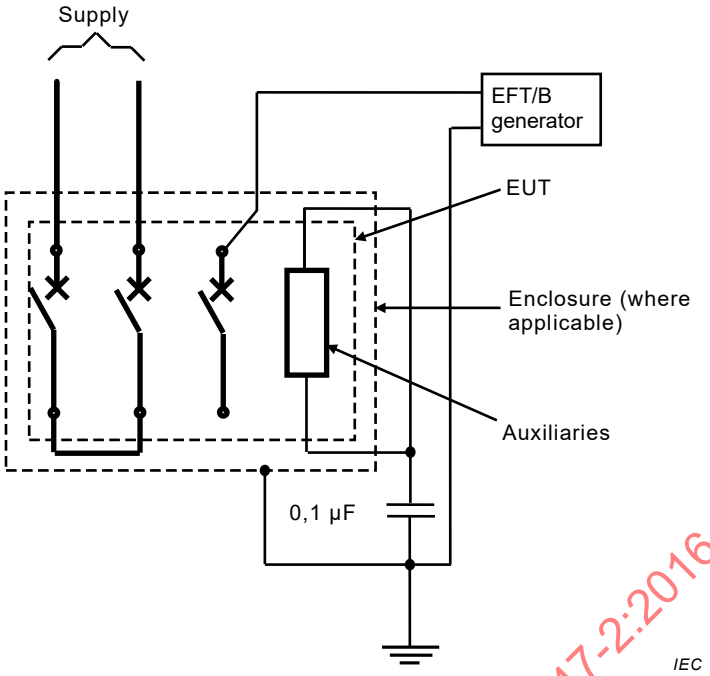


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

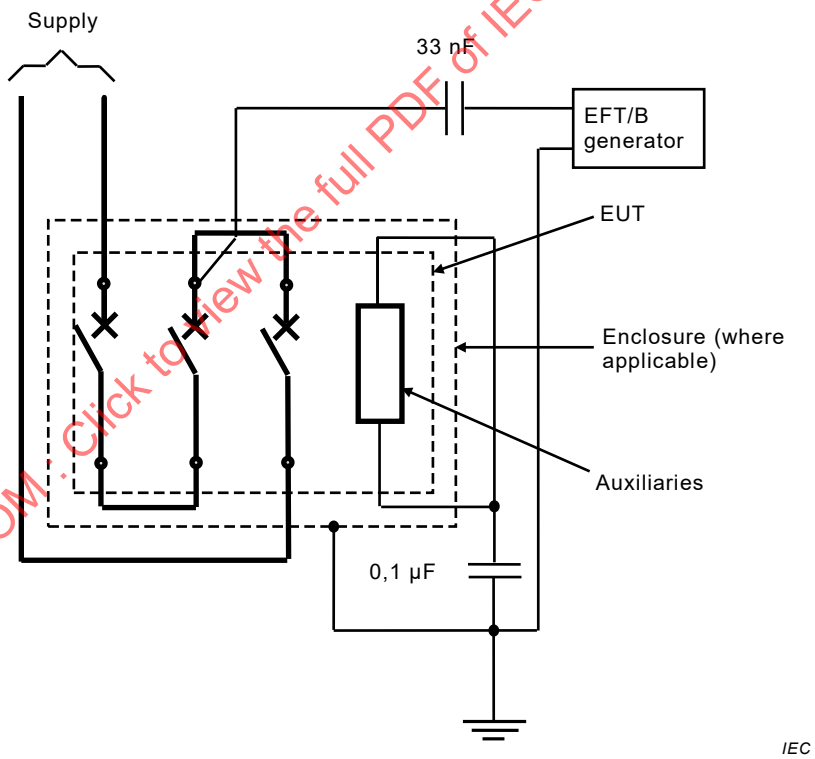
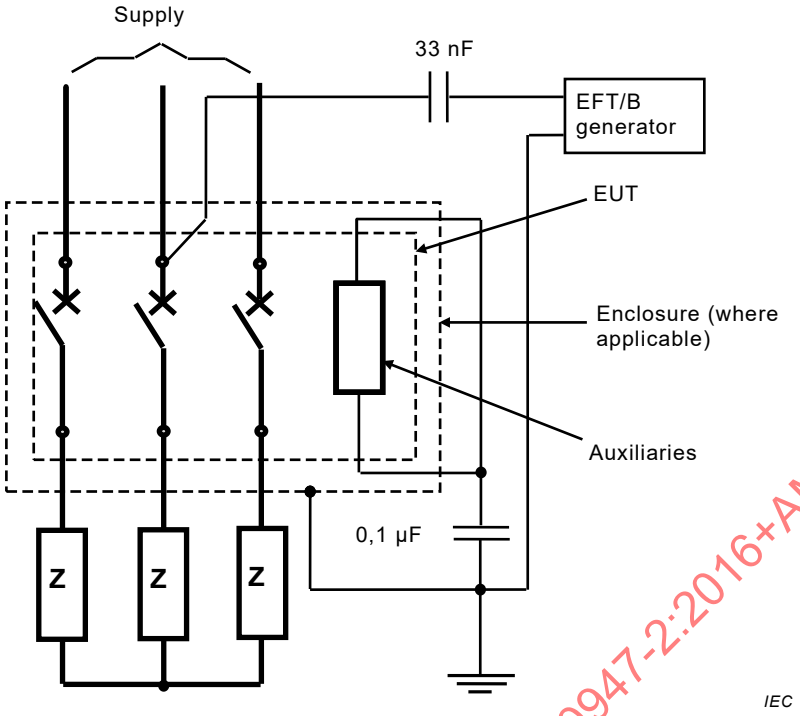


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series

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Key

Z impedance for adjusting the current (where required)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

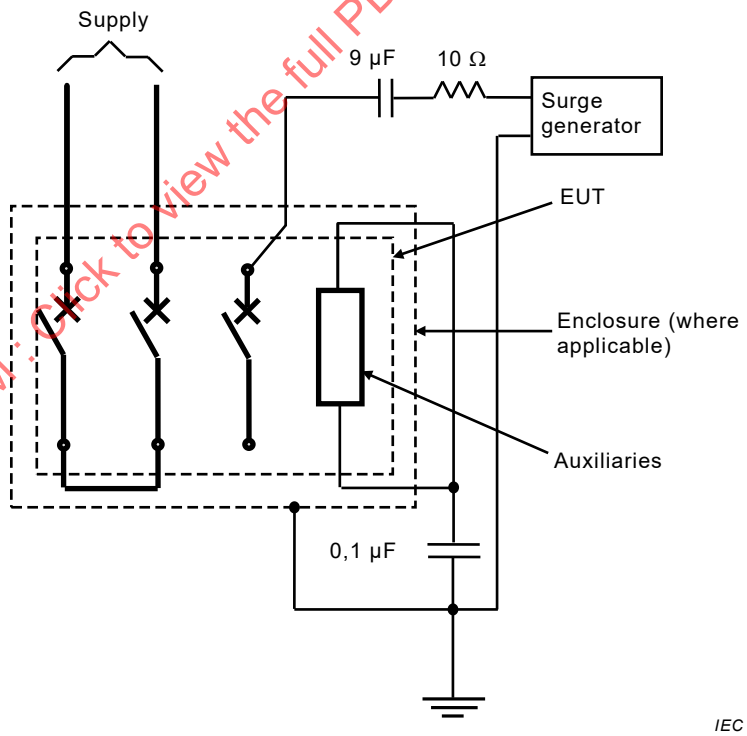


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

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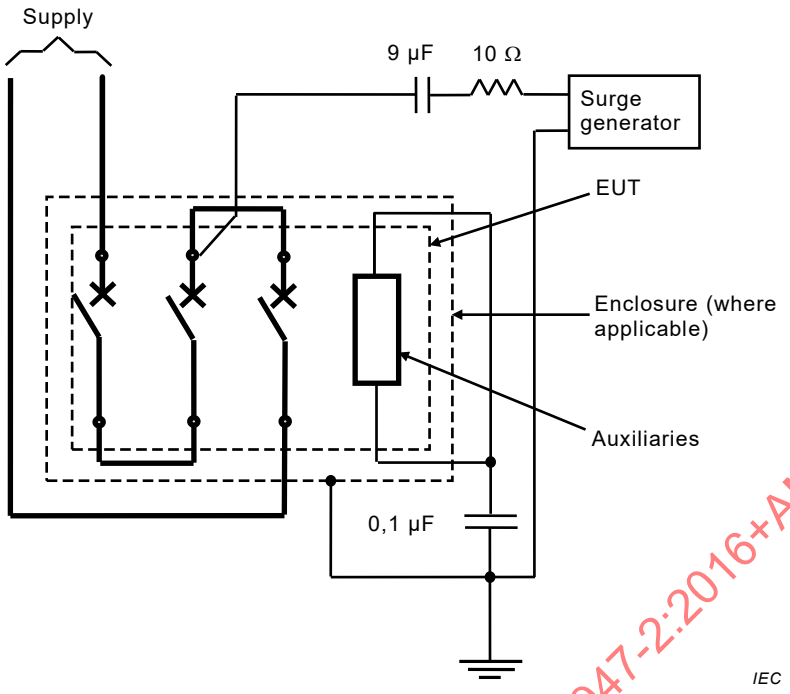
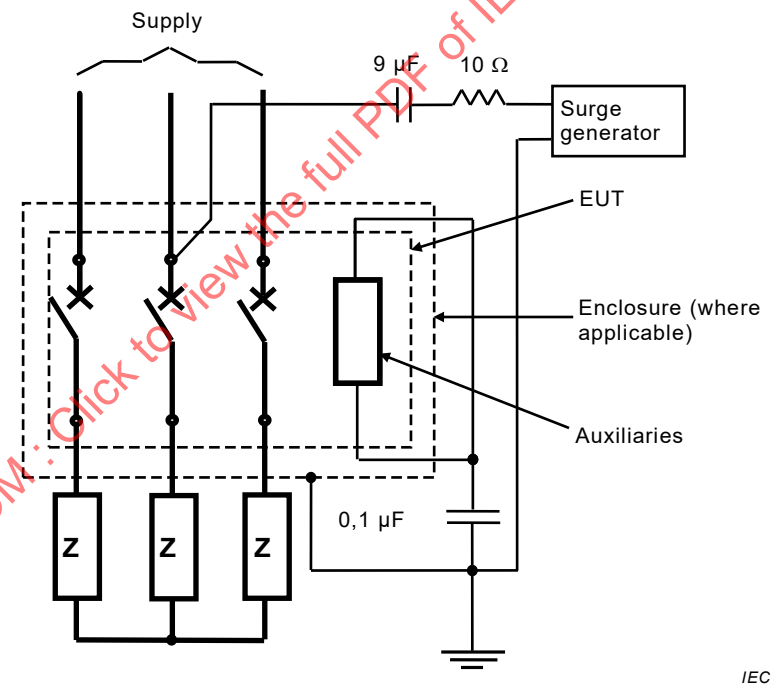


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.11 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection

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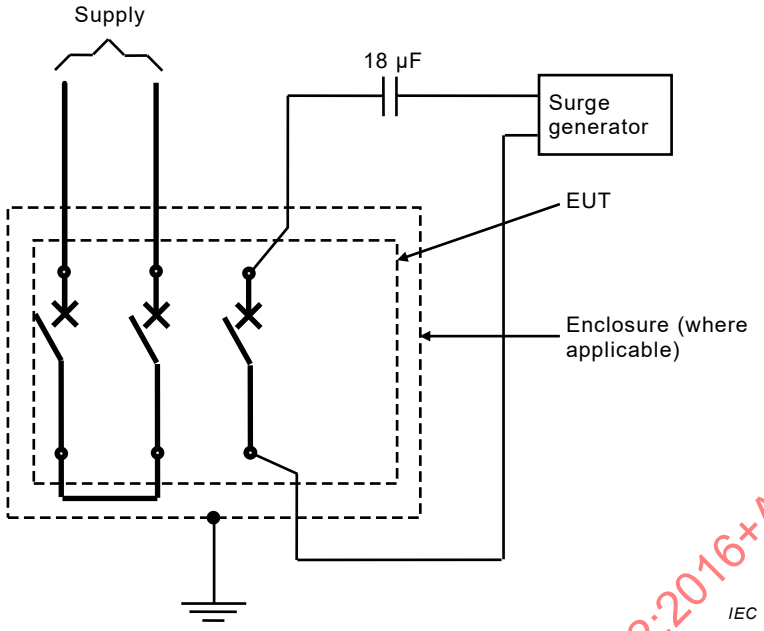


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

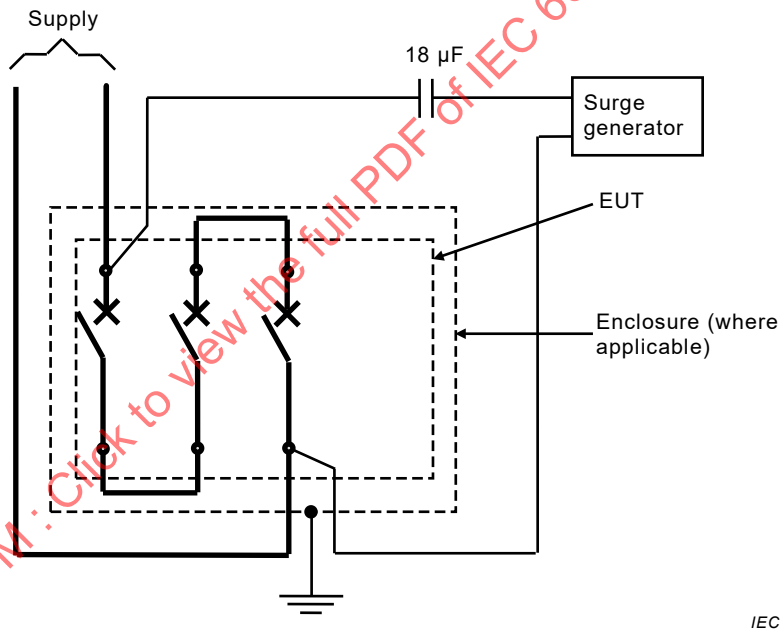
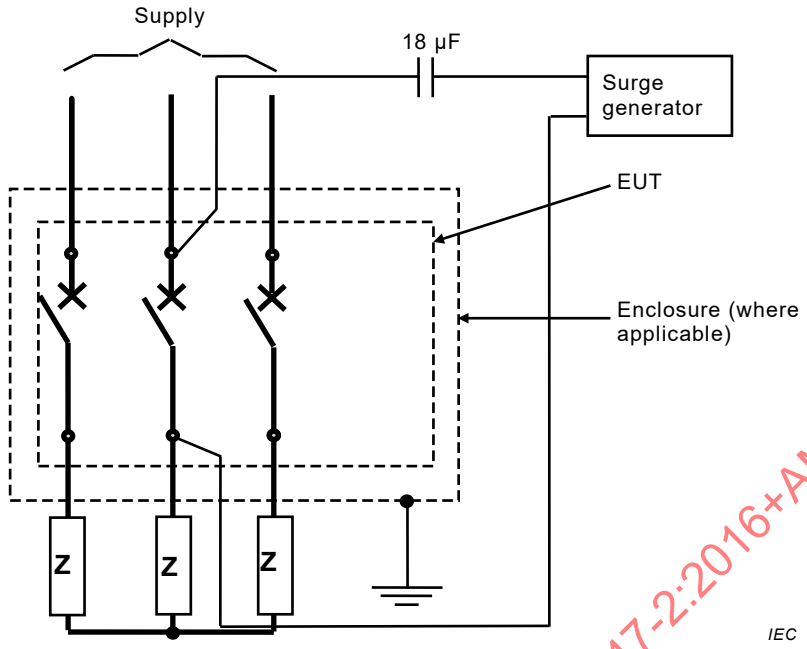


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series

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Key

Z impedance for adjusting the current (where required)

Figure F.14 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three-phase connection

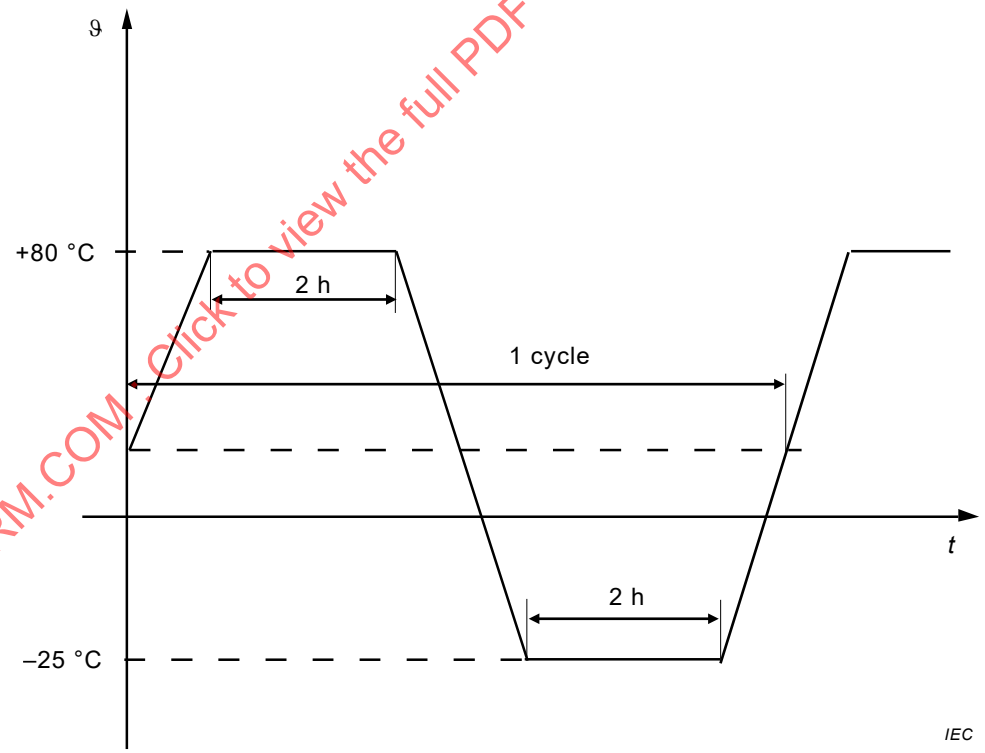
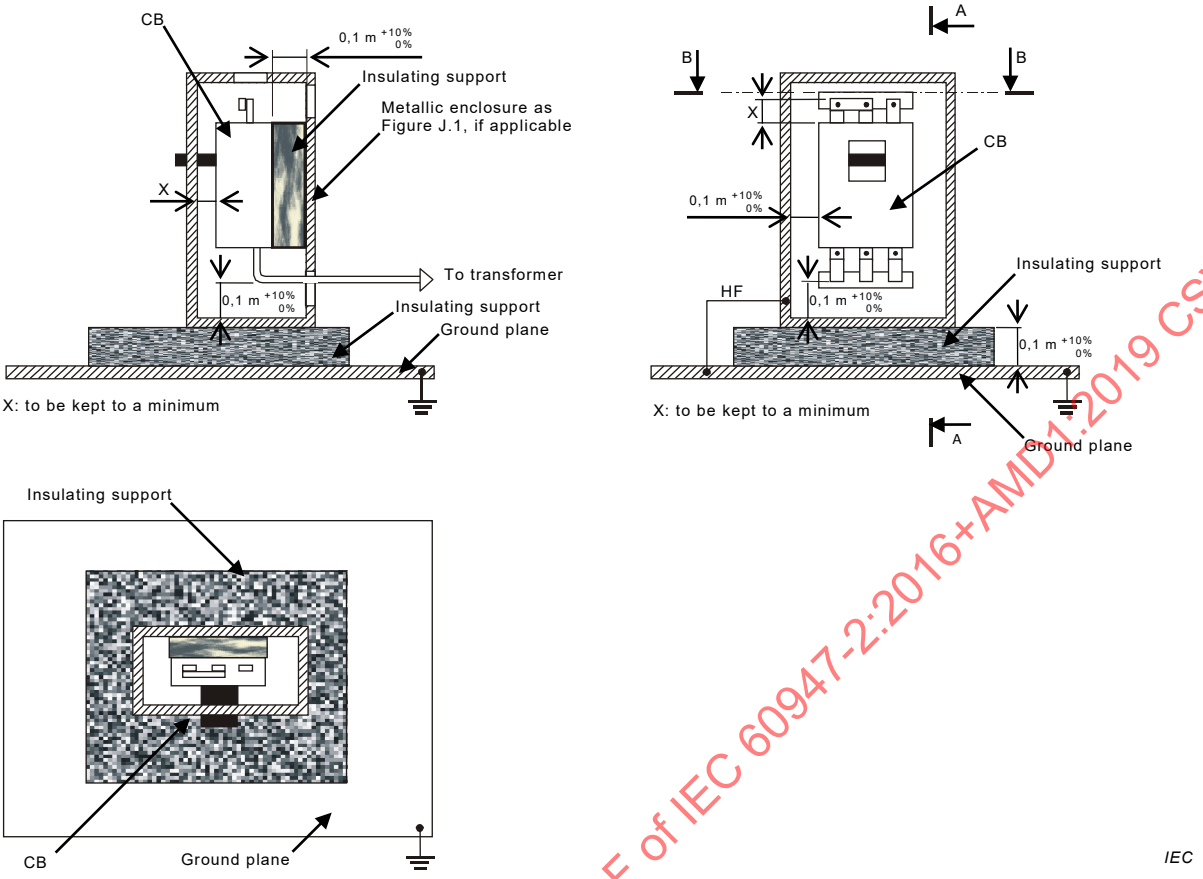


Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1

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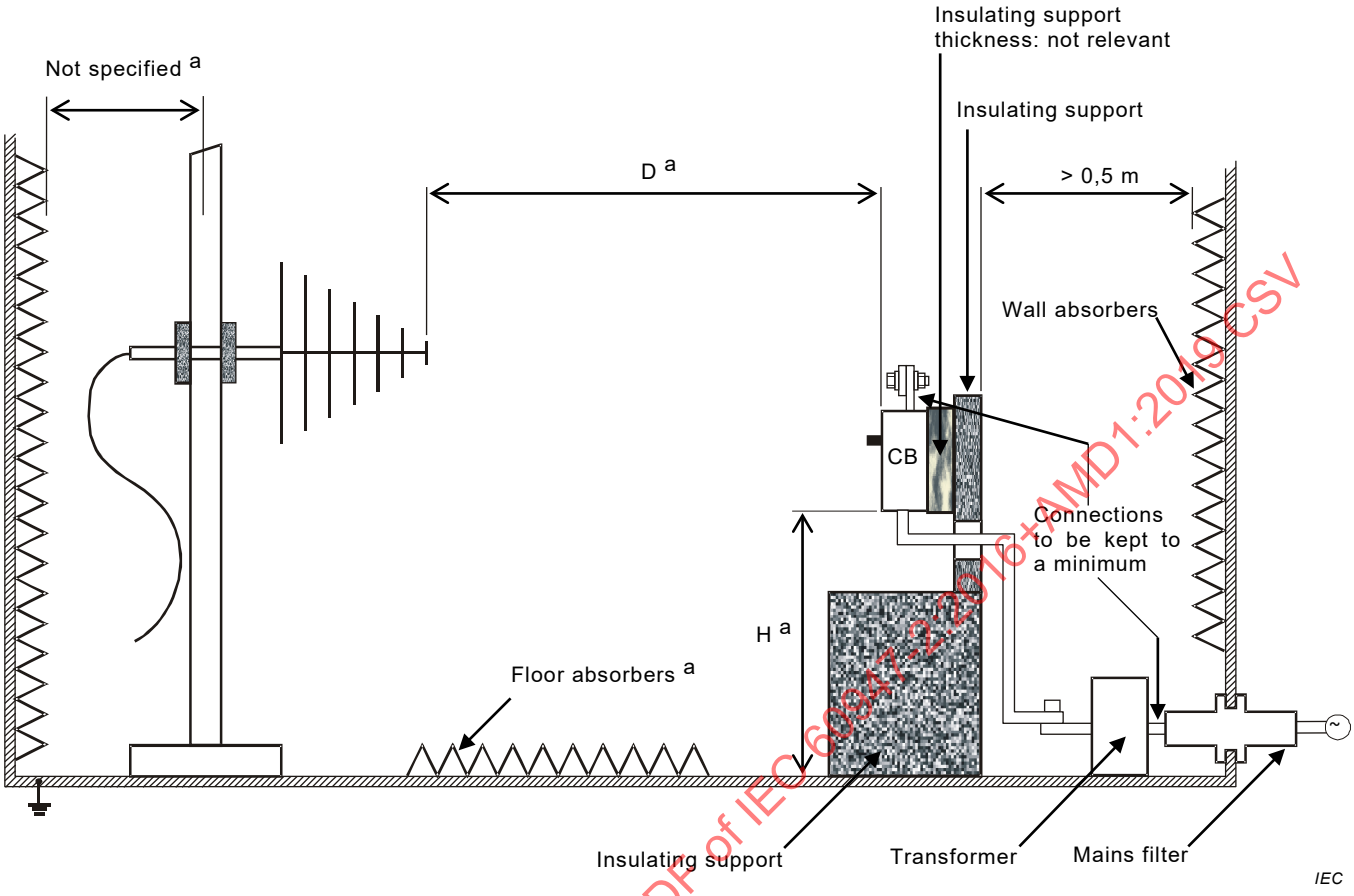
Key

CB circuit-breaker

NOTE The terminal arrangement can vary according to the type of circuit-breaker tested.

Figure F.16 – General test set-up for immunity tests

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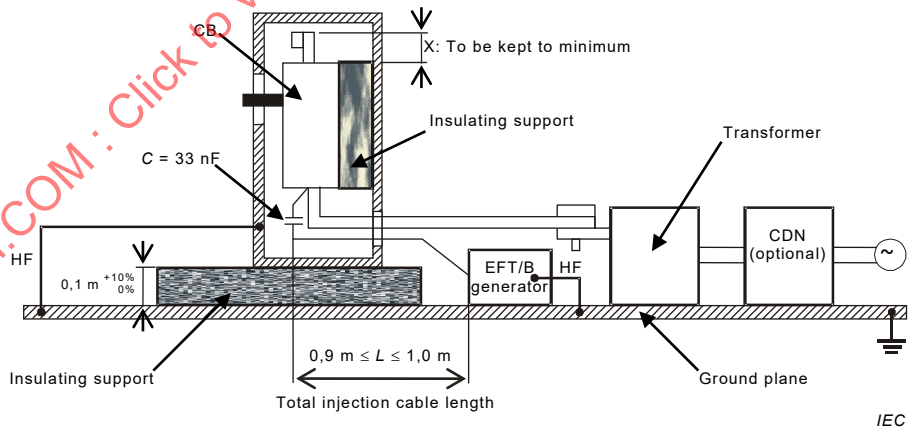


Key

CB circuit-breaker

a See IEC 61000-4-3

Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields



Key

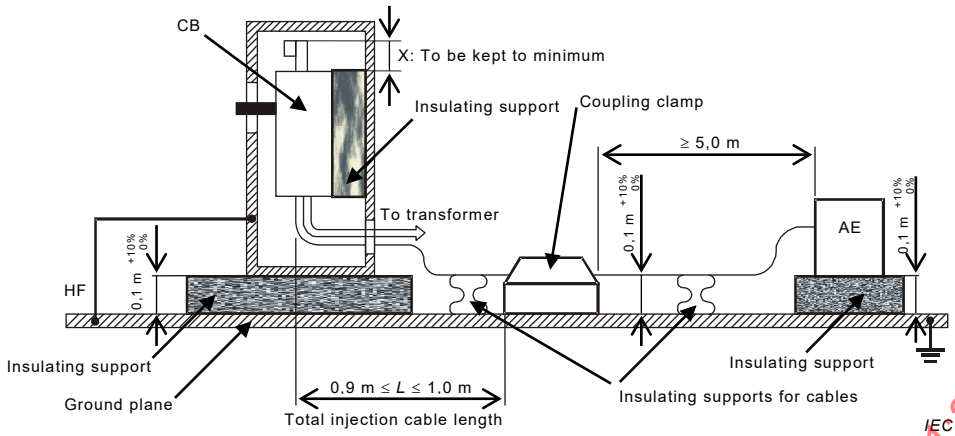
CB circuit-breaker

CDN coupling-decoupling network

HF high frequency connection

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines

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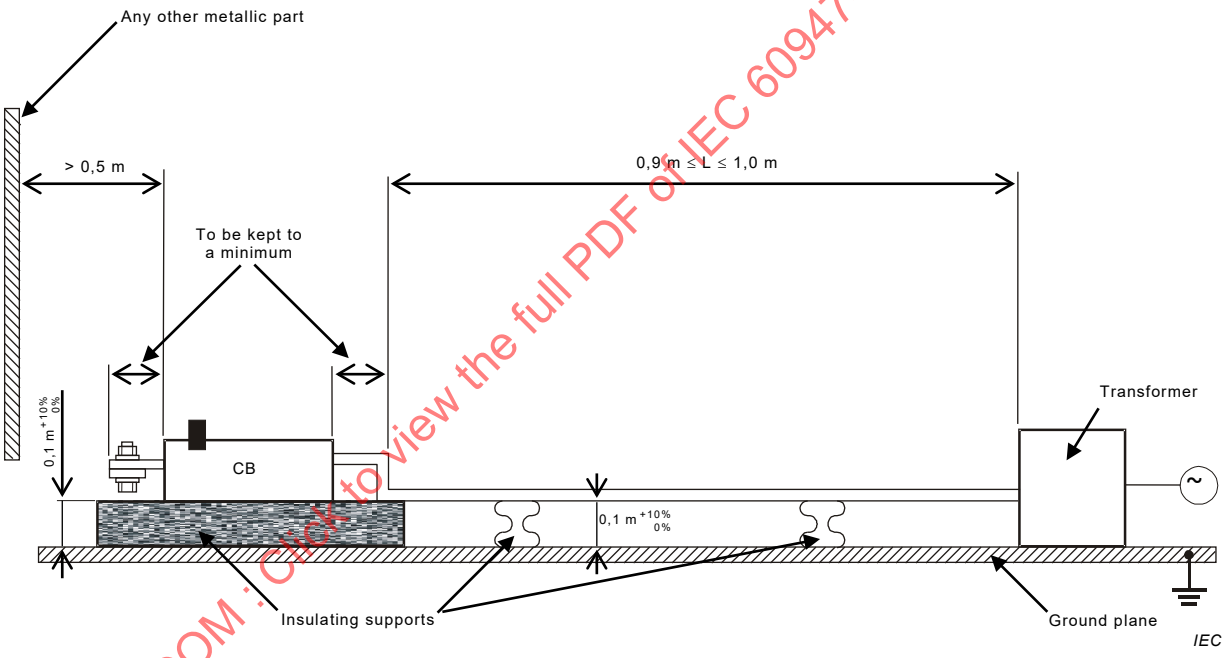
Key

AE auxiliary equipment

CB circuit-breaker

HF high frequency connection

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines



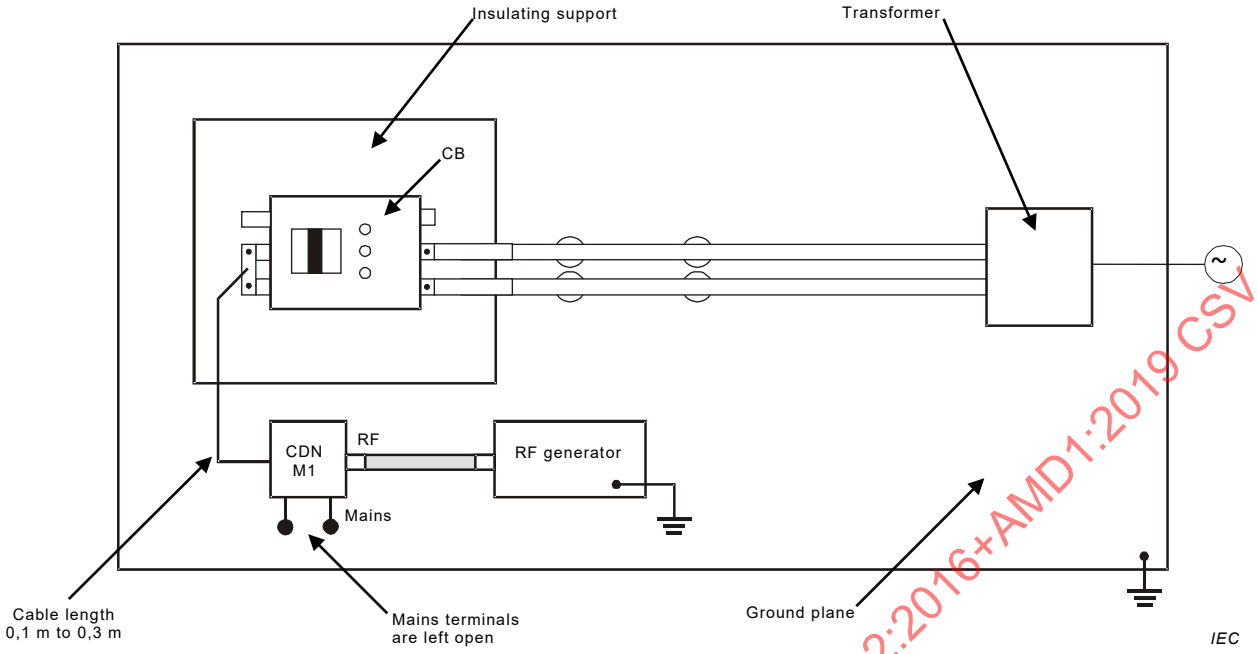
Key

CB circuit-breaker

NOTE The dimension *L* is the length of the conductor coupled at 0,1 m to the ground plane.

Figure F.20 – General test set-up for the verification of immunity to conducted disturbances induced by RF fields (common mode)

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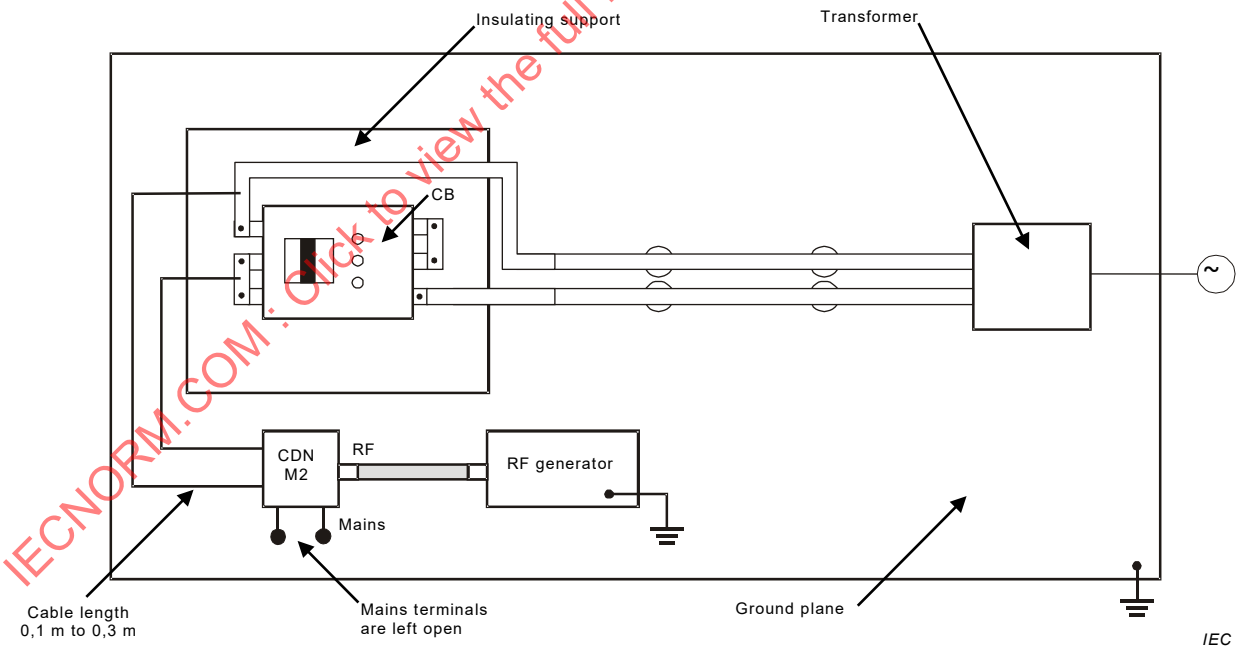
Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, the coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.21 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Two phase poles in series configuration



Key

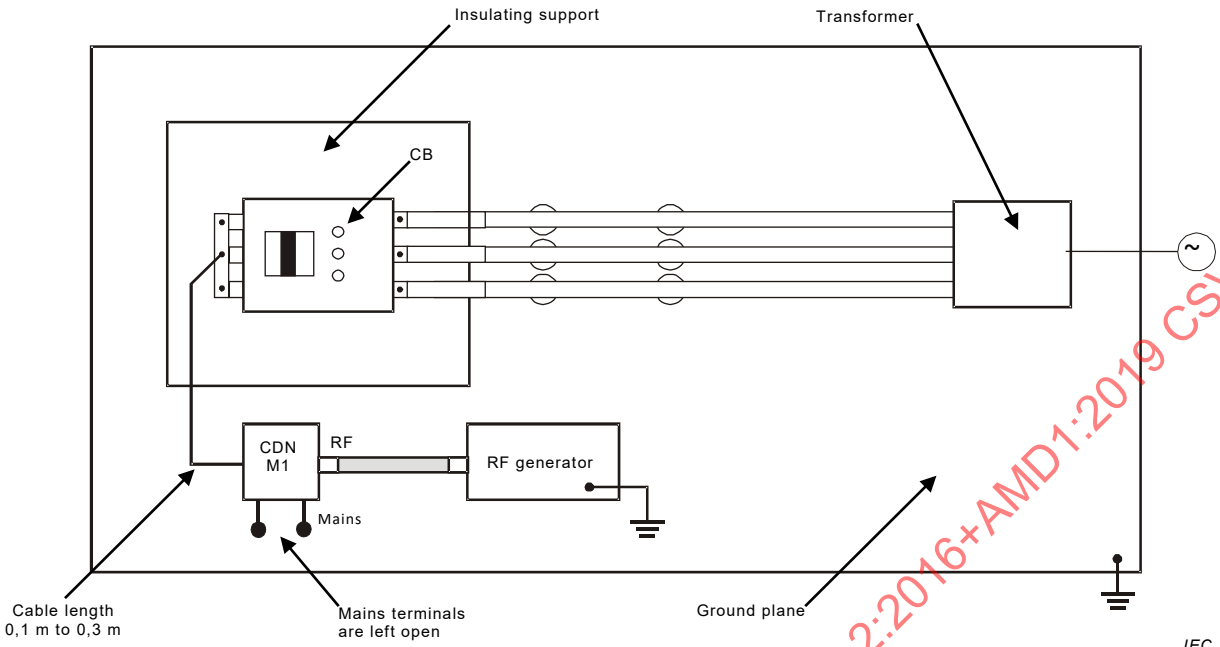
CB circuit-breaker

CDN M2 coupling-decoupling network M2

NOTE As an alternative to the coupling-decoupling network M2, coupling-decoupling network M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.22 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three phase poles in series configuration

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Key

CB	circuit-breaker
CDN M1	coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.23 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three-phase configuration

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Annex G
(normative)

Power loss

G.1 General

Power loss is not a fundamental characteristic of a circuit-breaker and need not be marked on the product.

It gives some indication of the heat generated under specified conditions.

Measurement of power loss shall be made in free air, on new samples, and shall be stated in watts.

G.2 Test methods

G.2.1 General case

Power loss is evaluated as follows, connections being in accordance with Figure G.1.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_k \cos \varphi_k$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I is the test current which shall be equal to I_n within the tolerances according to 8.3.2.2.2;

$\cos \varphi$ is the power factor.

The use of a wattmeter on each pole is recommended.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

For a.c. circuit-breakers of rated current not exceeding 400 A, it is acceptable to use single-phase a.c. measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure G.2.

$$\sum_{k=1}^{k=p} \Delta U_k \, I_n$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I_n is the rated current.

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G.2.3 DC circuit-breakers

For d.c. circuit-breakers, the power loss shall be measured with d.c. current.

It is evaluated as in G.2.2.

G.3 Test procedure

The power loss evaluation shall be made under rated current steady-state temperature conditions.

The voltage drop shall be measured between incoming and outgoing terminals on each pole.

The connecting leads to measuring instruments (e.g. voltmeter, wattmeter) shall be twisted together. The measuring loop shall be as small as practicable and shall be positioned similarly for each pole.

For evaluating the power loss of three-pole and four-pole a.c. circuit-breakers according to G.2.1, the test is performed under three-phase current conditions (see Figure G.1), without current in the fourth pole in the case of four-pole circuit-breakers.

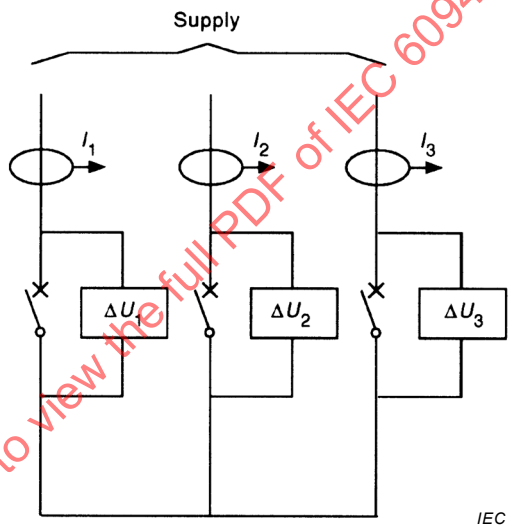


Figure G.1 – Example of power loss measurement according to G.2.1

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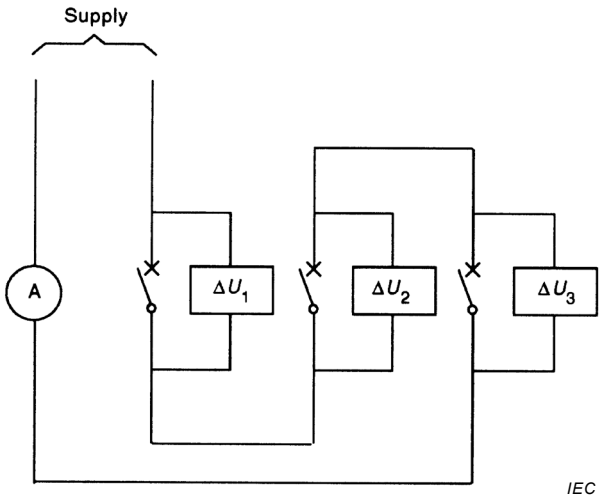


Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3

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Annex H
(normative)

Test sequence for circuit-breakers for IT systems

NOTE This test sequence is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a circuit-breaker when installed in IT systems (see 4.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit (I_{IT})	H.2
Verification of dielectric withstand	H.3
Verification of overload releases	H.4

H.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole circuit-breaker under the general conditions of 8.3.2, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay release tripping current or, in the absence of such a release, 1,2 times the maximum setting of the tripping current of the instantaneous release,

or, where relevant

– 1,2 times the maximum setting of the definite time delay release tripping current,

but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous pick-up current, allowing for the impedance of the circuit-breaker and its connections.

NOTE 2 Values higher than I_{IT} can be required, tested instead and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10. The power factor shall be according to Table 11, appropriate to the test current. When I_{IT} = 50 kA, the short-time or instantaneous pick-up setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

For 4-pole circuit-breakers with a protected neutral pole, the test voltage for that pole shall be phase-to-phase voltage divided by √3. This test is applicable only where the construction of the protected neutral pole differs from that of the phase poles.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

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O – *t* – CO

and shall be made on each pole separately, in turn.

If the circuit-breaker is provided with both a short-time delay release and an instantaneous release, the instantaneous release may operate before the short-time delay release, depending on the setting and the tolerances.

H.3 Verification of dielectric withstand

Following the test according to H.2, the dielectric withstand shall be verified according to 8.3.5.4.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 8.3.5.5.

H.5 Marking

~~Circuit-breakers for which all values of rated voltage have been tested according to this annex or are covered by such testing require no additional marking.~~

~~Circuit-breakers for which all values of rated voltage have not been tested according to this annex or are not covered by such testing shall be identified by the symbol ⊗ which shall be marked on the circuit-breaker immediately following these values of rated voltage, e.g., 690 V ⊗ in accordance with 5.2, item b).~~

~~Where a circuit-breaker has not been tested according to this annex, a single marking by the symbol ⊗ may be used provided it is so placed that it unmistakably covers all voltage ratings.~~

Subclause 5.2 applies with the following addition:

Circuit-breakers for which not all values of rated voltage are covered by the testing in accordance with this annex shall be marked in accordance with Table H.1.

Table H.1 – Product information

Item	Information	Marking location
H2.1	rated voltage(s) not suitable for IT system, as follows: immediately following each corresponding rated voltage, e.g. 690 V IT (IEC 60417-6363:2016-07) or immediately following the rated voltages grouped, e.g. 415 V 500 V 690 V } IT (IEC 60417-6363:2016-07)	Marked
Key Marked:marked on the product		

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Annex J
(normative)

Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers

J.1 General

Two sets of environmental conditions are considered and are referred to as follows:

– environment A;
– environment B.

Environment A: relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE 1 Environment A corresponds to equipment class A in CISPR 11 and CISPR ~~22~~ 32.

NOTE 2 Environment A equipment can cause electromagnetic interferences when installed in environment B.

Environment B: relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 3 Environment B corresponds to equipment class B in CISPR 11 and CISPR ~~22~~ 32.

NOTE 4 Environment B equipment will not cause electromagnetic interferences when installed in environment A.

For the purposes of this annex the term "EUT" means “equipment under test”.

NOTE 5 The EMC requirements for CBI (Annex L) and ICB (Annex O) are deemed to be covered by the relevant tests on the equivalent circuit-breaker (see L.2.1 and O.2.1).

The tests of J.2 and J.3 are applicable to devices incorporating electronic circuits except where specified otherwise in this standard.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this standard to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this standard, i.e., Annex B for circuit-breakers incorporating residual current protection (CBR), Annex F for circuit-breakers with electronic overcurrent protection, Annex M for modular residual current devices (MRCD) and Annex N for circuit-breaker auxiliaries.

A new device may be used for each test or one device may be used for several tests, at the manufacturer’s discretion. Devices rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

In the case of a range of devices with identical electronic controls (including dimensions, components, printed circuit board assemblies and enclosure, if any) and the same design of current sensors, it is sufficient to test only one device in the range.

The tests shall be performed with a specific mounting; free air or within an enclosure, as specified in J.2 and J.3.

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J.2 Immunity

J.2.1 General

Subclause 7.3.2.2 of IEC 60947-1:2007/AMD1:2010 applies with the following additions.

Immunity tests shall be performed according to Table J.1. The immunity levels specified in this table can be higher than those required by Table 23 of IEC 60947-1:2007/AMD1:2010, in order to provide increased reliability of the circuit-breaker protection functions.

The reference data for the additional test specifications is given in Table J.2.

For the purposes of this clause (J.2), the term "power port" covers the main circuit, auxiliary power supply port(s) and any auxiliary connected to the main circuit.

For the immunity tests, the following performance criteria shall be defined:

Performance criterion A: during the test, the resistance against unwanted operation (step 1) and the functional characteristics (step 2) are verified. Any monitoring function shall correctly indicate the status.

Performance criterion B: during the test, the resistance against unwanted operation is verified. Monitoring functions may indicate a false status. After the test the functional characteristics are verified.

Details of the verification of performance are given in the respective annex (Annex B, Annex F, Annex M or Annex N).

For all immunity tests, the EUT shall be tested as floor-standing equipment (see IEC 61000-4 series).

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Table J.1 – EMC – Immunity tests

Description	Reference standard	Test level [a]	Performance criterion	Mounting
Electrostatic discharges	IEC 61000-4-2	8 kV contact 8 kV air	B	Enclosure Figure J.1
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	10 V/m (up to 2 GHz) 3 V/m (from 2 GHz to 2,7 GHz)	A	Free air [c]
Electrical fast transients/bursts	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. or d.c.: 4 kV $U_e < 100$ V, a.c. or d.c.: 2 kV [f] Signal port: 2 kV [g]	B	Enclosure Figure J.1
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth 2 kV line-to-line (Annex F and Annex N) 4 kV line-to-line (Annex B and Annex M) [e] Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line Power port, d.c. [f]: 0,5 kV line-to-earth 0,5 kV line-to-line Signal port [h]: 2 kV line-to-earth 1 kV line-to-line	B	Enclosure Figure J.1
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port: 10 V Signal port: 10 V [g]	A	Free air [c]
Power frequency magnetic fields	Not applicable	Not applicable	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11 [d]		[d]	Free air
Harmonics	IEC 61000-4-13 [b]	[b]	[b]	Free air
Current dips	[b]	[b]	[b]	Free air

[a] The immunity levels specified are generally higher than the requirements of IEC 60947-1 in order to provide greater security for the circuit protection functions of the device.

[b] A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.

[c] Unless the circuit-breaker is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report. The enclosure shall be connected to the ground plane in accordance with the manufacturer's instructions.

[d] A specific test procedure and a performance criterion are defined in Annex B in the case of CBRs functionally dependent on line voltage and in Annex M in the case of MRCDs functionally dependent on a voltage source, in the absence of an appropriate basic standard. These tests are not applicable to circuit-breakers with electronic overcurrent protection as described in Annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.7).

[e] The immunity level is higher for residual current devices because they perform safety functions.

[f] Not applicable to input ports intended for connection to a battery or a rechargeable battery which shall be removed or disconnected from the apparatus for recharging. Apparatus with a d.c. power input port intended for use with an a.c.-d.c. power adapter shall be tested on the a.c. power input of the a.c.-d.c. power adapter specified by the manufacturer or, where none is so specified, using a typical a.c.-d.c. power adapter. The test is not applicable to d.c. power input ports intended to be permanently connected to cables less than 3 m in length.

[g] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

[h] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 10 m. When shielded cables are used, this test is applied only to the shield.

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Description	Reference standard	Test level	Performance criterion	Mounting
Electrostatic discharges	IEC 61000-4-2	6 kV contact 8 kV air	B	Enclosure Figure J.1
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	80 MHz to 1 GHz: 10 V/m 1,4 GHz to 6 GHz: 3 V/m	A	Free air [c]
Electrical fast transients/bursts [k]	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. / d.c.: 4 kV 5 kHz or 100 kHz $U_e < 100$ V, a.c. / d.c. [f]: 2 kV 5 kHz or 100 kHz Signal port [g]: 2 kV 5 kHz or 100 kHz	B	Enclosure Figure J.1
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth 2 kV line-to-line (Annex F and Annex N) 4 kV line-to-line (Annex B and Annex M) [e] Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line Power port, d.c.[f]: 1 kV line-to-earth 0,5 kV line-to-line Signal port [h] [j]: 2 kV line-to-earth 1 kV line-to-line	B	Enclosure Figure J.1
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port a.c. / d.c.: 10 V (150 kHz – 80 MHz) Signal port [g]: 10 V (150 kHz – 80 MHz)	A	Free air [c]
Power frequency magnetic fields	Not applicable	Not applicable	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11 [d]	[d]	[d]	Free air
Harmonics	IEC 61000-4-13 [b]	[b]	[b]	Free air
Current dips	[b]	[b]	[b]	Free air

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[a]	Vacant.
[b]	A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.
[c]	Unless the circuit-breaker is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report. The enclosure shall be connected to the ground plane in accordance with the manufacturer's instructions.
[d]	A specific test procedure and a performance criterion are defined in Annex B in the case of CBRs functionally dependent on line voltage and in Annex M in the case of MRCDs functionally dependent on a voltage source, in the absence of an appropriate basic standard. These tests are not applicable to circuit-breakers with electronic overcurrent protection as described in Annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.7).
[e]	The immunity level is higher for residual current devices because they perform safety functions.
[f]	Not applicable to input ports intended for connection to a battery or a rechargeable battery, which shall be removed or disconnected from the apparatus for recharging. Apparatus with a d.c. power input port intended for use with an a.c. – d.c. power adapter shall be tested on the a.c. power input of the a.c. – d.c. power adapter specified by the manufacturer or, where none is so specified, using a typical a.c. – d.c. power adapter. The test is not applicable to d.c. power input ports intended to be permanently connected to cables less than 3 m in length.
[g]	Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.
[h]	Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 10 m. When shielded cables are used, this test is applied only to the shield.
[j]	Signal lines with direct connection to a.c. power ports shall be treated as a.c. power ports.
[k]	The repetition frequency (5 kHz or 100 kHz) shall be agreed between the manufacturer and the testing station, and shall be stated in the test report.

The appropriate test set-up and circuit diagram for each immunity test are as shown in Table J.2.

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Table J.2 – Reference data for immunity test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Electrostatic discharges	CBR	J.2.2, ~~B.8.12.1.2~~ B.8.13.1.2	Figure J.1, Figure J.3	Figure B.1
	CB	J.2.2, F.4.2	Figure J.3, Figure F.16	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.2, M.8.16.1.2	Figure J.1, Figure J.3	Figure M.3
	Other devices [a]	J.2.2, N.2.2	[b]	[b]
Radiated radio-frequency electromagnetic fields	CBR	J.2.3, ~~B.8.12.1.3~~ B.8.13.1.3	Figure J.4	Figure B.1
	CB	J.2.3, F.4.3	Figure F.16, Figure F.17	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.3, M.8.16.1.3	Figure J.4, Figure M.20	Figure M.3
	Other devices [a]	J.2.3, N.2.3	[b]	[b]
Electrical fast transients/bursts	CBR	J.2.4, ~~B.8.12.1.4~~ B.8.13.1.4	Figure J.5, Figure J.6	Figure B.1
	CB	J.2.4, F.4.4	Figure F.16, Figure F.18, Figure F.19	Figure F.6, Figure F.7 or Figure F.8
	MRCD	J.2.4, M.8.16.1.4	Figure J.5, Figure J.6, Figure M.21	Figure M.3
	Other devices [a]	J.2.4, N.2.4	[b]	[b]
Surges	CBR	J.2.5, ~~B.8.12.1.5~~ B.8.13.1.5	[b]	Figure B.1
	CB	J.2.5, F.4.5	Line-to-earth: Figure F.16 Line-to-line: Figure F.16	Line-to-earth: Figure F.9, Figure F.10 or Figure F.11 Line-to-line: Figure F.12, Figure F.13 or Figure F.14
	MRCD	J.2.5, M.8.16.1.5	[b]	Figure M.3
	Other devices [a]	J.2.5, N.2.5	[b]	[b]
Conducted disturbances induced by radio-frequency fields	CBR	J.2.6, ~~B.8.12.1.6~~ B.8.13.1.6	[b]	Figure B.1
	CB	J.2.6, F.4.6	Figure F.16, Figure F.20, Figure F.21, Figure F.22, Figure F.23	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.6, M.8.16.1.6	Figure M.22	Figure M.3
	Other devices [a]	J.2.6, N.2.6	[b]	[b]

[a] Devices in the scope of Annex N.

[b] No additional figure necessary.

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J.2.2 Electrostatic discharges

The EUT shall be tested in a specific enclosure (see Table J.1). The test set-up and additional test requirements are given in Table J.2. Direct and indirect discharges shall be applied in accordance with IEC 61000-4-2.

The direct discharge tests shall be performed only on parts of the EUT normally accessible to the user, such as setting means, keyboards, displays, pushbuttons etc. The application points shall be stated in the test report.

Direct discharges are made 10 times for each polarity, at intervals of ≥ 1 s.

Indirect discharges shall be applied at selected points on the surface of the enclosure; the test at such points is made 10 times, for each polarity, at intervals of ≥ 1 s.

J.2.3 Radiated RF electromagnetic fields

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The EUT shall be tested on the front face only.

To enable repeatability, the actual test set-up shall be detailed in the test report.

Tests shall be performed with both horizontal and vertical antenna polarization.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz, 1 400 MHz to 2 000 MHz, and 2 110 MHz to 2 700 MHz, in accordance with Clause 8 of IEC 61000-4-3:2006. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 80 MHz; 100 MHz; 120 MHz; 180 MHz; 240 MHz; 320 MHz; 480 MHz; 640 MHz; 960 MHz; 1 400 MHz; 1 920 MHz, 2 150 MHz and 2 450 MHz, the operation being verified after the field at each frequency has stabilized.

J.2.4 Electrical fast transients/bursts (EFT/B)

The test shall be performed with the EUT in a specific enclosure (see Table J.1).

The test set-up is given in Table J.2.

For power and auxiliary supply ports, the coupling-decoupling network shall be used, except for Annex F where the direct injection method shall be used (see Figure F.18).

For signal ports the coupling-decoupling network or the clamp injection method shall be used, as applicable.

The disturbance shall be applied for 1 min, except where otherwise specified.

J.2.5 Surges

The test shall be carried out with the EUT in a specific enclosure (see Table J.1). The test levels and test set-up are given in Table J.1 and Table J.2, depending upon the EUT.

Pulses with both positive and negative polarity shall be applied, the phase angles being 0° and 90°.

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A series of five pulses is applied for each polarity and each phase angle (total number of pulses: 20), the interval between two pulses being approximately 1 min. A shorter interval may be used by agreement with the manufacturer.

J.2.6 Conducted disturbances induced by RF fields (common mode)

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The disturbances shall be injected, on power lines, by means of a coupling-decoupling network M1, M2 or M3 as applicable.

On signal lines, the disturbances shall be injected by means of a coupling-decoupling network. If not feasible, an E.M. clamp may be used.

The particular test set-up shall be detailed in the test report.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the range of 150 kHz to 80 MHz in accordance with Clause 8 of IEC 61000-4-6:2013. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 0,150 MHZ; 0,300 MHZ; 0,450 MHZ; 0,600 MHZ; 0,900 MHZ; 1,20 MHZ; 1,80 MHZ; 2,40 MHZ; 3,60 MHZ; 4,80 MHZ; 7,20 MHZ; 9,60 MHZ; 12,0 MHZ; 19,2 MHZ; 27,0 MHZ; 49,4 MHZ; 72,0 MHZ and 80,0 MHz, the operation being verified after the level of the disturbing voltage at each frequency has stabilized.

J.3 Emission

J.3.1 General

Subclause 7.3.3.2 of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Emission tests are performed according to Table J.3.

The reference data for the application of the figures for emission tests is given in Table J.4.

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Table J.3 – EMC – Emission tests

Description	Reference standard	Limits	Mounting
Harmonics	IEC 61000-3-2	[c]	[c]
Voltage fluctuations	IEC 61000-3-3	[c]	[c]
Conducted RF disturbances 150 kHz to 30 MHz[e]	CISPR 11[f] / CISPR ~~22~~32	Class A or class B, group 1[b, e]	Free air[d]
Radiated RF disturbances 30 MHz to 1 000 MHz[a]	CISPR 11[f] / CISPR ~~22~~32	Class A or class B, group 1[b]	Free air[d]

[a] Applicable only for EUT containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.

[b] Equipment class A in CISPR 11 and CISPR ~~22~~32 corresponds to environment A in IEC 60947-1. Environment A equipment can cause electromagnetic interferences when installed in environment B. The manufacturer of environment A equipment shall declare the risk of electromagnetic interference in the product documentation.

Equipment class B in CISPR 11and CISPR ~~22~~32 corresponds to environment B in IEC 60947-1. Environment B equipment will not cause electromagnetic interference when installed in environment A.

[c] No test required since the electronic control circuits operate at very low power and hence create negligible disturbances.

[d] Unless the EUT is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report.

[e] Circuit-breakers covered by Annex F are independent of line voltage or of any auxiliary supply. The electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

[f] A description of the test, the test method and the test set-up is given in Clause 7 of CISPR 11:2015, CISPR 11:2015/AMD1:2016.

Table J.4 – Reference data for emission test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Conducted RF disturbances	CBR	J.3.2, B.8.12.2.1	[a]	[a]
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.12.2.1	[a]	[a]
	Other devices	J.3.2, N.3.2	[a]	[a]
Radiated RF disturbances	CBR	J.3.3, B.8.12.2.1	Figure J.2	[a]
	CB	J.3.3, F.5.4	Figure J.2	Figure F.2, Figure F.3 Figure F.4
	MRCD	J.3.3, B.8.12.2.1	Figure J.2	[a]
	Other devices	J.3.3, N.3.3	[a]	[a]

[a] No additional figure necessary.

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J.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

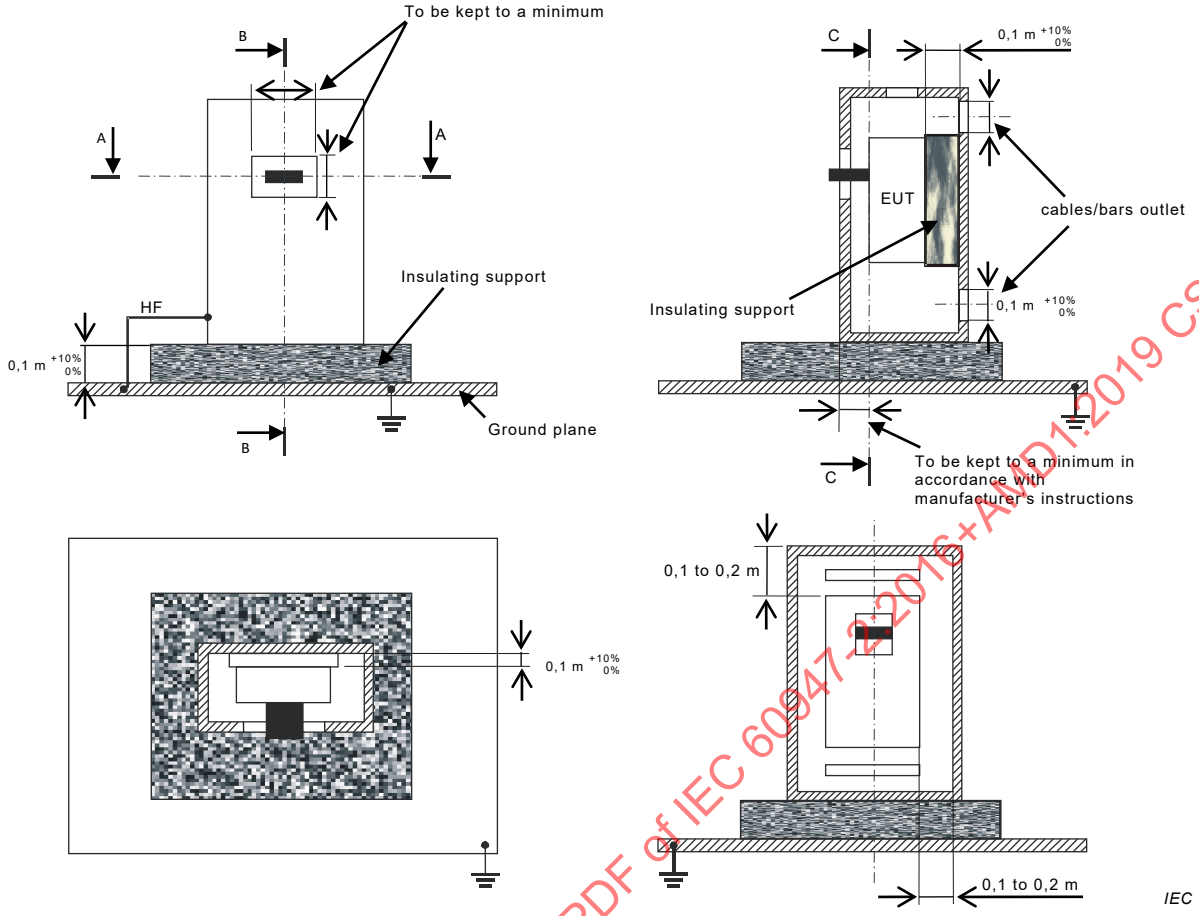
The test method and test arrangement shall be as in CISPR 11 or CISPR ~~22~~32, as relevant.

The particular test set-up, including the type of cable, shall be detailed in the test report.

J.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

The test set-up is shown in Figure J.2.

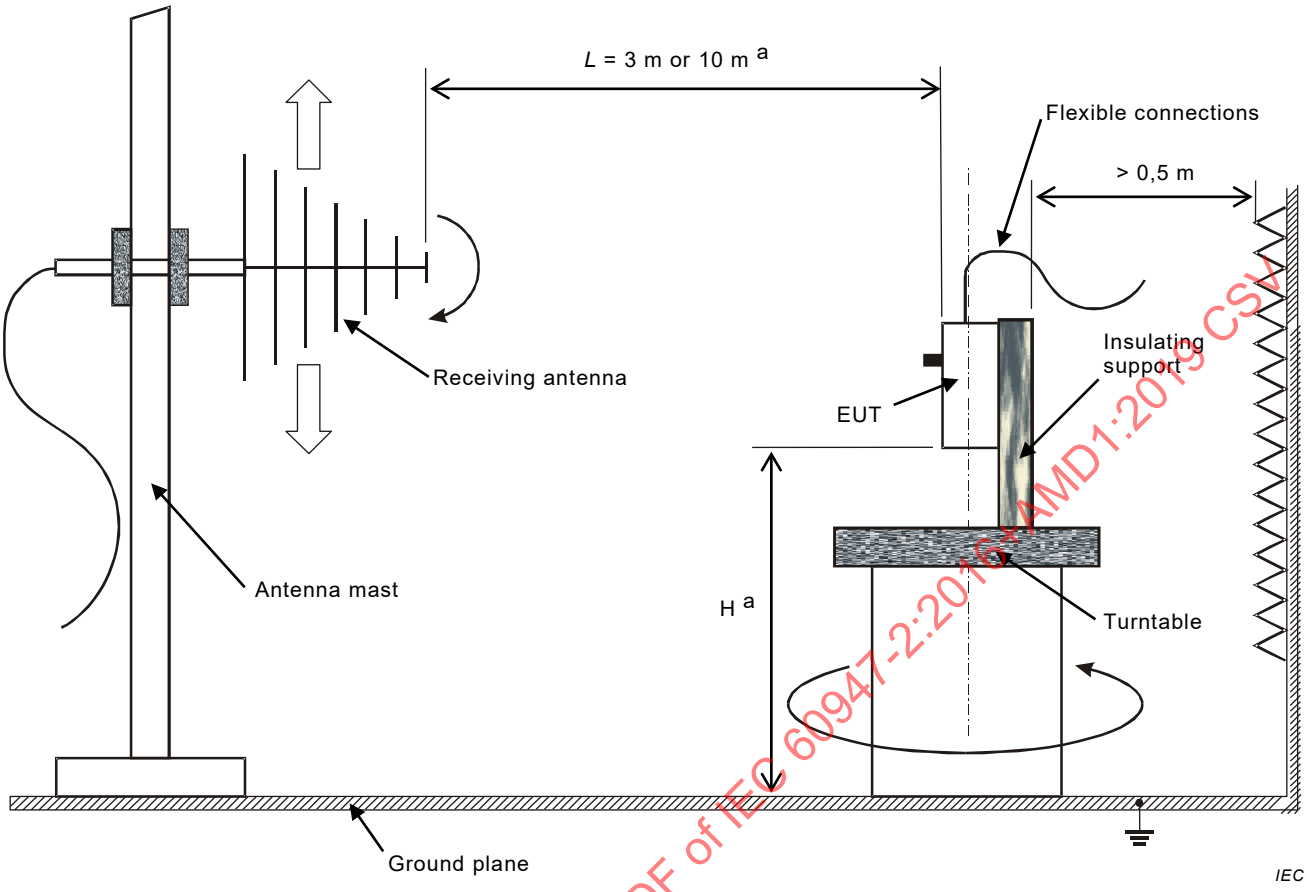
The particular test set-up including supply bars, transformer, etc. shall be detailed in the test report.



NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure

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[a] See CISPR 11/CISPR ~~22~~32.

Figure J.2 – Test set up for the measurement of radiated RF emissions

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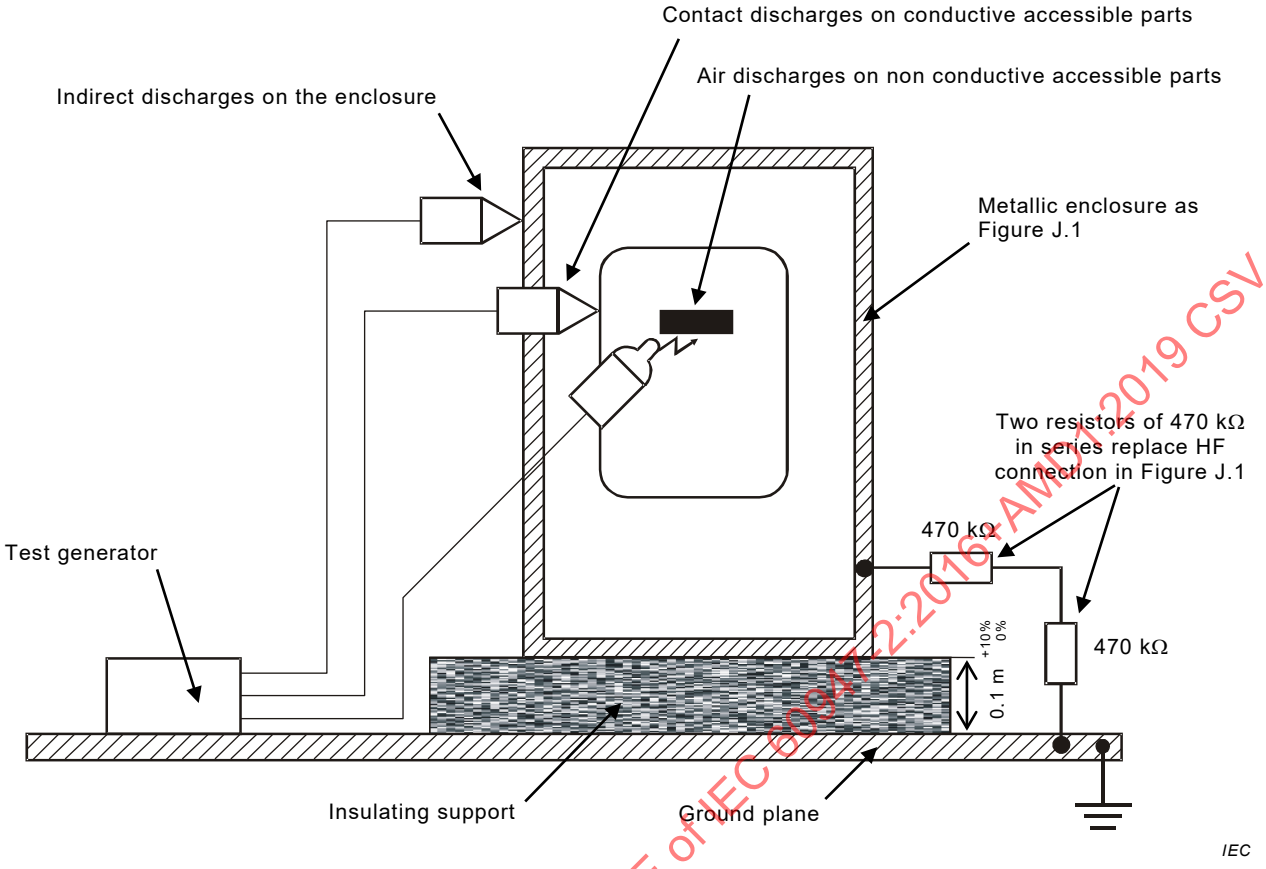
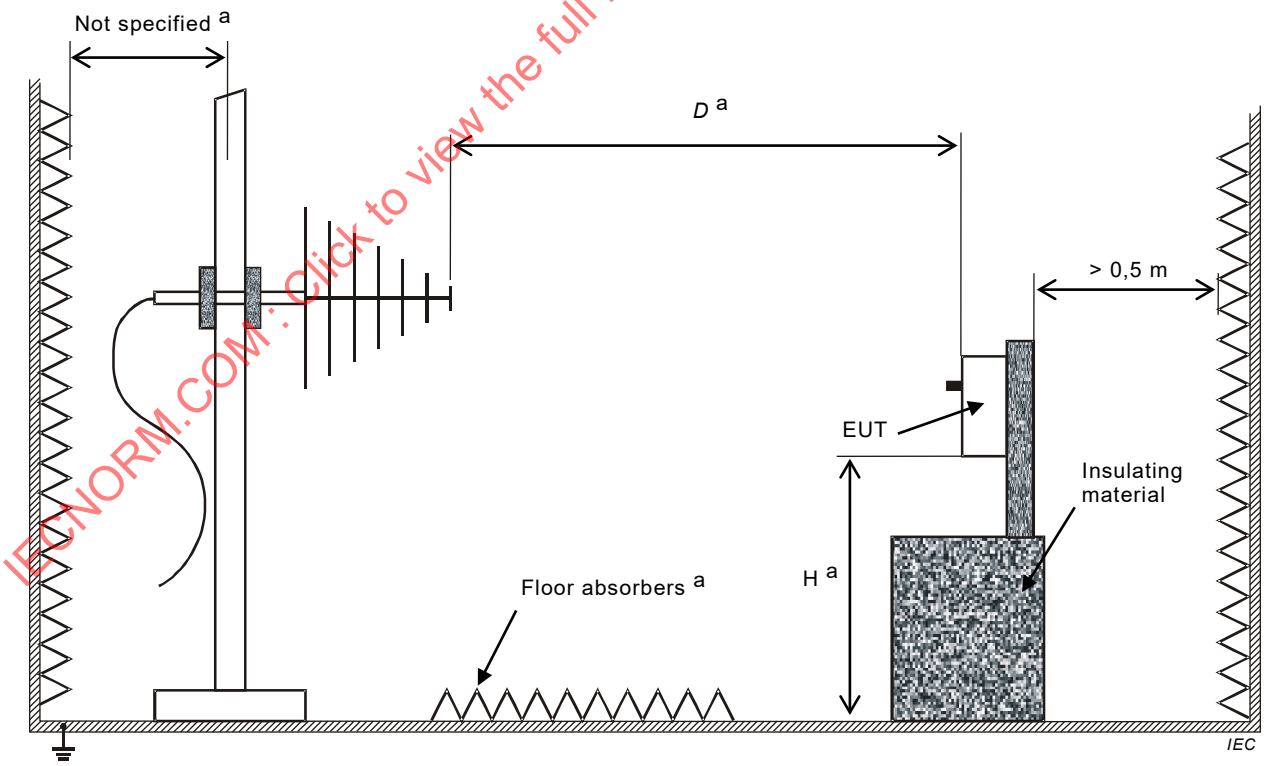


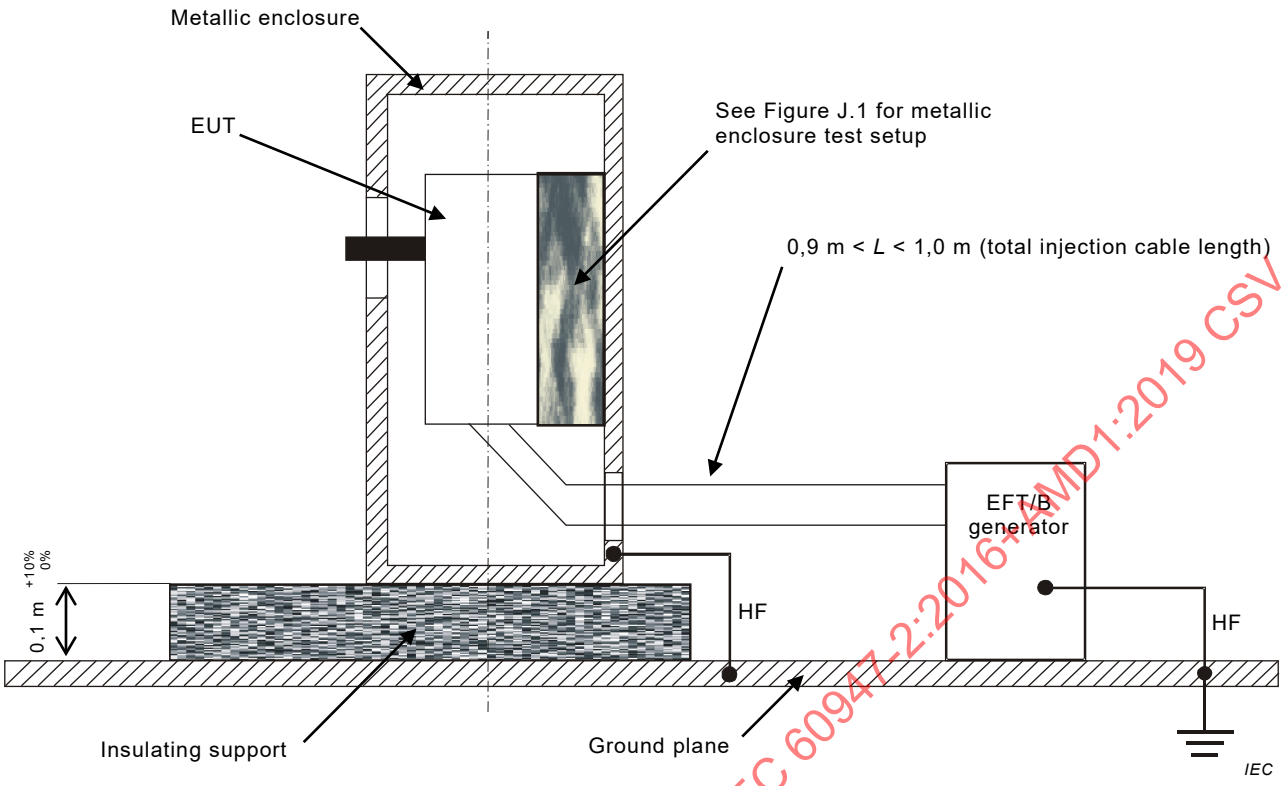
Figure J.3 – Test set up for the verification of immunity to electrostatic discharges



a See IEC 61000-4-3.

Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields

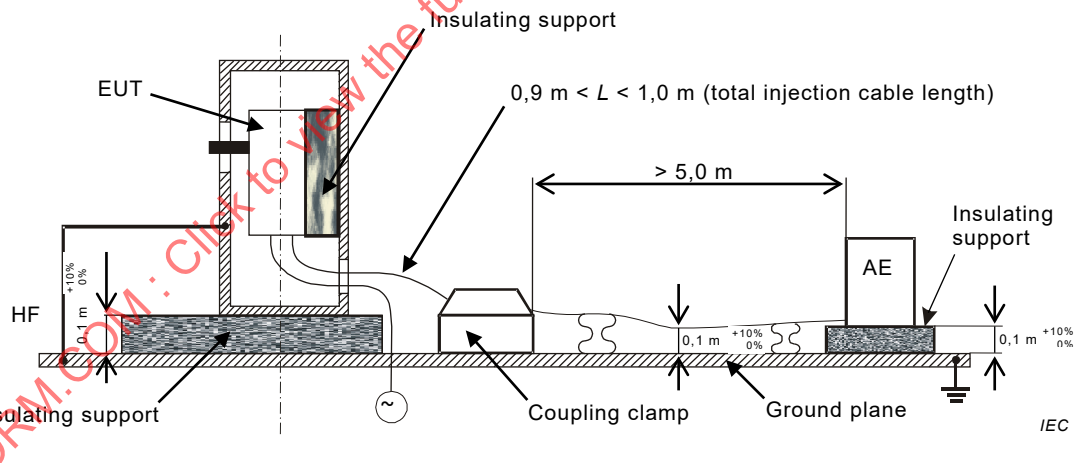
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Key

HF high frequency connection

Figure J.5 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



Key

AE auxiliary equipment

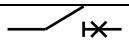
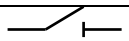
HF high frequency connection

Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

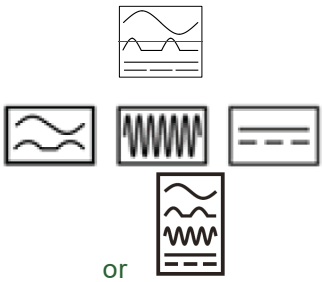
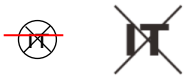
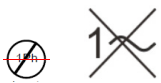
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Annex K
(informative)

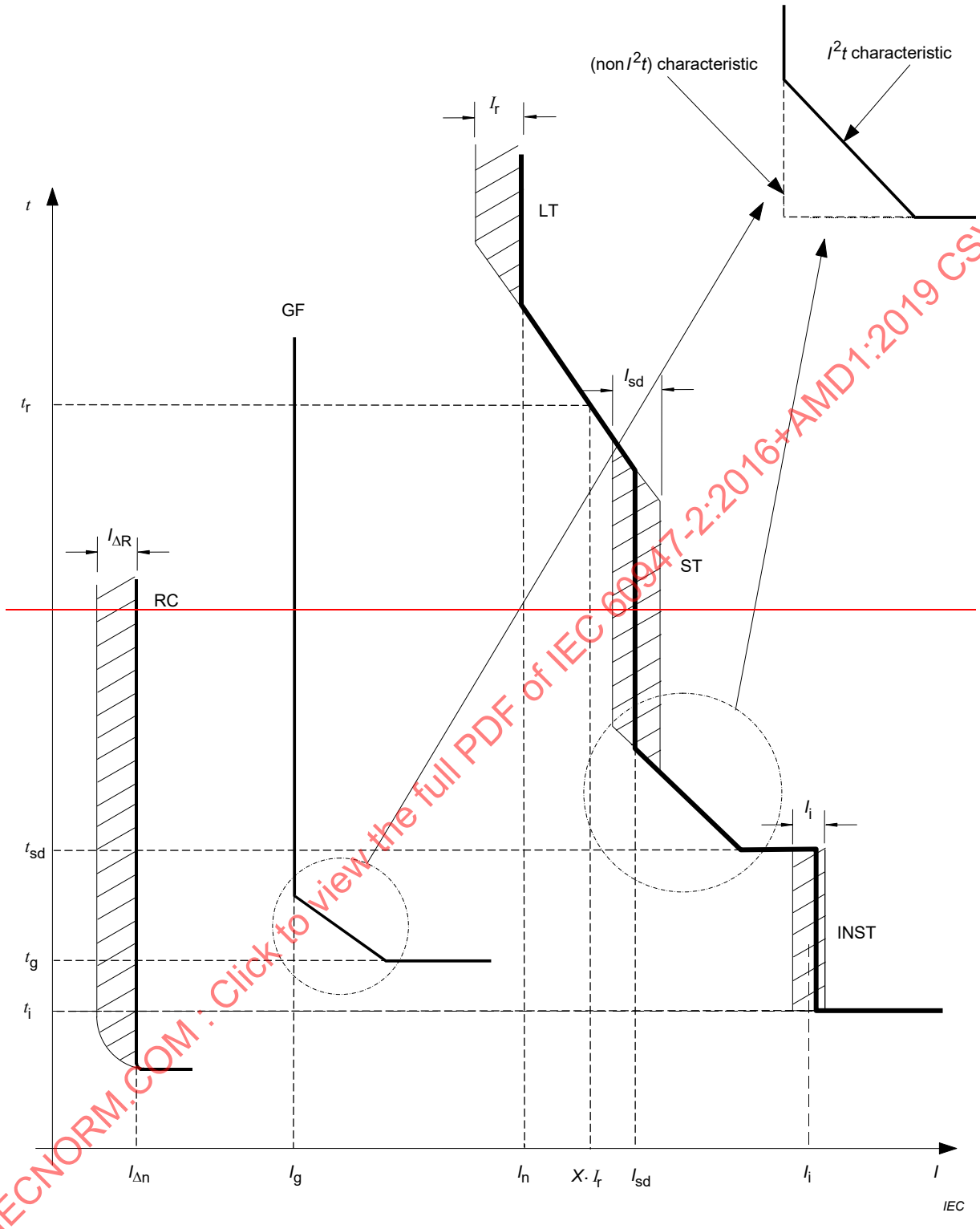
Glossary of symbols and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	5.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	5.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 combined with IEC 60617-S00220 (2007-01)	5.2 O.4
Isolation suitability – CBI		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		5.2
Protective earth terminal		IEC 60417-5019 (2006-08)	5.2
Rated control circuit voltage	U_c		4.7.2
Rated voltage of the voltage source of an MRCD	U_s		M.4.1.2.1
Rated voltage of the monitored circuit for an MRCD	U_n		Annex M
Rated current	I_n		4.3.3.3
Rated impulse withstand voltage	U_{imp}		4.3.2.3
Rated insulation voltage	U_i		4.3.2.2
Rated operational voltage	U_e		4.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		4.3.6.2.3
Rated short-circuit making capacity	I_{cm}		4.3.6.1
Rated short time withstand current	I_{cw}		4.3.6.4
Rated residual short time withstand current of an MRCD	$I_{\Delta w}$		M.4.3.5
Rated conditional short-circuit current	I_{cc}		Annex L Annex M
Rated conditional residual short-circuit current of an MRCD	$I_{\Delta c}$		M.4.3.2
Rated ultimate short-circuit breaking capacity	I_{cu}		4.3.6.2.2
Selectivity limit current	I_s		2.17.4
Take-over current	I_B		2.17.5
Conventional enclosed thermal current	I_{the}		4.3.3.2
Conventional free air thermal current	I_{th}		4.3.3.1
CBRs and MRCDs of type AC		IEC 60417-6148 (2012-01)	B.4.4.1 M.4.2.2.1
CBRs and MRCDs of type A		IEC 60417-6149 (2012-01)	B.4.4.2 M.4.2.2.2

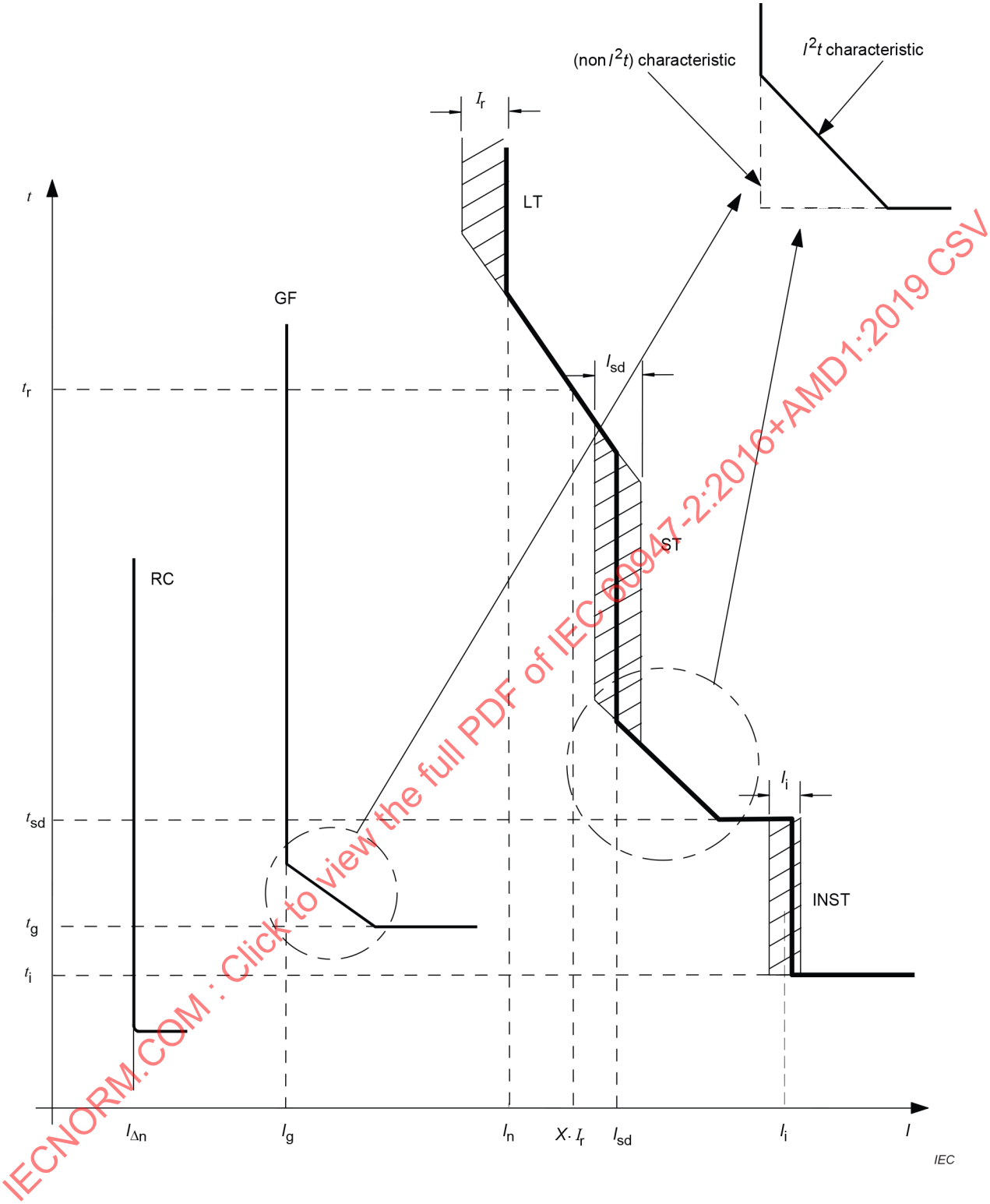
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Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
CBRs and MRCDs of type B	 or	IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11 or IEC 60417-6398:2017-12	M.4.2.2.3 B.4.4.3
Test device CBR or MRCD	T		B.7.2.6 M.7.2.6
Current setting of adjustable overload release	I_r		4.7.3
Corresponding tripping time	t_r		Figure K.1
Ground fault current setting	I_g		Figure K.1
Corresponding tripping time	t_g		Figure K.1
Individual pole short-circuit breaking capacity (phase/earthed systems)	I_{su}		Annex C
Individual pole short-circuit test current (IT systems)	I_{IT}		Annex H
Rated instantaneous short-circuit current setting	I_i		2.20 Figure K.1 Annex L Annex O
Maximum corresponding tripping time	t_i		Figure K.1
Not suitable for use in IT systems		IEC 60417-6363:2016-07	Annex H
Rated residual short-circuit making and breaking capacity	$I_{\Delta m}$		Annex B Annex M
Rated residual non-operating current	$I_{\Delta no}$		Annex B Annex M
Rated residual operating current	$I_{\Delta n}$		Annex B Annex M
~~Residual operating current~~	~~$I_{\Delta R}$~~		~~Figure K.1~~
Short time pick-up current	I_{sd}		Figure K.1
Corresponding tripping time	t_{sd}		Figure K.1
Suitability for phase earthed systems	C		4.3.2.1
Limiting non-actuating time at 2 $I_{\Delta n}$	Δt		Annex B
~~Time delay CBR or MRCD with limiting non-actuating time of 0,06 s~~	S		~~B.5 a) M.3.4~~
CBRs for use with 3-phase supply only		IEC 60417-6364:2016-07	B.8.9.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2

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RC residual current
GF ground fault
LT long time
ST short time
INST instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

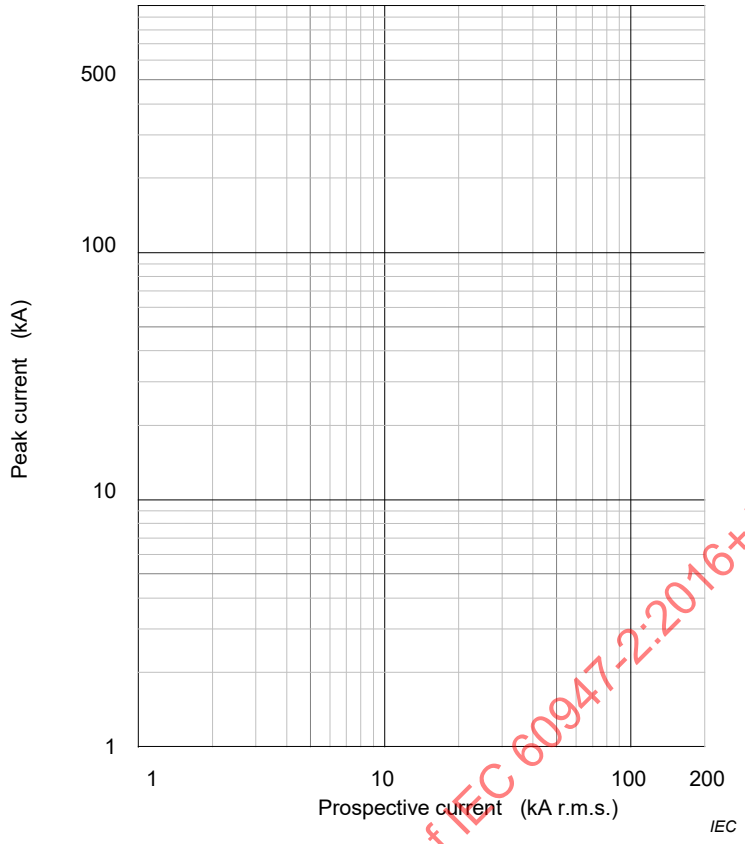


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

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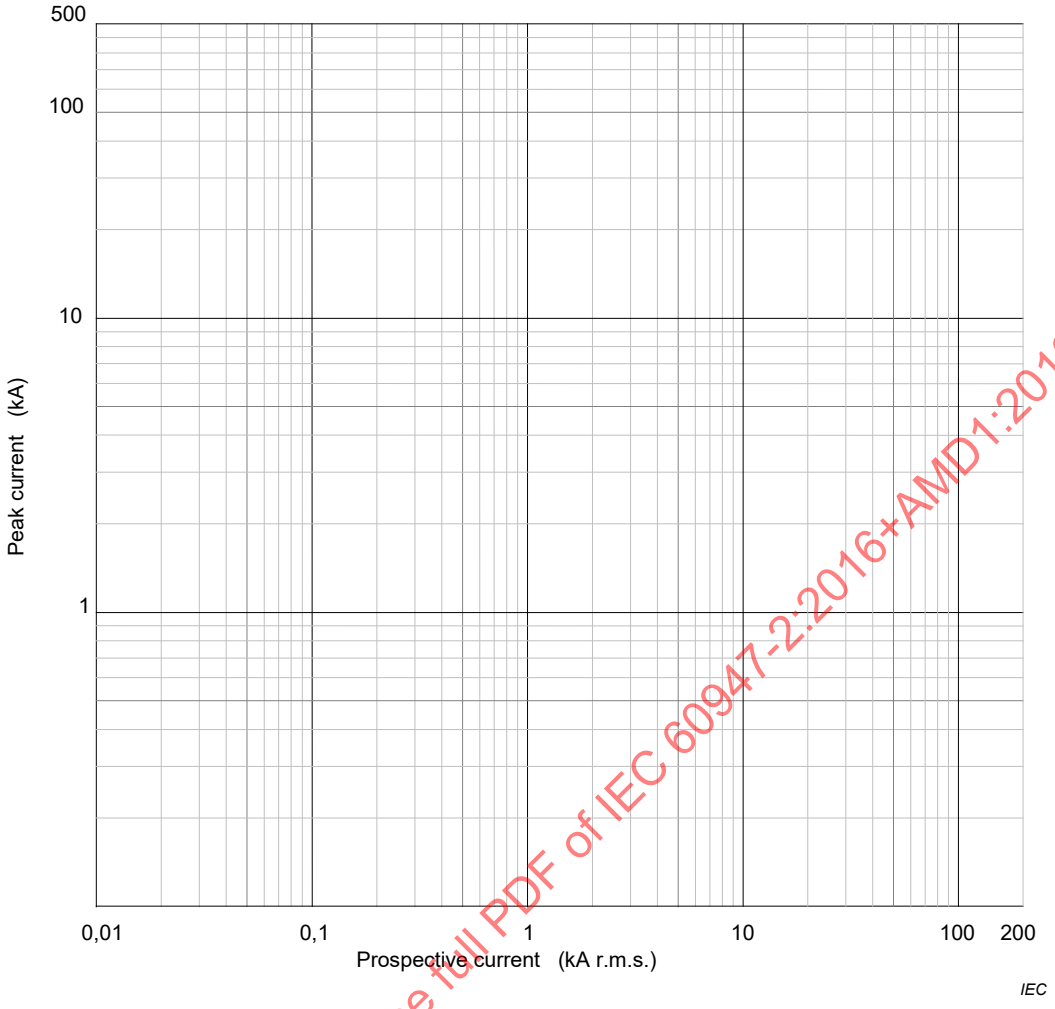


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

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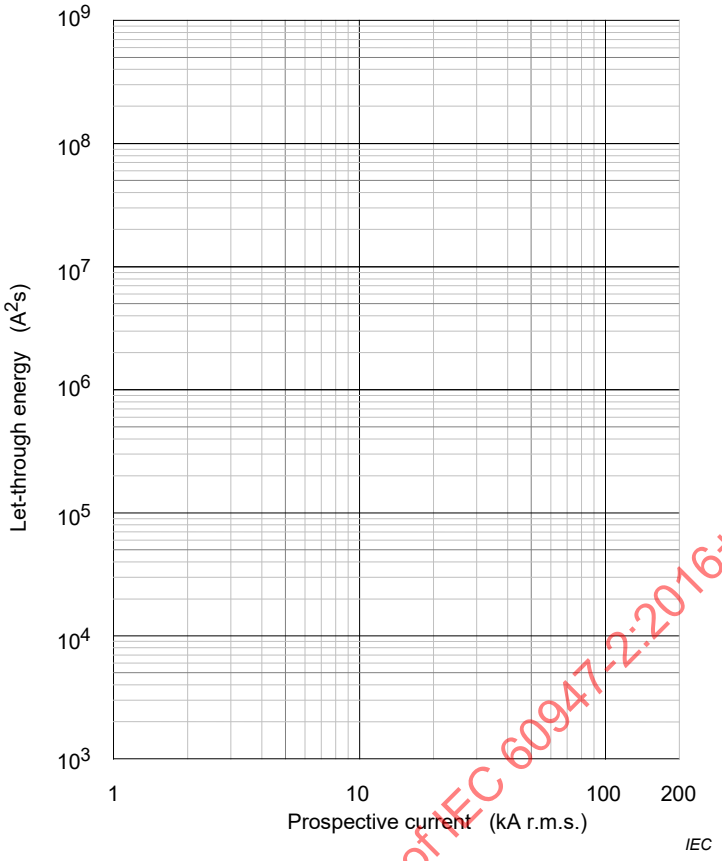


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

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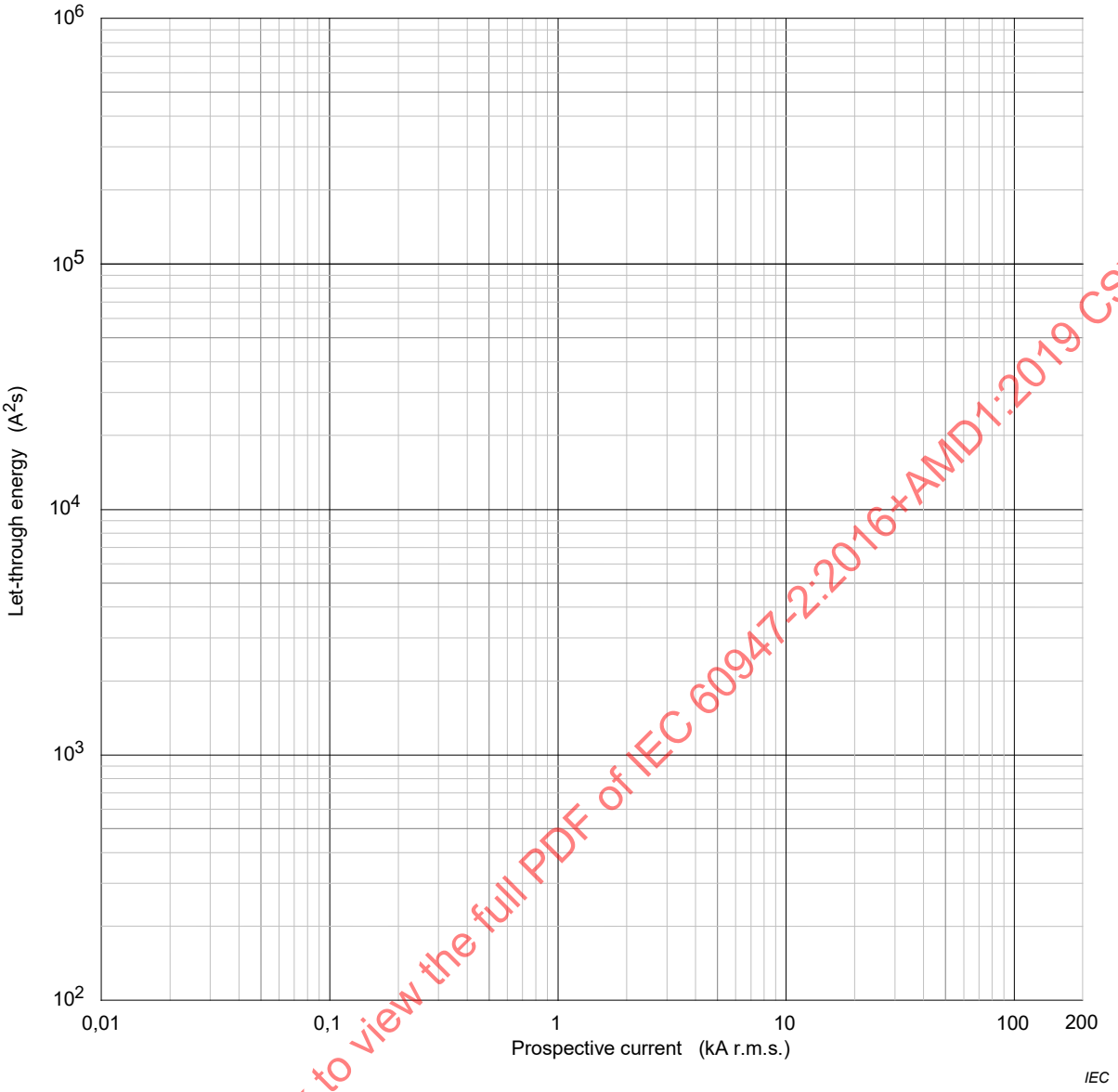
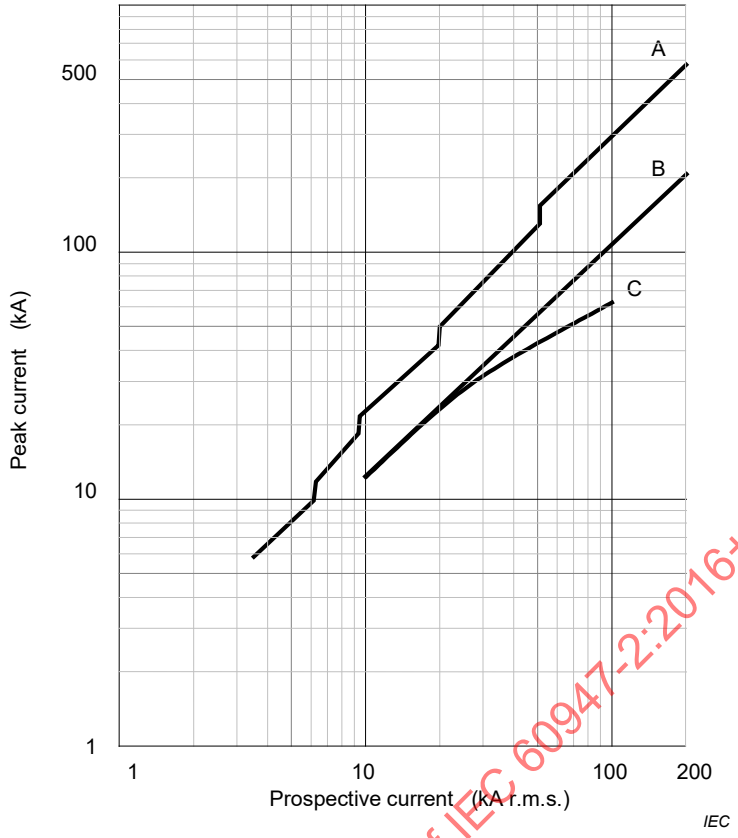


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA

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A Prospective asymmetric peak current under the test conditions of this standard

B Prospective symmetrical peak current

C Typical cut-off current characteristic

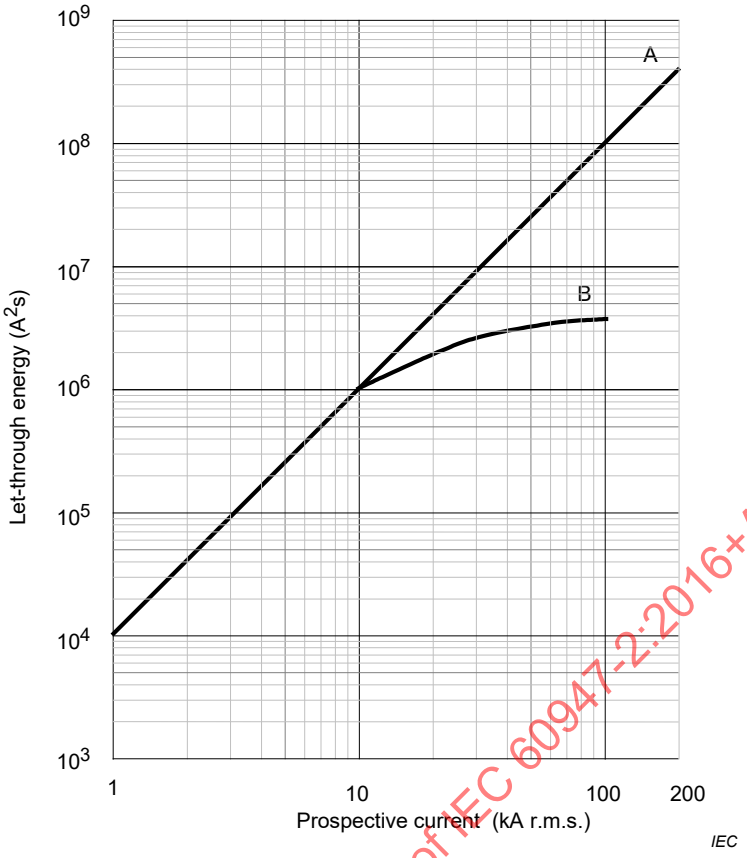
The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of cut-off current the effect of current limiting is shown by comparison with the current that would be let through (prospective current) if the circuit-breaker were not present. The comparison is made with the asymmetric (inrush) peak current or the symmetrical peak current (see 2.3).

The typical curve does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.6 – Example of the use of template to Figure K.2

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A Let-through energy of one half cycle of prospective current at 50 Hz

B Typical let-through energy characteristic of a 250 A MCCB at 400 V 50 Hz

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of let-through energy the effect of current limiting is shown by comparison with the energy that would be let through in one half-cycle of the symmetrical prospective current if the circuit-breaker were not present (see 2.3).

The typical curve for the 250 A MCCB does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.7 – Example of the use of template to Figure K.4

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Annex L
(normative)

Circuit-breakers not fulfilling the requirements for overcurrent protection

L.1 General

This annex covers circuit-breakers which do not fulfil the requirements for overcurrent protection specified in the main part of this standard, hereinafter referred as CBIs. They are capable of being tripped by an auxiliary device, e.g. shunt or undervoltage release. They do not provide circuit protection but may trip under short-circuit conditions for self-protection. They have a conditional short-circuit rating and may be used for isolation. They may incorporate accessories such as auxiliary and alarm switches for control purposes, and/or remote operators.

A CBI forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases (class Y) or the overload releases only (class X), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

L.2.1
equivalent circuit-breaker
circuit-breaker from which the CBI has been derived, which has been tested according to this standard and which has the same frame size as the CBI

L.2.2
overcurrent protective device
OCPD
device intended to protect a CBI against overcurrents by interrupting them, and incorporating overload protection no less effective than that of the equivalent circuit-breaker and an I_{cu} (for a circuit-breaker) or a breaking capacity (for a fuse) equal to or higher than that of the equivalent circuit-breaker

Note 1 to entry: The OCPD may be the equivalent circuit-breaker.

L.3 Classification

CBIs are classified as follows:

- class X: with integral non-adjustable instantaneous short-circuit releases for self-protection;
- class Y: without integral short-circuit releases.

L.4 Rated values

L.4.1 Rated current (I_n)

The rated current of a CBI shall not exceed the rated current of the equivalent circuit-breaker.

NOTE The rated current of a CBI can be correlated to the rated current corresponding to utilization category AC-22 (see Annex A of IEC 60947-1:2007/AMD2:2014).

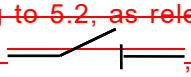
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L.4.2 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

A CBI may have a value of I_{cc} equal to or higher than that of the I_{cu} of the equivalent circuit-breaker.

L.5 Product information

~~A CBI shall be marked according to 5.2, as relevant, except that the symbol of suitability for isolation, if applicable, shall be  , replacing the symbol shown in the second dashed item of 5.2 a).~~

~~In addition it shall be marked as follows:~~

~~– for 5.2, item a): with the symbol according to the classification:~~

~~CBI-X I_i = …~~ ~~or~~ ~~CBI-Y~~ ~~as applicable.~~

~~where I_i is the rated instantaneous short-circuit current setting (see 2.20).~~

~~– for 5.2, item c): with the following items:~~

- ~~rated conditional short-circuit current (I_{cc});~~
- ~~the OCPD, if specified.~~

~~Manufacturer's instructions should draw attention to the fact that CBIs do not provide overcurrent protection.~~

Subclause 5.2 applies, as relevant, with modifications and additions as per Table L.1.

Table L.1 – Product information

Item	Information	Marking location
L1.1	Suitability for isolation, if applicable, with the symbol  (IEC 60617-S00288:2001-07) (this symbol substitutes the symbol used in Table 13, item 1.2)	Visible
L1.2	Classification, with the marking CBI-X I_i = … or CBI-Y as applicable, where I_i is the rated instantaneous short-circuit current setting (see 2.20)	Visible
L3.1	Rated conditional short-circuit current (I_{cc}) and, if specified, overcurrent protective device (OCPD)	Literature
L3.2	Statement that CBIs do not provide overcurrent protection	Literature
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Literature:provided in the manufacturer's literature		

L.6 Constructional and performance requirements

A CBI, being derived from the equivalent circuit-breaker (see L.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4.

NOTE A CBI can additionally comply with IEC 60947-3 and be marked accordingly.

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L.7 Tests

L.7.1 General

L.7.1.1 CBI of class X

The OCPD is specified.

Case 1:

$I_{cc} = I_{cu}$ of the equivalent circuit-breaker.

No additional tests are required.

NOTE The specified OCPD can be

– the equivalent circuit-breaker (see L.2.1);

– another circuit-breaker (see L.2.2);

– a fuse of conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and of a breaking capacity ≥ I_{cc} of the CBI.

Case 2:

$I_{cc} > I_{cu}$ of the equivalent circuit-breaker.

Tests shall be made according to L.7.2.1 and L.7.2.2, with the specified OCPD.

This applies when

– the specified OCPD is a circuit-breaker of the same frame size as the equivalent circuit-breaker and of $I_{cu} \geq I_{cc}$ of the CBI.

or

– the specified OCPD is a fuse having a conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and a breaking capacity ≥ I_{cc} of the CBI.

L.7.1.2 CBI of class Y

No tests are required, provided that one of the following two conditions are fulfilled:

– condition 1: $I_{cc} \leq I_{cw}$ of the equivalent circuit-breaker;

– condition 2: I_{cc} ≤ maximum setting of the rated instantaneous short-circuit current setting of the equivalent circuit-breaker.

If neither of the above conditions are fulfilled, tests are required as follows:

Case 1:

The OCPD is specified by the manufacturer.

Tests shall be made according to L.7.2.1 and L.7.2.2.

Case 2:

The OCPD is not specified.

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Tests shall be made according to L.7.2.1 and L.7.2.3.

L.7.2 Rated conditional short-circuit tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.1 case 2, or by L.7.1.2 case 1 or case 2, as applicable.

For CBIs having variants with different number of poles, tests shall be carried out on each variant.

L.7.2.1.2 Test conditions

Subclause 8.3.2.6 applies.

The test circuit shall be according to Figure A.4, SCPD being replaced by OCPD. If the OCPD is a circuit-breaker with adjustable overcurrent settings, these shall be set at maximum.

If the OCPD consists of a set of fuses, each test shall be made with a set of new fuses.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the OCPD is a circuit-breaker, the full length of cable (0,75 m) associated with the circuit-breaker may be on the supply side (see Figure A.4).

L.7.2.1.3 Behaviour during tests

Subclause 8.3.2.6.5 applies.

L.7.2.2 OCPD specified

L.7.2.2.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.2.2
Verification of dielectric withstand	L.7.2.2.3

L.7.2.2.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.2.3 Verification of dielectric withstand

Following the test of L.7.2.2.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

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L.7.2.3 OCPD not specified

L.7.2.3.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.3.2
Verification of dielectric withstand	L.7.2.3.3

L.7.2.3.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – *t* – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

During the test, the current shall be maintained for three cycles and then disconnected at the power supply.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.3.3 Verification of dielectric withstand

Following the test of L.7.2.3.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

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Annex M
(normative)

Modular residual current devices
(without integral current breaking device)

M.1 General

M.1.1 Field of application

The provisions of Annex B apply to this Annex M, adapting, amending or supplementing Annex B as necessary to cover its applicability to equipment where the current sensing means and/or the processing device are mounted separately from the current breaking device.

Throughout this annex, "CBR" as used in Annex B (see B.2.3.1), is replaced by "MRCD" (see M.2.2.1).

Wherever relevant, reference is made to the corresponding subclause of Annex B. In other cases, reference is made to the relevant subclause of the main body of this standard, or, where applicable, of IEC 60947-1.

This annex contains also additional definitions and characteristics not contained in Annex B, e.g. "type B" MRCDs (in the context of d.c. residual current), with consequent requirements and tests.

Since the equipment covered by this annex does not include a current breaking device, certain conventional phrases used in Annex B have been adapted accordingly in this annex, e.g. "ON position" is replaced by "ready condition", meaning "ready to operate".

M.1.2 Field of application

This annex applies to residual current operated devices which do not incorporate a current breaking device, hereinafter called "Modular Residual Current Device (MRCD)". They are primarily intended to be used in conjunction with circuit-breakers in accordance with this standard.

NOTE They can also be declared suitable for use in conjunction with other current breaking devices.

They may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements which shall be complied with by the MRCD.

M.2 Terms and definitions

The terms and definitions of Annex B apply.

The following additional terms and definitions apply to this annex.

M.2.1 Terms and definitions relating to the energization of an MRCD

M.2.1.1
voltage source
source intended to supply the energizing quantity; it may consist of:

– the line voltage

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– a voltage other than the line voltage

M.2.2 Terms and definitions relating to the operation and the functions of an MRCD

M.2.2.1
Modular Residual Current Device
MRCD
device or an association of devices comprising a current sensing means and a processing device designed to detect and to evaluate the residual current and to control the opening of the contacts of a current breaking device

M.2.2.2 Operating time

M.2.2.2.1
operating time of an MRCD
time which elapses between the instant when the residual operating current is suddenly applied and the instant when the MRCD output changes status

M.2.2.2.2
total operating time of an MRCD and associated current breaking device (combination time)
time which elapses between the instant when the residual operating current is suddenly applied and the instant of the arc extinction of the associated current breaking device

M.2.2.2.3
limiting non-operating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the MRCD without bringing it actually to operate

M.2.3
conditional residual short-circuit current
prospective residual current that a CBR, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions

M.2.4
residual short-time withstand current
residual current that a CBR in the closed position can carry during a specified short time under specified conditions

M.3 Classification

M.3.1 Classification according to the configuration of the primary conductors

M.3.1.1 Terminal type: MRCD with incoming and outgoing terminals and integral primary conductors

M.3.1.2 Through-conductor type

M.3.1.2.1 MRCD with sensing means and processing device combined.

M.3.1.2.2 MRCD with sensing means and processing device separate.

M.3.2 Classification according to the method of operation

M.3.2.1 MRCD without voltage source (see M.2.1.1)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in case of failure of the voltage source.

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M.3.2.2.2 Not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault.

M.3.3 Classification according to the possibility of adjusting the residual operating current

Subclause B.3.2 applies.

M.3.4 Classification according to time-delay of the residual current function

Subclause B.3.3 applies.

M.3.5 Classification according to behaviour in presence of a d.c. component

M.3.5.1 MRCD of type AC (see M.4.2.2.1)

M.3.5.2 MRCD of type A (see M.4.2.2.2)

M.3.5.3 MRCD of type B (see M.4.2.2.3)

M.4 Characteristics of MRCDs

M.4.1 General characteristics

M.4.1.1 Characteristics of the monitored circuit

M.4.1.1.1 Rated frequency range

Range of frequency values of the monitored circuit for which the MRCD is designed and for which it operates correctly under specified conditions.

M.4.1.1.2 Rated voltage (U_n)

Value of the voltage assigned by the manufacturer to the MRCD.

M.4.1.1.3 Rated current (I_n)

M.4.1.1.3.1 Terminal type

Subclause 4.3.3.3 applies.

M.4.1.1.3.2 Through-conductor type

Value of current, assigned to the MRCD by the manufacturer and marked in accordance with Table M.1, item g), which the MRCD can monitor in uninterrupted duty under specified conditions (see M.8.6).

M.4.1.1.4 Rated insulation voltage (U_i)

Voltage, assigned by the manufacturer, to which the dielectric tests and the MRCD creepage distances are referred with respect to the monitored circuit.

M.4.1.1.5 Rated impulse withstand voltage (U_{imp})

Peak value of the impulse voltage that the MRCD can withstand without failure and to which the values of the clearances are referred with regard to the monitored circuit.

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~~**M.4.1.2 Characteristics of the voltage source of MRCDs**~~

~~**M.4.1.2.1 Rated values of the voltage source of MRCDs (U_s)**~~

~~Values of the voltage source to which the operating functions of the MRCD are referred.~~

~~**M.4.1.2.2 Rated values of the frequencies of the voltage source of MRCDs**~~

~~Values of the frequencies of the voltage source to which the operating functions of the MRCD are referred.~~

~~**M.4.1.2.3 Rated insulation voltage (U_i)**~~

~~Subclause 4.3.1.2 of IEC 60947-1:2007 applies.~~

~~**M.4.1.2.4 Rated impulse withstand voltage (U_{imp})**~~

~~Subclause 4.3.1.3 of IEC 60947-1:2007 applies.~~

~~NOTE In the case of a specified power supply the requirement applies to the incoming connections.~~

~~**M.4.1.3 Characteristics of auxiliary contacts**~~

~~Subclause 4.6 of IEC 60947-1:2007 applies.~~

~~**M.4.2 Characteristics of MRCDs concerning their residual current function**~~

~~**M.4.2.1 General**~~

~~Subclause B.4.2.4 applies, replacing "non-actuating time" by "non-operating time", and with the following additions.~~

~~The maximum values of the MRCD operating time shall be stated by the manufacturer for residual current values equal to $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (or 0,25 A for $I_{\Delta n} \leq$ 30 mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n} \leq$ 30 mA).~~

~~The maximum combination time shall comply with Table B.1 for a non-time-delay type MRCD and with Table B.2 for a time-delay type MRCD having a limiting non-operating time of 0,06 s.~~

~~MRCDs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type. They shall be used only with a specified current breaking device.~~

~~**M.4.2.2 Operating characteristic in case of residual current with d.c. component**~~

~~**M.4.2.2.1 Type AC MRCD**~~

~~Subclause B.4.4.1 applies.~~

~~**M.4.2.2.2 Type A MRCD**~~

~~Subclause B.4.4.2 applies.~~

~~**M.4.2.2.3 Type B MRCD**~~

~~MRCD for which operation is ensured:~~

~~– for residual sinusoidal alternating currents,~~

~~– for residual pulsating direct currents,~~

~~– for residual pulsating direct currents superimposed by a smooth direct current of 6 mA,~~

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– for residual currents which may result from rectifying circuits, i.e.:

- single-phase connection with capacitive load causing smooth direct current,
- two-pulse bridge connection line-line,
- three-pulse star connection or six-pulse bridge connection,

with or without phase angle control, independent of polarity, whether suddenly applied or slowly rising.

M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 4.3.6.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.4 Peak withstand current

Subclause 2.5.28 of IEC 60947-1:2007 applies to the primary circuit of the MRCD.

M.4.3.5 Rated residual short-time withstand current ($I_{\Delta w}$)

The rated residual short-time withstand current of an equipment is the value of residual short-time withstand current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in this standard.

M.4.4 Preferred and limiting values

M.4.4.1 Preferred values of the rated residual operating current ($I_{\Delta n}$)

Subclause B.4.2.1 applies.

M.4.4.2 Minimum value of the rated residual non-operating current ($I_{\Delta no}$)

Subclause B.4.2.3 applies.

M.4.4.3 Limiting value of the non-operating overcurrent in the case of a single-phase load in a multiphase circuit

Subclause B.4.2.4 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

Subclause 4.5.1 applies.

M.5 Product information

The MRCD, processing device or sensing means, as applicable, shall be provided with the information as given in Table M.1. Any marking shall be durable. The marking shall be on the MRCD itself or on one or more nameplates. The manufacturer shall state:

– for a separate sensing means, the details of the sensing means including the conditions for connection to the processing device (cable type, length etc.);

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- for a through-conductor type MRCD, the dimensions of the conductor aperture(s) and the position of the through-conductors relative to the sensing means;
- for a terminal type MRCD, the maximum cross sectional area of the conductors to be connected;
- for all types, distances to be respected with regard to nearby conductors;
- for all types, the conditions to be observed for the connection between the processing device and the current breaking device;
- for all types, the SCPDs to be associated with the MRCD to achieve the rated conditional (residual or not) short-circuit current;
- for a non-time-delay type, the current breaking devices to be associated with the MRCD to meet the maximum combination times of Table B.1;
- for a time-delay type having a limiting non-operating time of 0,06 s, the current breaking device(s) to be associated with the MRCD to meet the combination times of Table B.2.

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Table M.1 – Product information

Information	Symbol	Location (see Note 1)	Single device	Separate devices	
				Sensing means	Processing device
a) manufacturer's name or trade mark		Marked	a	a	a
b) type designation or serial number		Marked	a	a	a
c) IEC 60947-2		Marked	a		a
d) rated voltage of the voltage source	U_s	Marked	a		a
e) rated voltage of the monitored circuit	U_n	Marked	a	a	
f) rated frequency of the voltage source		Literature			
g) rated frequency of the monitored circuit		Literature			
h) maximum rated current of the monitored circuit	I_n	Visible	a	a	a (see Note 2)
i) rated residual operating current (value(s) or range, as applicable)	$I_{\Delta n}$	Visible	a		a)
j) rated residual non-operating current if it differs from 0,5 $I_{\Delta n}$	$I_{\Delta no}$	Literature			
k) lowest residual current setting at 6 I_n for MRCDs with separate sensing means		Literature			
l) rated conditional short-circuit current and/or rated short-time withstand current, and rated conditional residual short-circuit current	I_{cc} I_{cw} $I_{\Delta c}$	Literature			
m) U_{imp} of the voltage source	U_{imp}	Literature			
n) U_{imp} of the monitored circuit	U_{imp}	Marked	a	a	
o) IP code, where applicable (see Annex C of IEC 60947-1:2007)	IP--	Literature			
p) position of use and mounting precautions		Literature			
q) output characteristics and/or specified current breaking device(s)		Literature			
r) operating characteristic in case of residual currents in the presence or absence of a d.c. component	Type AC Type A Type B	Visible	a		a
s) limiting non-operating time (value or range) at 2 $I_{\Delta n}$ for time-delay type, as applicable	Δt or S	Visible	a		a
t) test device	T	Visible	a		a
u) wiring diagram		Literature			

a Information/marking applies.

NOTE 1 Visible = marked on the device and visible after installation.
Literature = given in the manufacturer's catalogue or instructions.
Marked = marked on the device but not necessarily visible after installation.

NOTE 2 Only applicable if the residual current is marked as a percentage of I_n.

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M.6 Normal service, mounting and transport conditions

Clause 6 applies.

M.7 Design and operating requirements

M.7.1 Design requirements

It shall not be possible to modify the operating characteristic of an MRCD except by means which are specifically provided for setting the rated residual operating current or the definite time-delay.

NOTE MRCDs can be provided with means indicating the status of the outputs.

M.7.2 Operating requirements

M.7.2.1 Operation in case of a residual current

Subclause B.7.2.1 applies.

Compliance shall be checked by the tests of M.8.3.

M.7.2.2 Operation under short-circuit conditions

MRCDs shall have a rated conditional short-circuit current (I_{cc}) or a rated short-time withstand current (I_{cw}), but may have both. They shall also have a rated conditional residual short-circuit current ($I_{\Delta c}$) or a rated residual short-time withstand current ($I_{\Delta w}$), but may have both.

MRCDs shall comply with the relevant tests of M.8.14.

M.7.2.3 Mechanical and electrical endurance

MRCDs shall comply with the tests of M.8.11.

M.7.2.4 Effects of environmental conditions

MRCDs shall comply with the test of M.8.15.

M.7.2.5 Dielectric properties

MRCDs shall be capable of withstanding the impulse withstand voltage declared by the manufacturer in accordance with 7.2.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

MRCDs shall comply with the tests of M.8.4.

Clearances from the live parts of the monitored circuit to:

- the live parts of the MRCD,
- the parts intended to be grounded,
- the clearances between the current paths, for terminal type MRCDs,

shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 according to the rated impulse withstand voltage.

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M.7.2.6 Test device

MRCDs shall be provided with a test device to simulate the passing through the detecting device of a residual current, in order to allow periodic testing of the ability of MRCDs to operate.

The test device shall satisfy the tests of M.8.5.

The protective conductor, if any, shall not become live when the test device is operated.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; the use of a light colour is recommended.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

M.7.2.7 Value of the non-operating overcurrent in case of a single phase load

MRCDs shall comply with the test of M.8.6.

M.7.2.8 Resistance of MRCDs to unwanted tripping due to surge currents resulting from impulse voltages

MRCDs shall withstand the test of M.8.7.

M.7.2.9 Behaviour of MRCDs of type A and B in case of an earth fault current comprising a d.c. component

MRCDs of type A and type B shall comply with the tests of M.8.8, as applicable.

M.7.2.10 Requirements for MRCDs with voltage source

MRCDs functionally dependent on a voltage source shall operate correctly at any value of the voltage between 0,85 and 1,1 times the rated value U_s (see M.2.1.1 and M.4.1.2.1).

According to their classification, MRCDs functionally dependent on a voltage source shall comply with the requirements given in Table M.2.

Table M.2 – Requirements for MRCDs with voltage source

Classification of the device according to M.3.2.2	Behaviour in case of failure of the voltage source
MRCD operating automatically without delay in case of voltage source failure (M.3.2.2.1)	Operating without delay according to M.8.12
MRCD operating automatically with delay in case of voltage source failure (M.3.2.2.1)	Operating with delay according to M.8.12
MRCD not operating automatically after failure of the voltage source but able to operate as intended in case of a residual current fault arising (M.3.2.2.2)	Operating according to M.8.13

M.7.2.11 Temperature-rise of terminal type MRCDs

M.7.2.11.1 General

The temperature-rise of the parts of terminal type MRCDs shall not exceed the values specified in 7.2.2 of IEC 60947-1:2007/AMD2:2014.

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~~**M.7.2.11.2 Ambient air temperature**~~

~~The temperature-rise limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014 are only applicable if the ambient air temperature remains between the limits given in M.6.~~

~~**M.7.2.11.3 Main circuit of terminal type MRCDs**~~

~~The main circuit of the MRCD, to which the monitored circuit is connected, shall withstand the rated current as defined in M.4.1.2.3, without the temperature-rises exceeding the limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014.~~

~~**M.7.2.12 Electromagnetic compatibility**~~

~~Requirements of Annex J apply to the sensing means and the processing device of the MRCD, connected in accordance with the manufacturer's instructions.~~

~~Tests shall be made in accordance with M.8.16.~~

~~Immunity to voltage variations is covered by the requirements of M.7.2.10.~~

~~**M.7.2.13 Behaviour of MRCDs in case of failure of the sensing means connection**~~

~~For MRCDs with separate sensing means, if the sensing means are disconnected, then:~~

~~– the MRCD shall operate, or~~

~~– the MRCD shall provide a signal to indicate such disconnection, or~~

~~– it shall be possible to verify the disconnection by operating the test device.~~

~~Compliance is verified by the tests of M.8.9.~~

~~**M.7.2.14 Behaviour of MRCDs according to the rated frequency**~~

~~The MRCD shall operate correctly within its rated frequency range.~~

~~Compliance is verified by the tests of M.8.3.3 and M.8.5.~~

~~M.8 Tests~~

~~M.8.1 General~~

~~M.8.1.1 Type tests~~

~~Type tests are grouped together in a number of sequences, as shown in Table M.3.~~

~~In the case of MRCDs with multiple settings of residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.~~

~~In the case of MRCDs with adjustable time-delay (see B.3.3.2.2), the tests shall be made at the highest setting, unless otherwise stated.~~

~~The release of the associated breaking device, when applicable, shall be energized at its lowest rated voltage.~~

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Table M.3 – Test sequences

Sequences		
M I	Operating characteristics	M.8.3
	Dielectric properties	M.8.4
	Operation of the test device at the limits of rated voltage	M.8.5
	Limiting value of the non-operating current under overcurrent conditions	M.8.6
	Resistance against unwanted tripping due to surge currents resulting from impulse voltages	M.8.7
	Behaviour in case of an earth fault current comprising a d.c. component	M.8.8
	Behaviour in case of failure of the connection to the sensing means	M.8.9
	Temperature-rise	M.8.10
	Mechanical and electrical endurance	M.8.11
	Behaviour in the case of failure of the voltage source for MRCDs classified under M.3.2.2.1	M.8.12
	Behaviour of MRCDs classified under M.3.2.2.2. in the case of failure of the voltage source	M.8.13
M II	Behaviour of MRCDs under short-circuit conditions	M.8.14
M III	Effects of environmental conditions	M.8.15
M IV	Electromagnetic compatibility	M.8.16

For terminal-type MRCDs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants construction is not identical to the variant tested then those variants shall also be tested.

One sample shall be tested for each of the test sequences M I, M II and M III.

For test sequence M IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Unless otherwise specified, each type test (or sequence of type tests) is carried out on the MRCD in new and clean condition, the influencing quantities having their normal reference values.

The MRCD shall be installed individually, according to the manufacturer's instructions, in free air, unless otherwise specified. Ambient temperature shall be between 15 °C and 30 °C unless otherwise specified. Connections and mounting shall comply with the manufacturer's instructions.

M.8.1.2 Routine tests

Subclause 8.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except in so far as 7.1 applies.

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Test sequence M I

M.8.3 Verification of the operating characteristics

M.8.3.1 General

The MRCD shall be installed, mounted and wired according to the manufacturer's instructions. Unless otherwise specified, it is connected to a test equipment, as specified by the manufacturer, representing normal service conditions for the output circuit (e.g. connection to a circuit-breaker) in order to verify the change in the status of the output and the combination time (see M.2.2.2.2).

M.8.3.2 Test conditions for MRCDs without voltage source

Subclause B.8.2.2 applies.

M.8.3.3 Test conditions for MRCDs with voltage source

The tests shall be carried out at the following values:

– 0,85 times the minimum rated value of the source voltage for tests specified in M.8.3.4 and M.8.3.5.2;

– 1,1 times the maximum rated value of the source voltage for tests specified in M.8.3.5.3.

MRCDs with a range of rated frequencies shall be tested at the highest and lowest frequencies. However, for MRCDs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover both frequencies.

M.8.3.4 Off-load tests at 20 °C ± 5 °C

M.8.3.4.1 General

With the connections as shown in Figure M.1, Figure M.2 or Figure M.3, the MRCD shall comply with the tests of M.8.3.4.2, M.8.3.4.3 and M.8.3.4.4 as well as with the test of M.8.3.4.5 where applicable; all these tests are carried out on a single current path. Each verification shall comprise three measurements, as applicable.

Unless otherwise specified:

– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time-delay shall be set to its minimum value.

M.8.3.4.2 Verification of operation in case of a steady increase of the residual current (Figure M.1)

The test switches S_1 and S_2, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, up to $I_{\Delta n}$ in approximately 30 s. Three current measurements causing change in status of the output are carried out.

The three values measured shall be situated between the rated residual non-operating current $I_{\Delta no}$ and $I_{\Delta n}$.

M.8.3.4.3 Verification of operation in case of closing on residual current (Figure M.2)

The MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this device shall be given in the test report.

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The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or at each specific setting of the residual operating current if applicable), the test switch S_2 and the breaking device being closed, switches S_1 and S_a (if applicable) are closed simultaneously. The combination time is measured three times.

No measurements shall exceed the limiting value specified for $I_{\Delta n}$ in M.4.2.

M.8.3.4.4 Verification of operation in case of a sudden appearance of residual current (Figure M.2 and Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in M.4.2, the test switches S_1, and S_a if applicable, and the test equipment being in the closed position, and the MRCD being ready to operate, the residual current is suddenly established by closing the test switch S_2.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}:

– none of the values of operating time shall exceed the values indicated by the manufacturer,

– none of the values of combination time shall exceed the limits specified in M.4.2.

M.8.3.4.5 Verification of the limiting non-operating time of time delayed type MRCDs (Figure M.3)

The MRCD is connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at the value 2 $I_{\Delta n}$, the test switches S_1, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S_2 for a time equal to the limiting non-operating time declared by the manufacturer in accordance with M.4.2.

The test is made 3 times. The MRCD shall not operate.

If the MRCD has an adjustable current setting and/or an adjustable time-delay, the test is made, as applicable, at the lowest setting of the residual operating current and at the maximum and minimum settings of the time-delay.

M.8.3.5 Tests at the temperature limits

M.8.3.5.1 General

Subclause B.8.2.5 applies.

M.8.3.5.2 Off-load test at –5 °C

Subclause B.8.2.5.2 applies, but in accordance with M.8.3.4.4 and M.8.3.4.5 if applicable.

M.8.3.5.3 On-load test at +40 °C

Subclause B.8.2.5.3. applies.

After reaching thermal steady-state conditions, the MRCD is submitted to the tests described in M.8.3.4.4 and in M.8.3.4.5 if applicable.

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~~**M.8.4 Verification of dielectric properties**~~

~~**M.8.4.1 Verification of rated impulse withstand voltage**~~

~~**M.8.4.1.1 General**~~

~~The MRCD shall comply with the requirements stated in M.7.2.5. The tests shall be carried out in all the auxiliary contact positions.~~

~~The tests are made in accordance with 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 with the following additions.~~

~~**M.8.4.1.2 Verification of rated impulse withstand voltage with respect to the monitored circuit**~~

~~**M.8.4.1.2.1 Tests for terminal type MRCD**~~

~~The test voltage, defined in M.7.2.5, is applied as indicated in 8.3.3.4.1 item 2), of IEC 60947-1:2007/AMD1:2010.~~

~~**M.8.4.1.2.2 Tests for MRCDs of through-conductor type**~~

~~The test is carried out on a sensing means through which runs an uninsulated busbar, installed according to the manufacturer's instructions.~~

~~The test voltage, defined in M.7.2.5, is applied as follows:~~

~~a) between all the conductors of the monitored circuit connected together and the mounting plate if the sensing means are separate;~~

~~b) between all the conductors of the monitored circuit connected together and the processing device enclosure or its mounting plate if the sensing means are combined;~~

~~c) between each auxiliary circuit and~~

~~– the monitored circuit;~~

~~– the enclosure or mounting plate of the MRCD.~~

~~**M.8.4.1.3 Verification of rated impulse withstand voltage of the voltage source circuit (if applicable)**~~

~~If the voltage source circuit is supplied directly from the monitored circuit, the tests are carried out in accordance with M.8.4.1.2.1.~~

~~If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2007 is applied as follows:~~

~~a) between all the supply terminals of the voltage source circuit connected together and the enclosure or mounting plate of the MRCD;~~

~~b) between each supply terminal of the voltage source circuit and the other supply terminals connected together and connected to the enclosure or mounting plate of the MRCD.~~

~~**M.8.4.2 Capability of any circuits connected to the monitored circuit in respect of withstanding d.c. voltages due to insulation measurements**~~

~~The need for this verification of MRCDs which cannot be disconnected in service is under consideration.~~

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~~**M.8.5 Verification of the operation of the test device at the limits of the rated voltage**~~

~~Subclause B.8.4 applies, replacing the rated voltage by the rated voltage of the voltage source. The MRCD shall be tested in association with the test equipment specified in M.8.3.1.~~

~~**M.8.6 Verification of the limiting value of non-operating current under overcurrent conditions, in case of a single phase load**~~

~~The MRCD is connected according to Figure M.4 a), b) or c), as applicable, paying particular attention to the positioning of the conductors in case of a through-conductor type according to the manufacturer's instructions, the switch S_1 being open. The switch S_a, where applicable, is then closed and the voltage U_s is applied.~~

~~The test is made in accordance with B.8.5 at a current of 6 I_n. For MRCDs with separate sensing means, the test shall be made at the lowest residual current setting value declared by the manufacturer.~~

~~No change of state of the MRCD shall occur.~~

~~**M.8.7 Resistance against unwanted tripping due to surge currents resulting from impulse voltages**~~

~~**M.8.7.1 General**~~

~~For MRCDs with adjustable time-delay, the time-delay shall be set at its minimum.~~

~~**M.8.7.2 Verification of the resistance to unwanted tripping in case of loading of the network capacitance**~~

~~Subclause B.8.6.2 applies, replacing Figure B.5 by Figure M.5.~~

~~No change of state of the MRCD shall occur.~~

~~**M.8.7.3 Verification of the resistance to unwanted tripping in case of flashover without follow-on current**~~

~~Subclause B.8.6.3 applies, replacing Figure B.7 by Figure M.6.~~

~~No change of state of the MRCD shall occur.~~

~~**M.8.8 Verification of the behaviour in case of an earth fault current comprising a d.c. component**~~

~~**M.8.8.1 General**~~

~~The test conditions of M.8.3.1, M.8.3.2 and M.8.3.3 apply.~~

~~**M.8.8.2 Type A MRCD**~~

~~**M.8.8.2.1 General**~~

~~Type A MRCDs shall satisfy the tests from M.8.8.2.2 to M.8.8.2.5.~~

~~For MRCDs the operation of which depends on a voltage source the tests are made at 1,1 and 0,85 times the rated voltage of the voltage source (U_s).~~

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M.8.8.2.2 Verification of operation in case of a continuous rise of a residual pulsating direct current

Subclause B.8.7.2.1 applies, replacing Figure B.8 by Figure M.7.

The switches S_1 and S_2, and S_a if applicable, are closed, the MRCD being ready to operate.

M.8.8.2.3 Verification of operation in case of a suddenly appearing residual pulsating direct current

Tests of B.8.7.2.2 apply with the following modifications.

The test circuit shall be in accordance with Figure M.8 or Figure M.9, as applicable.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement instrument indicating the change in status of the output;
– for the second step, the MRCD is connected to a breaking device, specified by the manufacturer, and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The switches S_1, and S_a if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

The test is carried out at each value of the residual current specified:

– for the first step, none of the operating times measured shall exceed the values indicated by the manufacturer for the response time of the MRCD only;
– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.2.4 Verification of operation with load at the reference temperature

The tests of M.8.8.2.2 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current, the current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure M.7c).

M.8.8.2.5 Verification of operation in case of a residual pulsating direct current superimposed by a smooth direct current of 6 mA

Tests of B.8.7.2.4 apply with the following modifications.

The test circuit shall be in accordance with Figure M.10 a), b) or c), as applicable.

M.8.8.3 Type B MRCD

M.8.8.3.1 General

Additionally to the tests specified in M.8.3.4 and M.8.3.5, type B MRCDs shall comply with the tests from M.8.8.3.2 to M.8.8.3.6. For MRCDs with voltage source, these tests are carried out at 1,1 and 0,85 times the rated voltage of the source voltage.

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M.8.8.3.2 Verification of operation in case of a slowly rising residual smooth direct current

The test circuit shall be in accordance with Figure M.11, switches S_1 and S_2, and S_a if applicable, being closed. Each current path is tested twice in position I and twice in position II of switch S_3.

The residual current, starting from zero, shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.3 Verification of operation in case of a suddenly appearing residual smooth direct current

The test circuits shall be in accordance with Figure M.12 and Figure M.13.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement apparatus giving the status of the output;

– for the second step, the MRCD is connected to a current breaking device, specified by the manufacturer and installed on the monitored circuit. The characteristics of this breaking device shall be given in the test report.

The circuit being successively calibrated at the values specified hereafter, the auxiliary switch S_1 or S_a, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S_2.

The test is carried out at each value of residual current specified in Table B.1, multiplied by two.

Two operating time measurements are performed for each value, the auxiliary switch S_3 being in position I for the first measurement and in position II for the second measurement:

– for the first step, none of the values obtained shall exceed the values indicated by the manufacturer for the actuating time of the MRCD alone,

– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.4 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection

The test circuit shall be in accordance with Figure M.14, the switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out twice.

For each test, starting from zero, the current shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 2 $I_{\Delta n}$.

M.8.8.3.5 Verification of operation in case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line

The test circuit shall be in accordance with Figure M.15, with switches S_1 and S_2, and S_a if applicable, being in the closed position. The test shall be carried out on all possible combinations of pairs of current paths for the MRCD sensing means.

For each test, starting from zero, the current shall be steadily increased to 1,4 $I_{\Delta n}$ within 30 s. Operation shall occur between 0,5 and 1,4 $I_{\Delta n}$.

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NOTE 1 To simplify tests for residual currents caused by a fault in a circuit supplied by a two-pulse bridge connection line-to-line or a three-pulse star connection or six-pulse bridge connection, the verification of the operation is carried out only with a residual current slowly rising and a phase control angle of $\alpha = 0°$.

NOTE 2 To simplify tests for residual currents caused by a fault in a three-phase rectified circuit, the verification of the operation is carried out only for a three-pulse star connection.

M.8.8.3.6 Verification of operation with load at the reference temperature

The tests of M.8.8.3.2, M.8.8.3.4 and M.8.8.3.5 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current.

M.8.9 Verification of the behaviour of MRCDs with separate sensing means in case of a failure of the sensing means connection

M.8.9.1 General

For MRCDs with a range of rated values of the voltage source, tests shall be made for each rated value, according to M.8.9.2 or M.8.9.3, as applicable, according to the manufacturer's instructions.

M.8.9.2 Test method 1

The MRCD shall be connected to the external sensing means and is supplied successively with each rated voltage, as shown in Figure M.16. There shall be no fault current flowing in the sensing means and the test circuit shall not be activated.

The sensing means are disconnected and the MRCD shall operate or provide a signal to indicate such disconnection.

The time interval between the disconnection and the output status change is measured.

Three measurements are carried out; no value shall exceed 5 s.

M.8.9.3 Test method 2

Tests shall be carried out as follows:

a) The test device is activated. The MRCD shall operate.

b) The sensing means are disconnected and the test device is activated. The MRCD shall not operate.

M.8.10 Verification of temperature-rise of terminal type MRCDs

M.8.10.1 General

Unless otherwise specified, the MRCD is connected with the appropriate conductors whose cross-sections are specified in Tables 9, 10 and 11 of IEC 60947-1:2007, and is fixed on a mat black painted plywood board of about 20 mm thickness.

The test shall be carried out in an atmosphere protected against abnormal external heating or cooling.

M.8.10.2 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 8.3.3.3.4 of IEC 60947-1:2007, at the rated current I_n.

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During this test, temperature-rise shall not exceed the values listed in Table 2 of IEC 60947-1:2007 and Table 3 of IEC 60947-1:2007/AMD2:2014.

M.8.11 Verification of mechanical and electrical endurance

The MRCD output is submitted to mechanical and electrical endurance tests including:

– 500 off-load operations controlled by the test device;

– 500 off-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path;

– 500 on-load operations controlled by the test device;

– 500 on-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path.

The on-load tests are carried out on a circuit corresponding to the output rating given by the manufacturer.

After the tests, the MRCD shall show no damage impairing its further use. The output shall be able to withstand in the open position a voltage equal to twice its maximum rated value given by the manufacturer.

NOTE 1 This verification is not applicable if the output is designed for a specific load and does not have a rated output voltage.

For MRCDs having more than one output rating, two tests shall be made:

– a test at the highest rated current at the corresponding voltage;

– a test at the highest rated voltage at the corresponding current.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

NOTE 2 If the MRCD output has an appropriate AC15 rating, according to IEC 60947-5-1, the tests of this subclause are not necessary.

M.8.12 Verification of the behaviour of MRCDs in case of failure of the voltage source for MRCDs classified under M.3.2.2.1

M.8.12.1 General

For adjustable residual operating current MRCDs, the test shall be carried out at the lowest setting.

For adjustable time-delayed MRCDs, the test is carried out at any one of the time-delay settings.

The voltage applied is the rated voltage of the voltage source (U_s).

For MRCDs having a range of rated voltages of the voltage source, the tests shall be made at the maximum and minimum values of the voltage range.

M.8.12.2 Determination of the limiting value of the voltage source

Tests shall be carried out in accordance with B.8.8.2, replacing "line voltage" by "voltage source" and "line terminals" by "voltage source terminals".

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M.8.12.3 Verification of automatic opening in case of voltage source failure

Tests are carried out in accordance with B.8.8.3, replacing "line voltage" by "voltage source" and "line terminals" by "voltage source terminals", but in this case the time interval between the switching off and the change in status of the output shall be measured.

Three measurements are carried out:

– for instantaneous MRCDs, no value shall exceed 1 s;

– for time-delayed MRCDs, no value shall exceed 1 s plus the set time-delay.

M.8.13 Verification of the behaviour of MRCDs with voltage source as classified under M.3.2.2.2 in case of failure of the voltage source

The provisions of B.8.9 apply in the case where the voltage source is the line voltage of the monitored circuit. In the case where the voltage source is other than the line voltage, a test shall be made as follows.

For MRCDs having an adjustable residual operating current, the test shall be made at the lowest setting.

For MRCDs having an adjustable time-delay, the test is made at any one of the time-delay settings.

The MRCD is connected according to Figure M.3 and is supplied with its rated voltage, or in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_a or S_1, as applicable; the MRCD shall not operate.

The switch S_a or S_1, as applicable, is then reclosed and the voltage is reduced to 70 % of the lowest rated voltage. The rated residual current $I_{\Delta n}$ is then applied by closing S_2; the MRCD shall operate.

Test sequence M II

M.8.14 Verification of the behaviour of the MRCD under short-circuit conditions

M.8.14.1 General

Since an MRCD is not a switching device, where it has been tested with a given SCPD according to M.8.14.3 and M.8.14.5, tests with other SCPDs of a lower peak current and lower I^2t are considered to be also covered.

M.8.14.2 General conditions for the test

M.8.14.2.1 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies, replacing Figures 9, 10, 11 and 12 by Figure M.17, Figure M.18 and Figure M.19.

For short-time withstand tests, the SCPD shall be omitted.

M.8.14.2.2 Tolerances on the test quantities

Table 8 of IEC 60947-1:2007 applies.

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M.8.14.2.3 Power factor of test circuit

Table 11 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 8.3.2.2.3, item a), of IEC 60947-1:2007/AMD2:2014 applies.

M.8.14.2.5 Calibration of the test circuit

The SCPD and the MRCD, if of the terminal type, are replaced by temporary connections of impedance negligible compared with that of the test circuit. For other MRCDs, the conductors through the sensing means are part of the calibrating circuit.

For the test at rated conditional short-circuit current I_{cc}, the resistors R and the reactors L are adjusted so as to obtain, at the test voltage, a current equal to I_{cc}, at the prescribed power factor. The test circuit is energised simultaneously in all poles.

For the tests at rated residual conditional short-circuit current $I_{\Delta c}$, the additional impedance Z is used so as to obtain the required current values.

M.8.14.2.6 Condition of the MRCD for tests

The wiring and the fixing of the MRCD shall be in accordance with the manufacturer's instructions.

This is particularly the case for MRCDs of the through-conductor type for installing conductors that pass through the sensing means.

The MRCD shall be mounted on a metal plate.

M.8.14.2.7 Condition of the MRCD after tests

After each test of M.8.14.3, M.8.14.4 and M.8.14.5, the MRCD shall show no damage impairing its further use and, in case of a terminal type MRCD, shall be capable of withstanding a voltage equal to twice its rated voltage under the conditions of 8.3.3.6.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2 and M.8.12.3, if applicable, and limited to one measurement.

M.8.14.3 Verification of the rated conditional short-circuit current (I_{cc})

M.8.14.3.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated short-time withstand current I_{cw}.

M.8.14.3.2 Test conditions

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal type MRCD.

M.8.14.3.3 Test procedure

The rated voltage of the voltage source, if applicable, is applied.

The following sequence of operations is performed:

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O – *t* – O

M.8.14.3.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 8.3.4.3 of IEC 60947-1:2007 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of Figure M.17, Figure M.18 and Figure M.19 shall be omitted for the test.

M.8.14.5 Verification of the rated conditional residual short-circuit current ($I_{\Delta c}$)

M.8.14.5.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated residual short-time withstand current $I_{\Delta w}$.

M.8.14.5.2 Test conditions

The MRCD shall be tested under the conditions prescribed in M.8.14.2.1 but shall be connected so that the short-circuit current is a residual current. For residual short-circuit tests, the connection B, indicated by the dashed line in Figure M.17, Figure M.18 and Figure M.19, replaces the connection through the sensing means, between X and Y.

The test is carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

M.8.14.5.3 Test procedure

The following sequence is performed without synchronisation with respect to the voltage wave:

O – *t* – O

M.8.14.5.4 Behaviour of the MRCD during the tests

During the tests the MRCD may operate.

M.8.14.6 Verification of rated residual short-time withstand current ($I_{\Delta w}$)

Subclause M.8.14.4 applies except that the MRCD shall be connected so that the short-circuit current is a residual current.

Test sequence M III

M.8.15 Verification of effects of environmental conditions

The tests conditions of B.8.11 apply.

At the end of the tests, the MRCD shall be capable of performing satisfactorily the tests specified in B.8.10.4.2.

Test sequence M IV

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~~**M.8.16 Verification of electromagnetic compatibility**~~

~~**M.8.16.1 Immunity tests**~~

~~**M.8.16.1.1 General**~~

~~Subclause B.8.12.1 applies, replacing "CBR" by "MRCD" where necessary, except that the verifications after the tests shall be a measurement of the operating time (see M.2.2.2.1) at I_{An}, which shall not exceed the value declared by the manufacturer (see M.4.2). The test circuit for the verification shall be in accordance with Figure M.3.~~

~~**M.8.16.1.2 Electrostatic discharges**~~

~~Subclause B.8.12.1.2 applies with the additional specifications given in M.8.16.1.1.~~

~~**M.8.16.1.3 Radiated RF electromagnetic fields**~~

~~Subclause B.8.12.1.3 applies with the additional specifications given in M.8.16.1.1.~~

~~The test set-up shall be in accordance with Figure J.4, and Figure M.20 for MRCDs with separate sensing means.~~

~~**M.8.16.1.4 Electrical fast transients/bursts (EFT/B)**~~

~~Subclause B.8.12.1.4 applies with the additional specifications given in M.8.16.1.1.~~

~~The test set-up shall be in accordance with Figure J.5 and Figure J.6, and Figure M.21 for MRCDs with separate sensing means.~~

~~**M.8.16.1.5 Surges**~~

~~Subclause B.8.12.1.5 applies with the additional specifications given in M.8.16.1.1.~~

~~**M.8.16.1.6 Conducted disturbances induced by RF fields (common mode)**~~

~~Subclause B.8.12.1.6 applies with the additional specifications given in M.8.16.1.1.~~

~~The test set-up shall be in accordance with Figure M.22 for MRCDs with separate sensing means.~~

~~An EM clamp may be used when normal functioning cannot be achieved because of the impact of the CDN on the MRCD.~~

~~**M.8.16.2 Emission tests**~~

~~Subclause B.8.12.2 applies.~~

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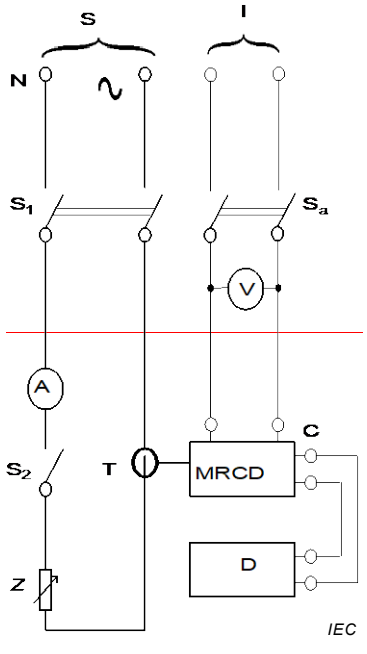


Figure M.1a) – MRCD with separate sensing means

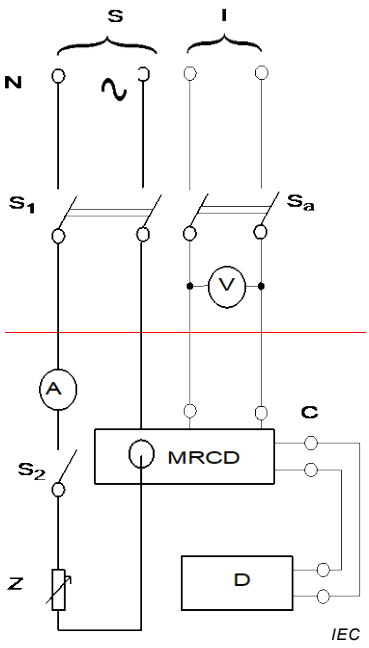


Figure M.1b) – MRCD with integral sensing means

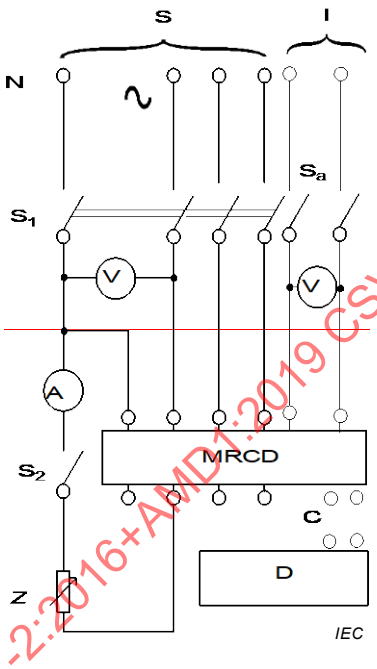


Figure M.1c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

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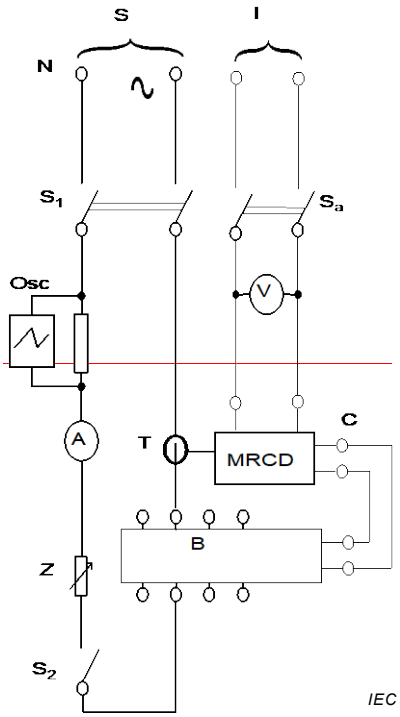


Figure M.2a) – MRCD with separate sensing means

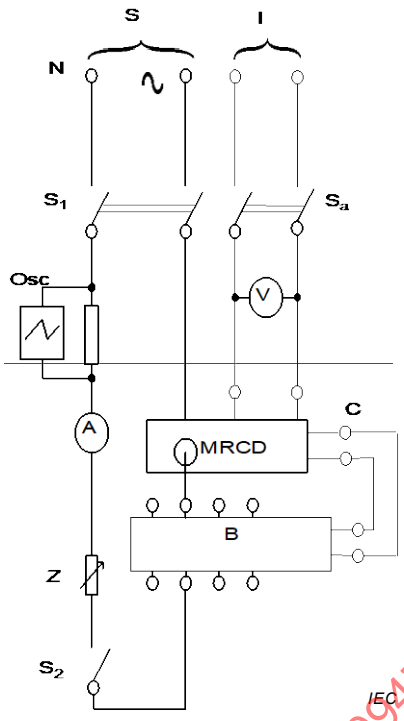


Figure M.2b) – MRCD with integral sensing means

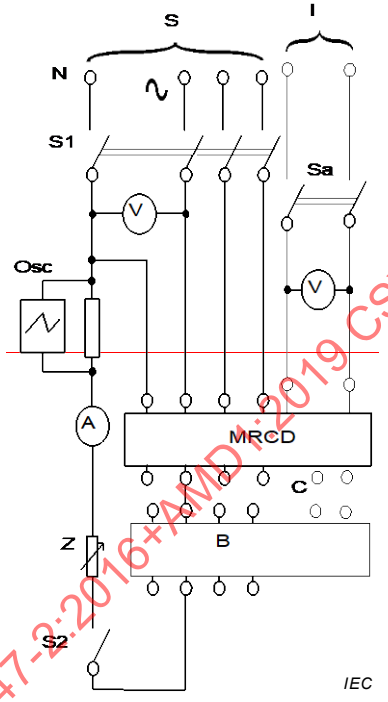


Figure M.2c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

B breaking device

Osc oscilloscope

Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with breaking device)

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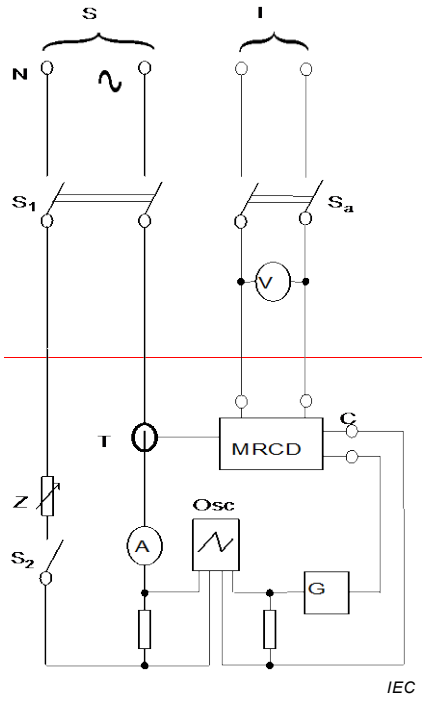


Figure M.3a) – MRCD with separate sensing means

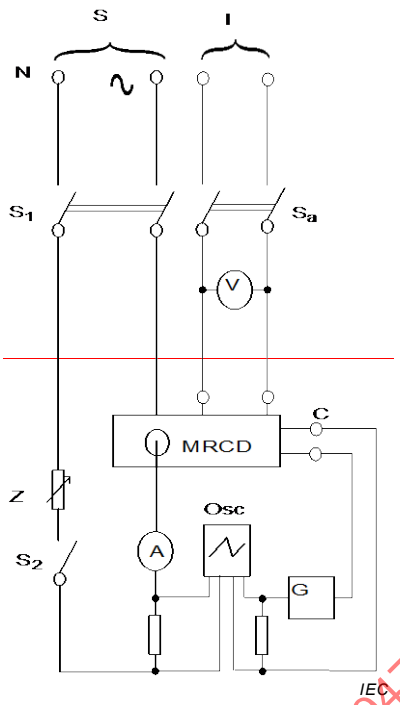


Figure M.3b) – MRCD with integral sensing means

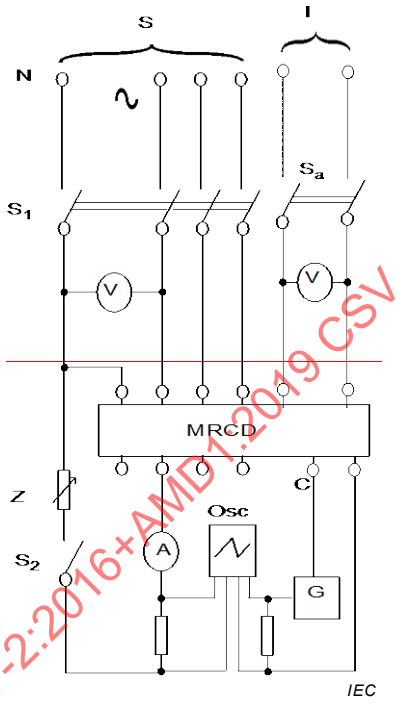


Figure M.3c) – Terminal type MRCD

Key

S power supply
I separate voltage source, if applicable
V voltmeter
A ammeter
S_1 multipole switch
S_2 single-pole switch
S_a auxiliary switch
Z variable impedance
T sensing means
C output circuit
G generator
Osc oscilloscope

Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without breaking device)

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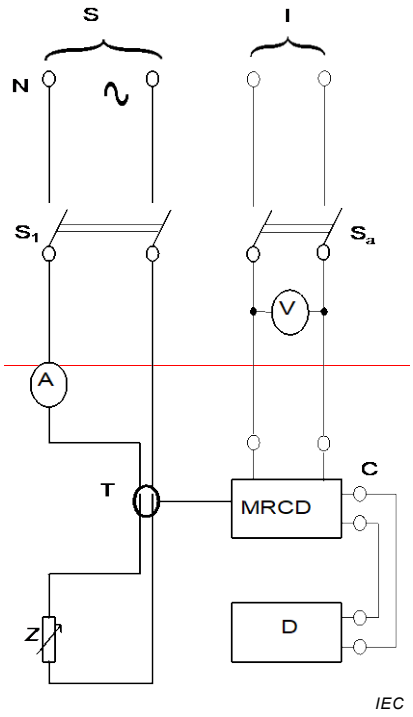


Figure M.4a) – MRCD with separate sensing means

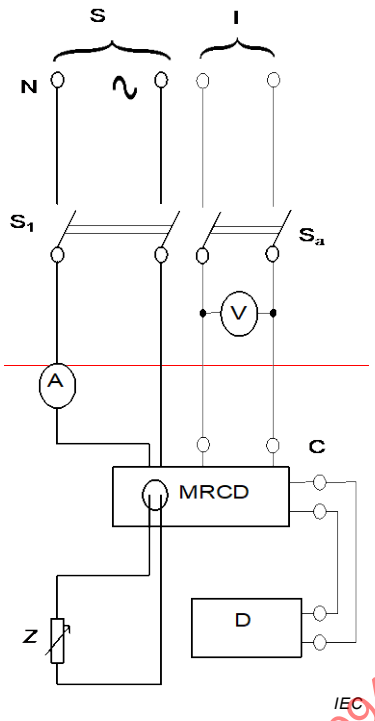


Figure M.4b) – MRCD with integral sensing means

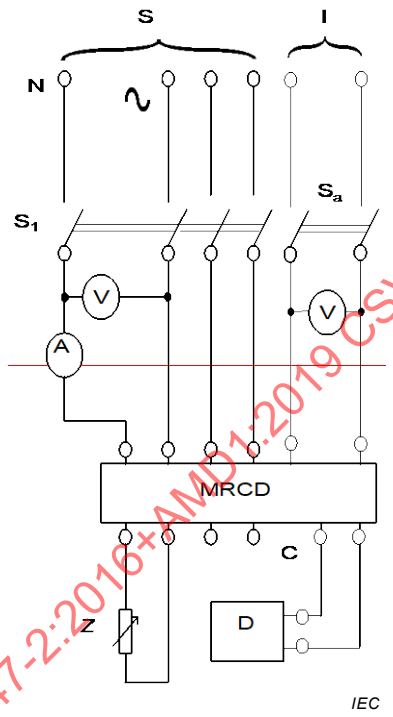


Figure M.4c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multipole switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions

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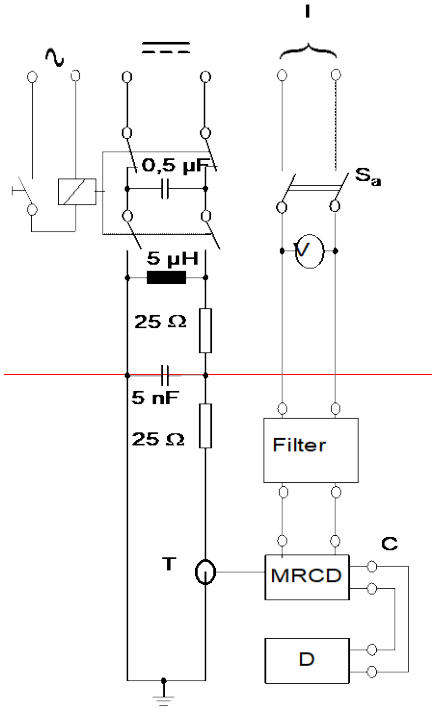


Figure M.5a) – MRCD with separate sensing means

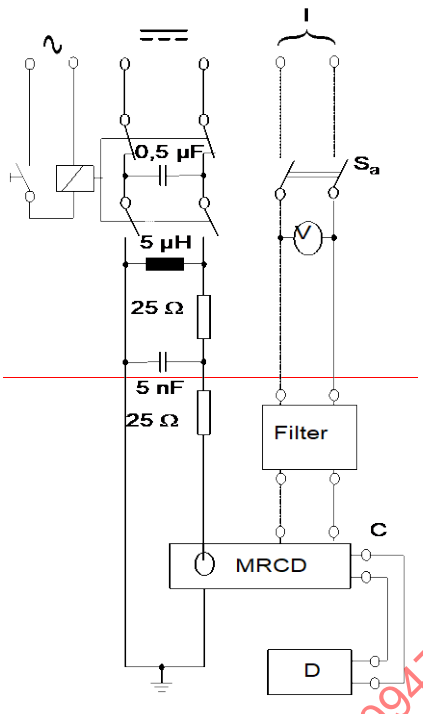


Figure M.5b) – MRCD with integral sensing means

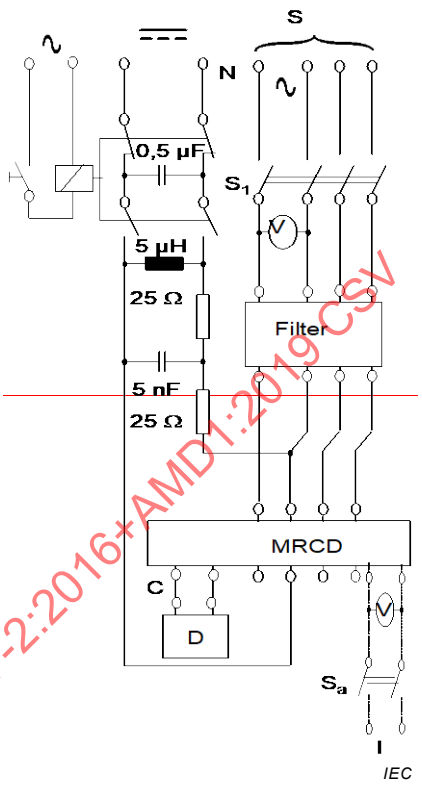


Figure M.5c) – Terminal type MRCD

Key

S power supply

V voltmeter

I separate voltage source, if applicable

S_a auxiliary switch

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

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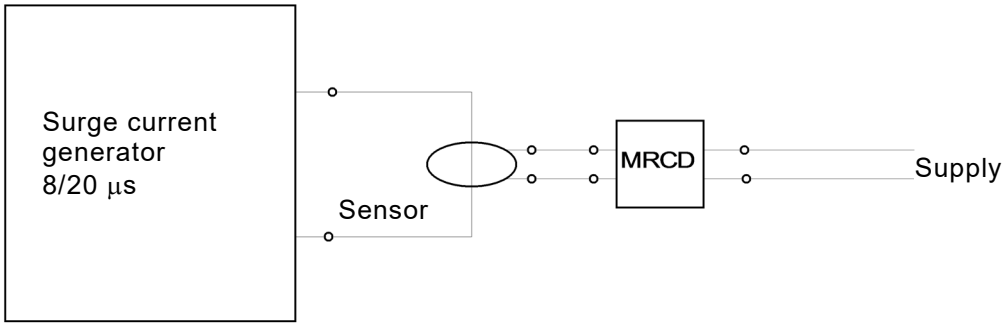


Figure M.6a) MRCD with separate sensing means

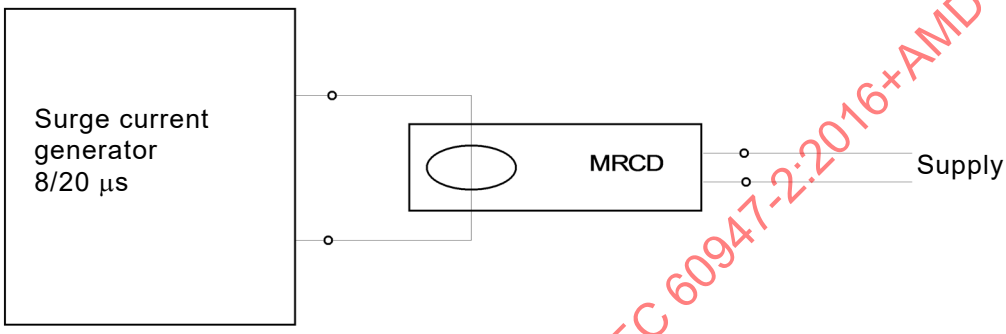


Figure M.6b) MRCD with integral sensing means

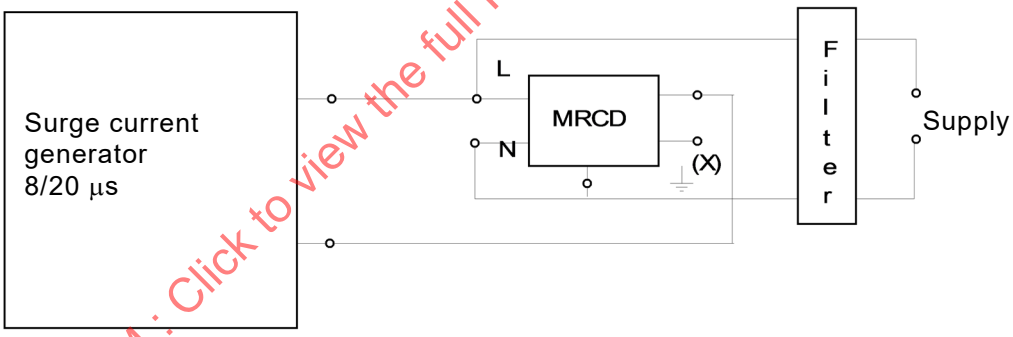


Figure M.6c) Terminals type MRCD

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~~**Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current**~~

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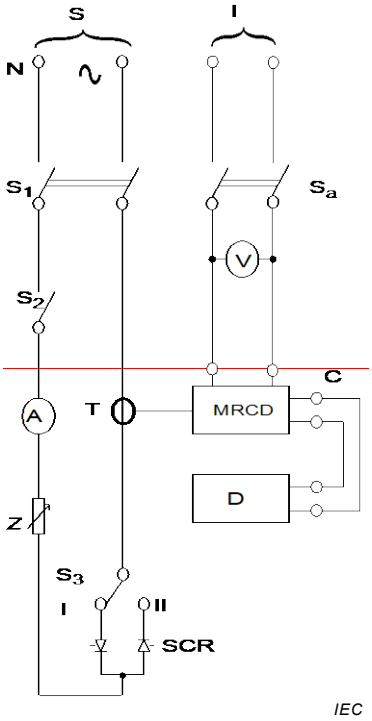


Figure M.7a) – MRCD with separate sensing means

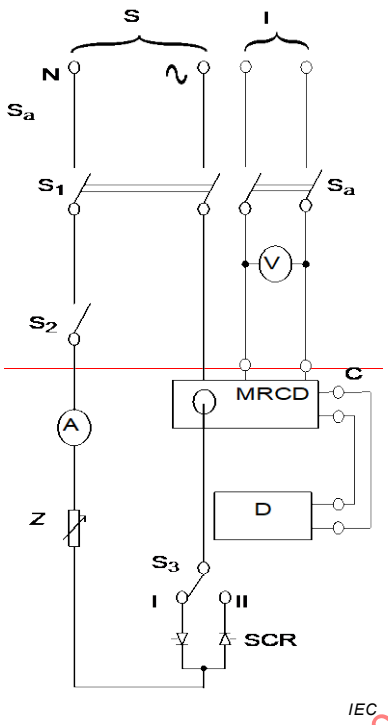


Figure M.7b) – MRCD with integral sensing means

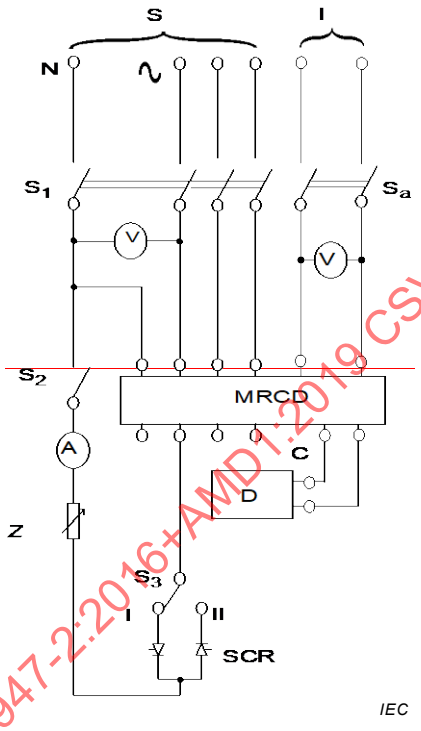


Figure M.7c) – Terminal type MRCD

Key

S power supply
I separate voltage source, if applicable
V voltmeter
A ammeter
S_1 multipole switch
S_2 single-pole switch
S_3 inverter switch
S_a auxiliary switch
Z variable impedance
T sensing means
C output circuit
D instrument indicating the change of status
SCR thyristor

Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current

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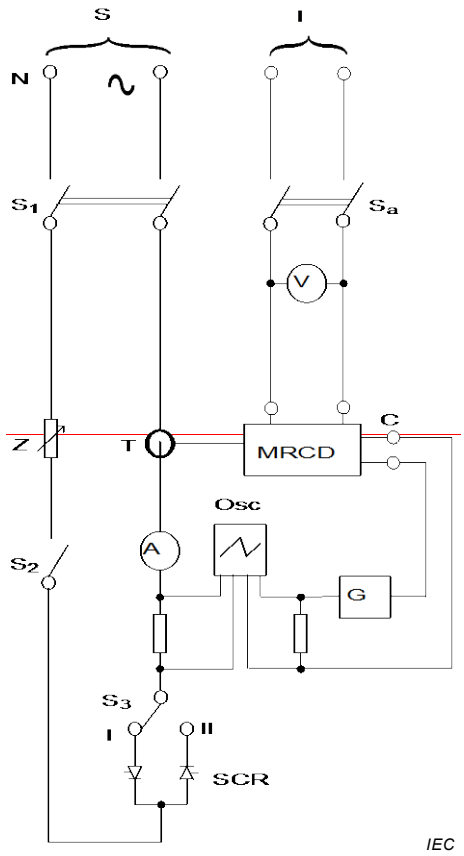


Figure M.8a) – MRCD with separate sensing means

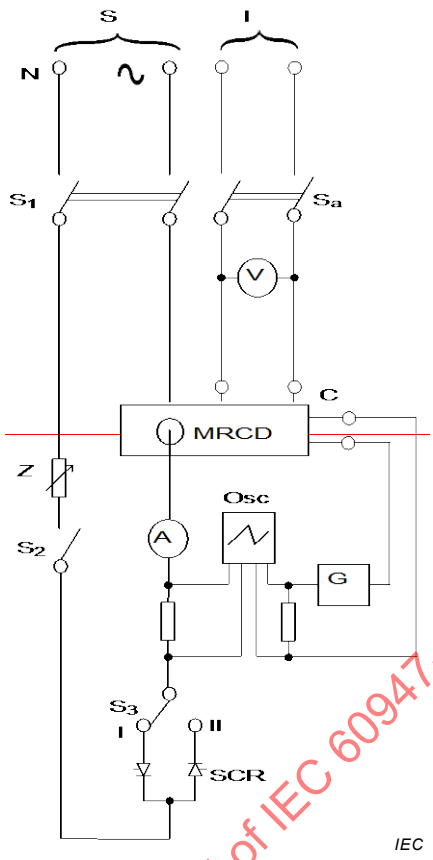


Figure M.8b) – MRCD with integral sensing means

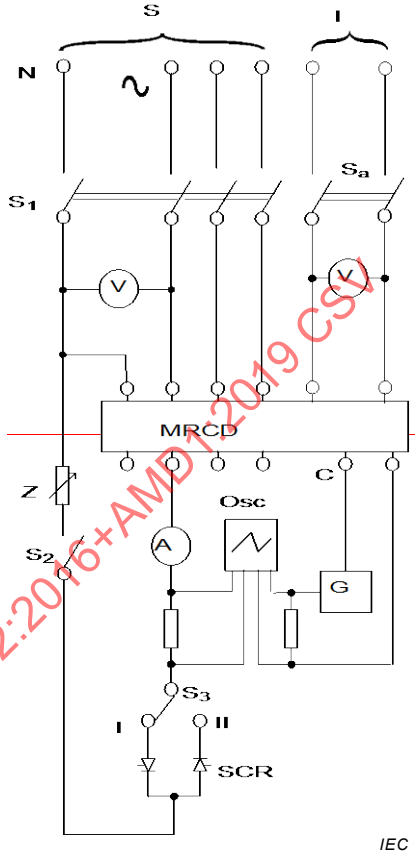


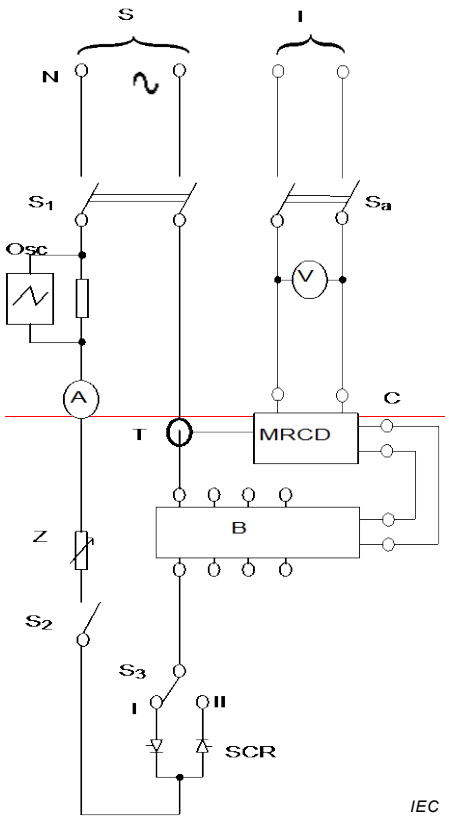
Figure M.8c) – Terminal type MRCD

Key

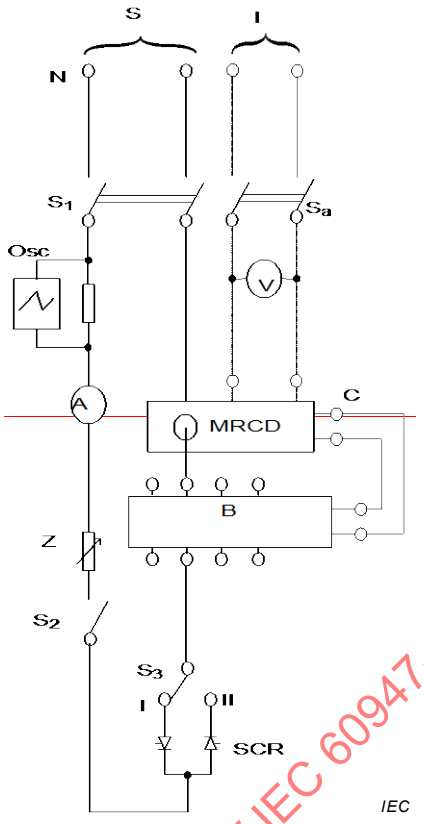
S power supply
I separate voltage source, if applicable
V voltmeter
A ammeter
S_1 multipole switch
S_2 single-pole switch
S_3 inverter switch
Sa auxiliary switch
Z variable impedance
T sensing means
C output circuit
G generator
Osc oscilloscope
SCR thyristor

Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without breaking device)

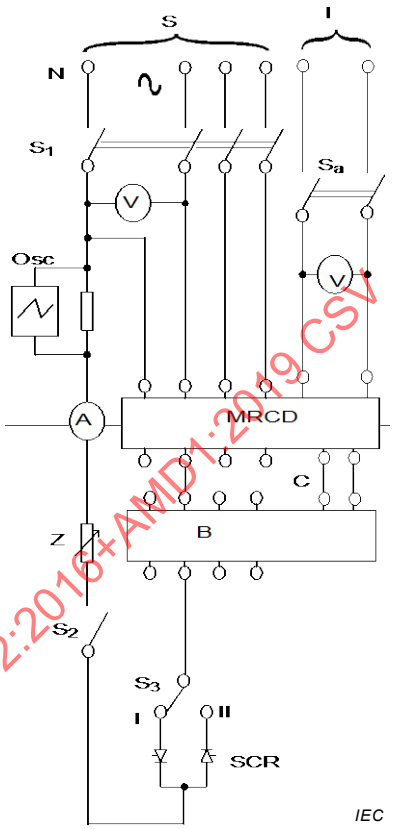
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~~Figure M.9a) – MRCD with separate sensing means~~



~~Figure M.9b) – MRCD with integral sensing means~~



~~Figure M.9c) – Terminal type MRCD~~

~~Key~~

~~S power supply~~
~~I separate voltage source, if applicable~~
~~V voltmeter~~
~~A ammeter~~
~~S_1 multipole switch~~
~~S_2 single-pole switch~~
~~S_3 inverter switch~~
~~S_a auxiliary switch~~
~~Z variable impedance~~
~~T sensing means~~
~~C output circuit~~
~~B breaking device~~
~~Osc oscilloscope~~
~~SCR thyristor~~

~~Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with breaking device)~~

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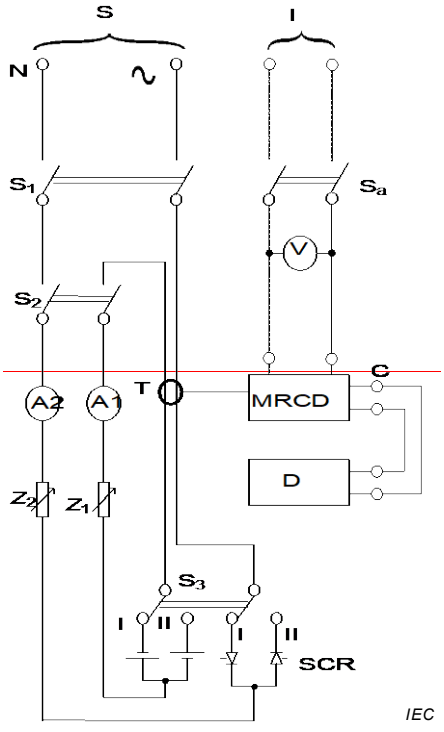


Figure M.10a) – MRCD with separate sensing means

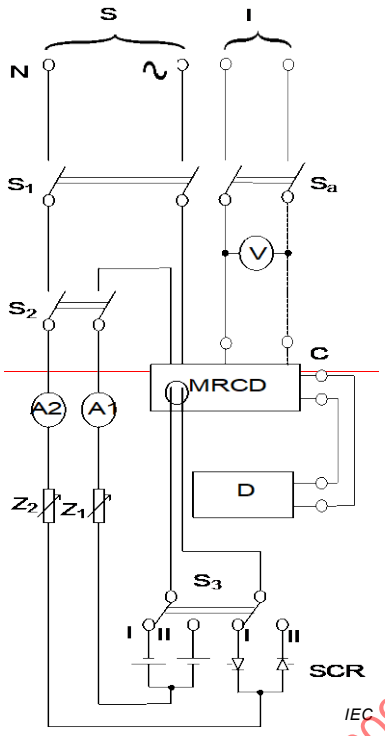


Figure M.10b) – MRCD with integral sensing means

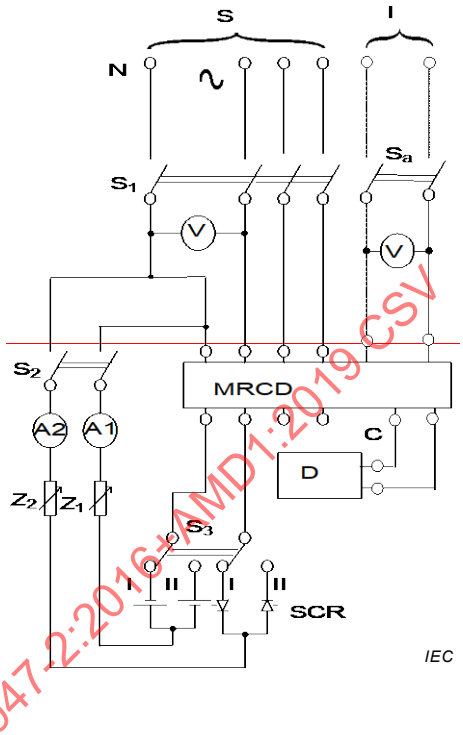


Figure M.10c) – Terminal type MRCD

Key

S power supply

I separate voltage source if applicable

V voltmeter

A_1 ammeter measuring d.c. current

A_2 ammeter measuring a.c. r.m.s. current

S_1 multipole switch

S_2 two-pole switch

S_3 double inverter switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

D instrument indicating the change of status

SCR thyristor

Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by smooth direct current of 6 mA

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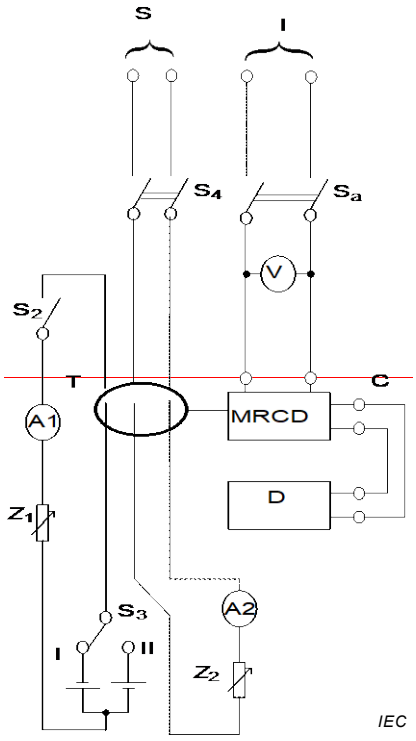


Figure M.11a) – MRCD with separate sensing means

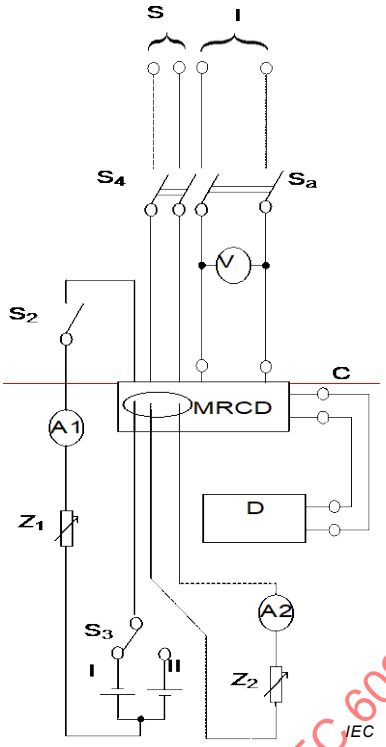


Figure M.11b) – MRCD with integral sensing means

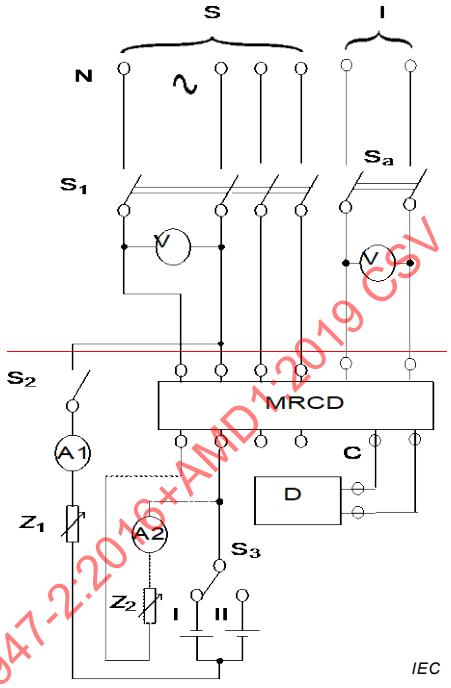


Figure M.11c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A_1 ammeter measuring d.c. current

A_2 ammeter measuring a.c. r.m.s. current

S_1 multipole switch

S_2 single-pole switch

S_3 double inverter switch

S_4 two-pole switch

S_a auxiliary switch

Z_1, Z_2 variable impedances

T sensing means

C output circuit

D instrument indicating the change of status

Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current

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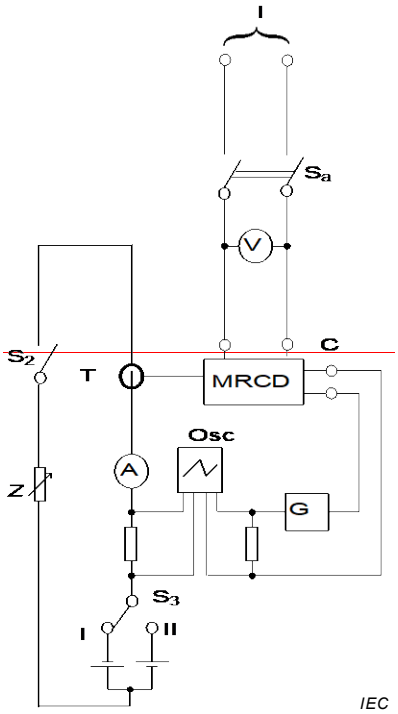


Figure M.12a) – MRCD with separate sensing means

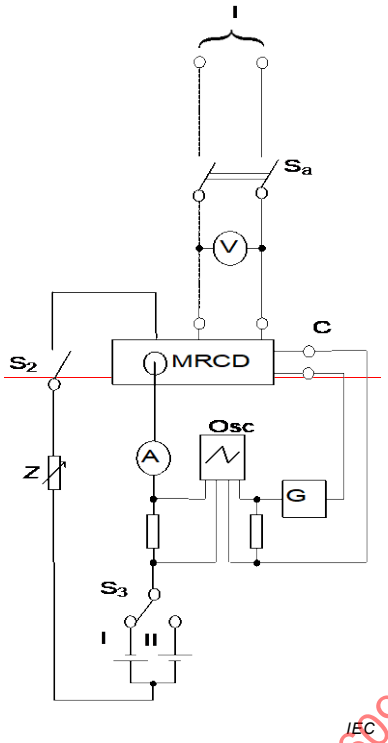


Figure M.12b) – MRCD with integral sensing means

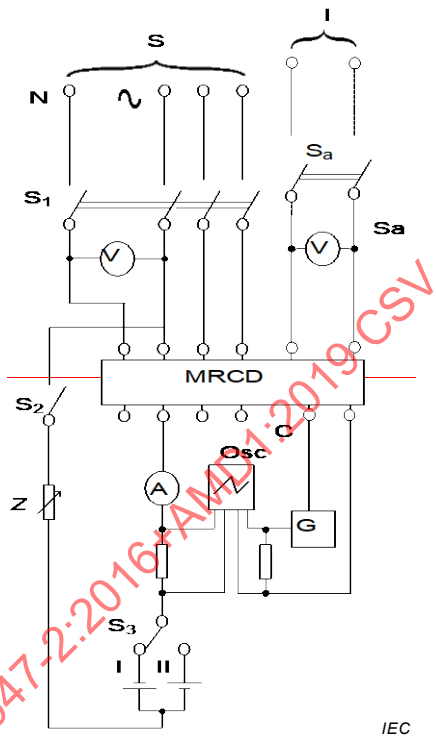


Figure M.12c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter measuring d.c. current

S_1 multipole switch

S_2 single-pole switch

S_3 inverter switch

S_a auxiliary switch

Z variable impedance

T sensing means

C output circuit

G generator

Osc oscilloscope

Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without breaking device)

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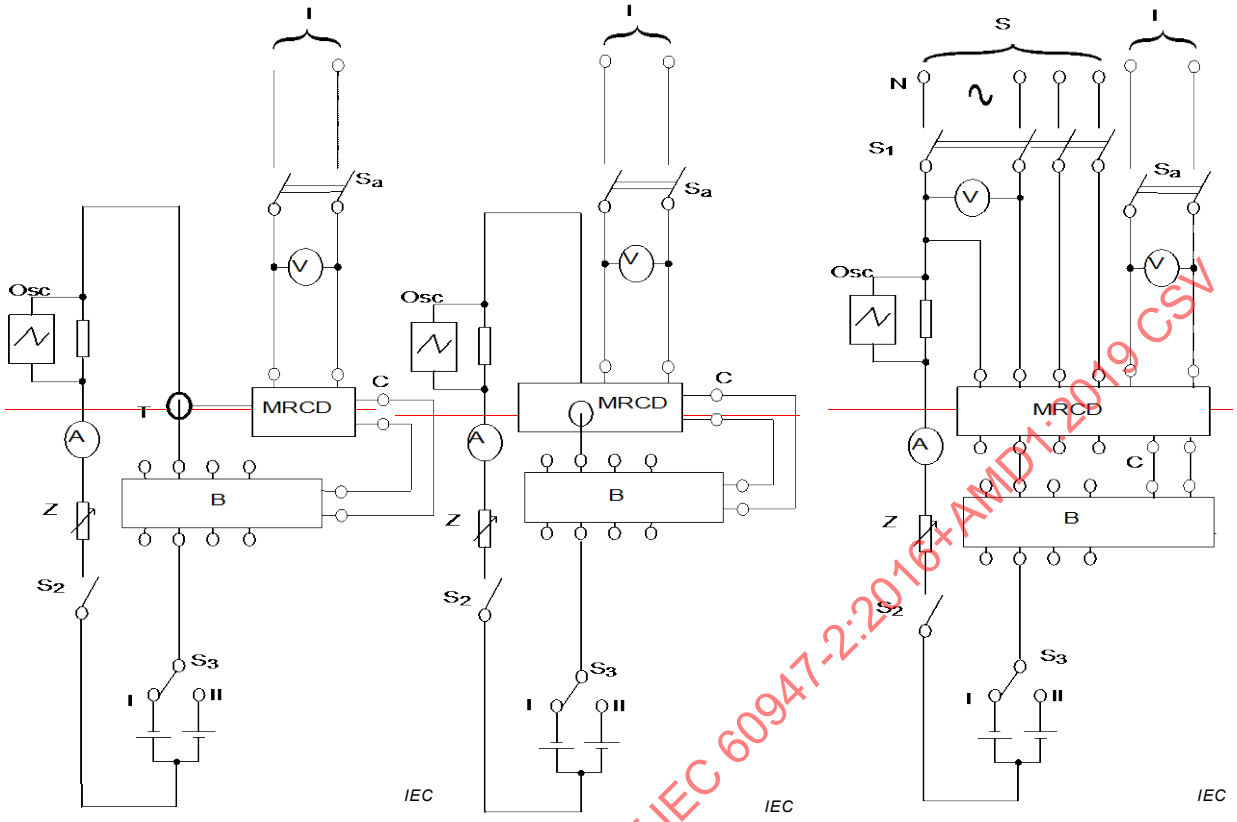


Figure M.13a) – MRCD with separate sensing means

Figure M.13b) – MRCD with integral sensing means

Figure M.13c) – Terminal type MRCD

Key

S power supply

I separate voltage source if applicable

V voltmeter

A ammeter measuring d.c. current

S_1 multipole switch

S_2 single-pole switch

S_3 inverter switch

S_a auxiliary switch

Z variable impedance

T sensing means

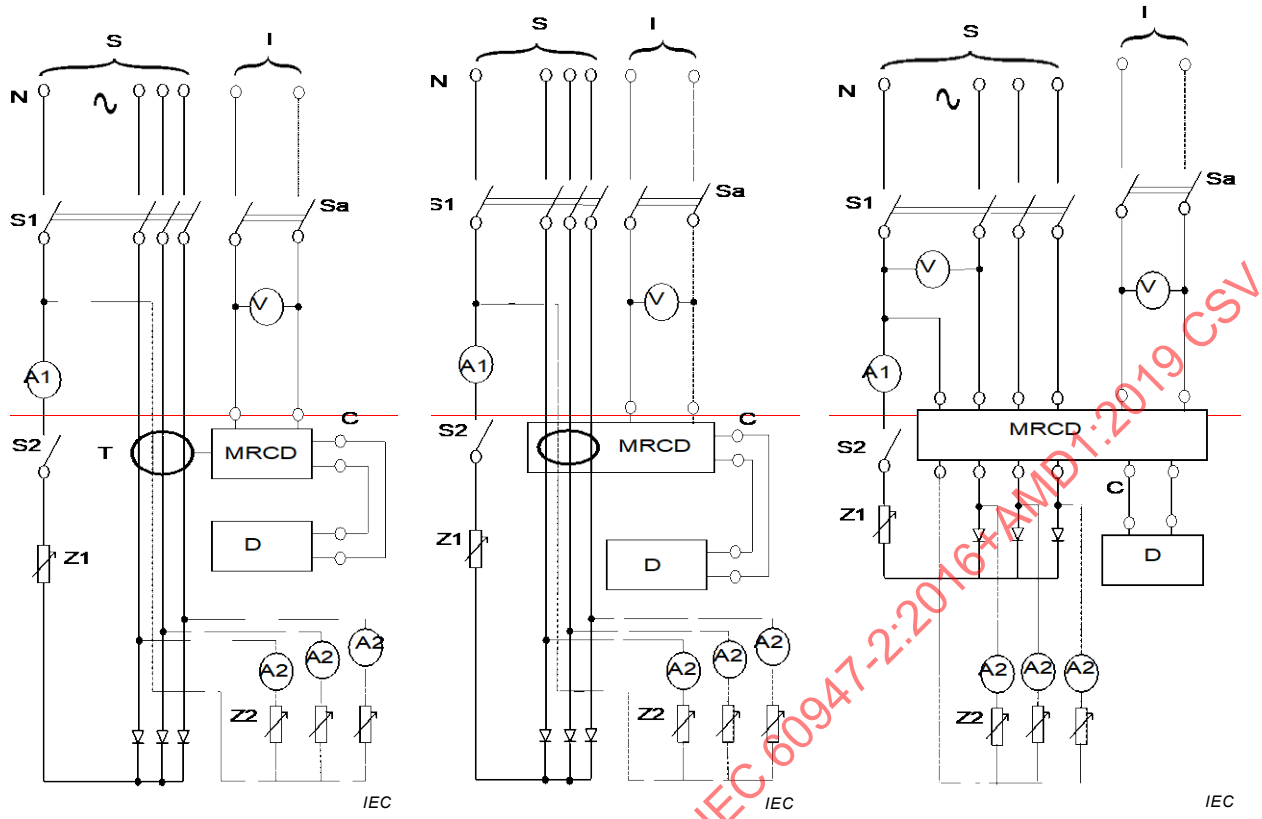
C output circuit

B breaking device

Osc oscilloscope

Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with breaking device)

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~~Figure M.14a) – MRCD with separate sensing means~~

~~Figure M.14b) – MRCD with integral sensing means~~

~~Figure M.14c) – Terminal type MRCD~~

~~Key~~

~~S power supply~~

~~I separate voltage source, if applicable~~

~~V voltmeter~~

~~A_1 ammeter measuring r.m.s. current~~

~~A_2 ammeter measuring a.c. current~~

~~S_1 multipole switch~~

~~S_2 single-pole switch~~

~~S_a auxiliary switch~~

~~Z_1, Z_2 variable impedances~~

~~T sensing means~~

~~C output circuit~~

~~D instrument indicating the change of status~~

~~Figure M.14 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection~~

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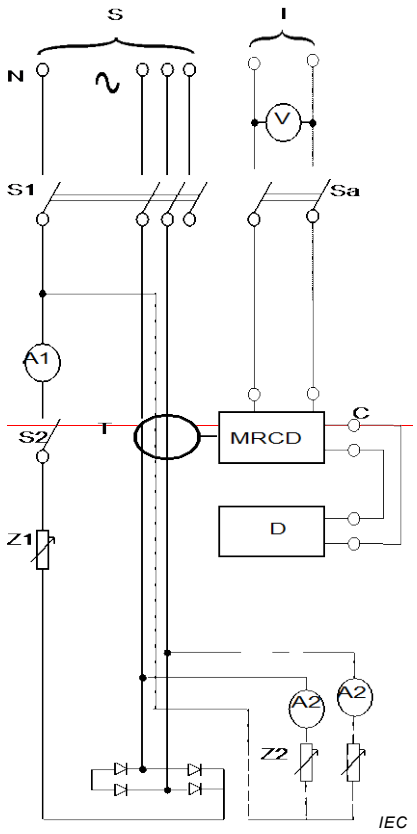


Figure M.15a) – MRCD with separate sensing means

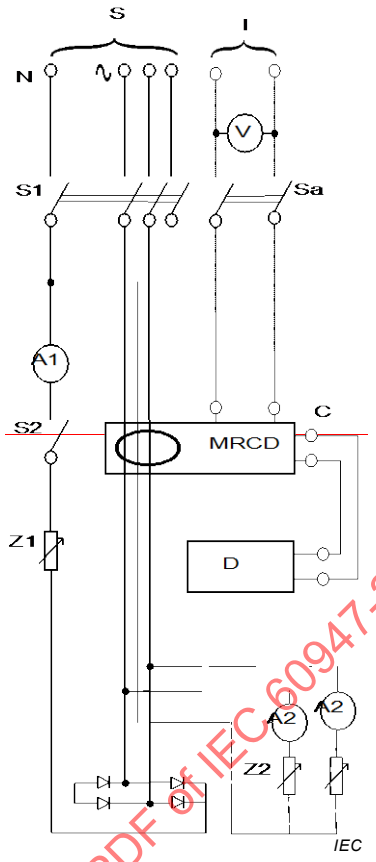


Figure M.15b) – MRCD with integral sensing means

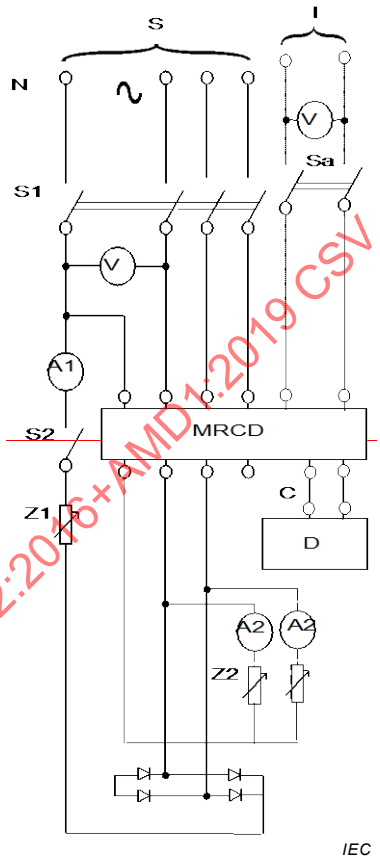


Figure M.15c) – Terminal type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A_1 ammeter measuring r.m.s. current

A_2 ammeter measuring a.c. current

S_1 multipole switch

S_2 single-pole switch

S_a auxiliary switch

Z_1, Z_2 variable impedances

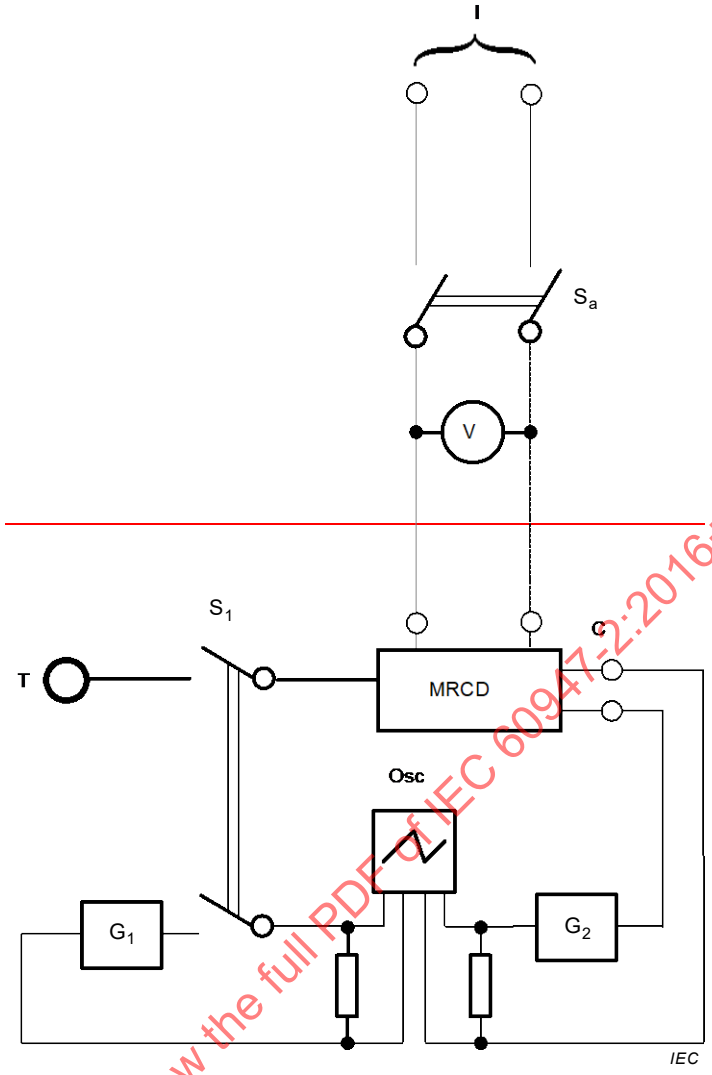
T sensing means

C output circuit

D instrument indicating the change of status

Figure M.15 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line

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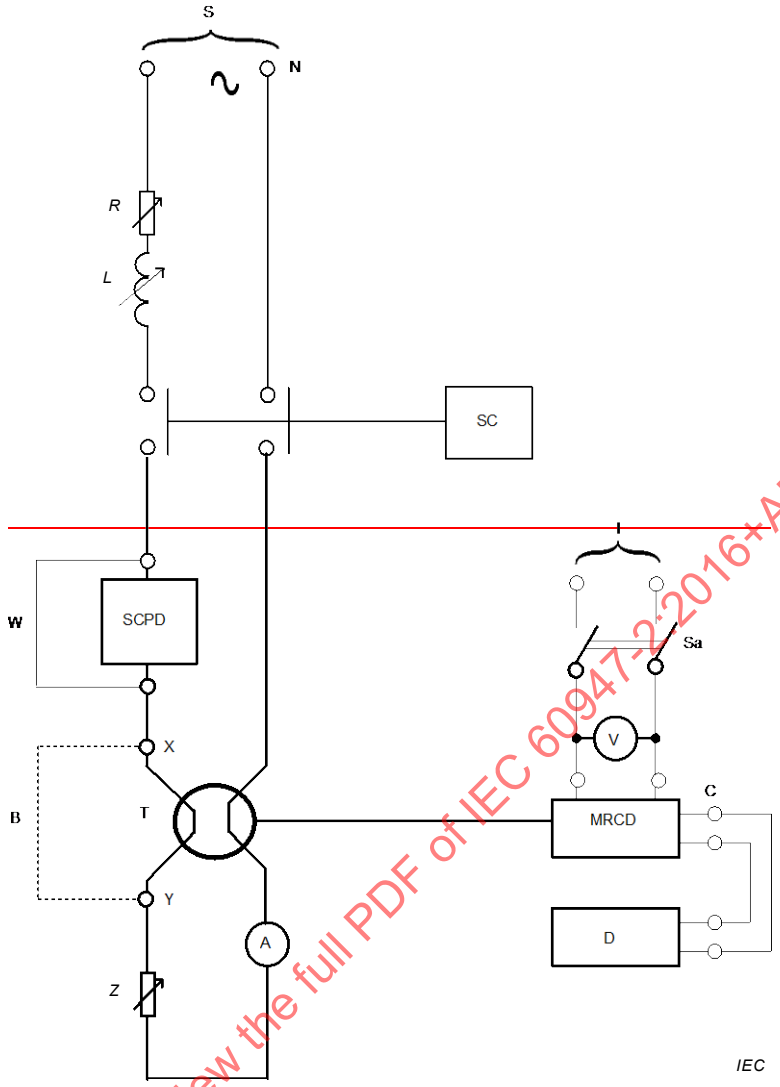


Key

I separate voltage source, if applicable
V voltmeter
S_1 multipole switch
S_a auxiliary switch
T sensing means
C output circuit
G generator
Osc oscilloscope

Figure M.16 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensor means connection

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Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistance

Z variable impedance

T sensing means

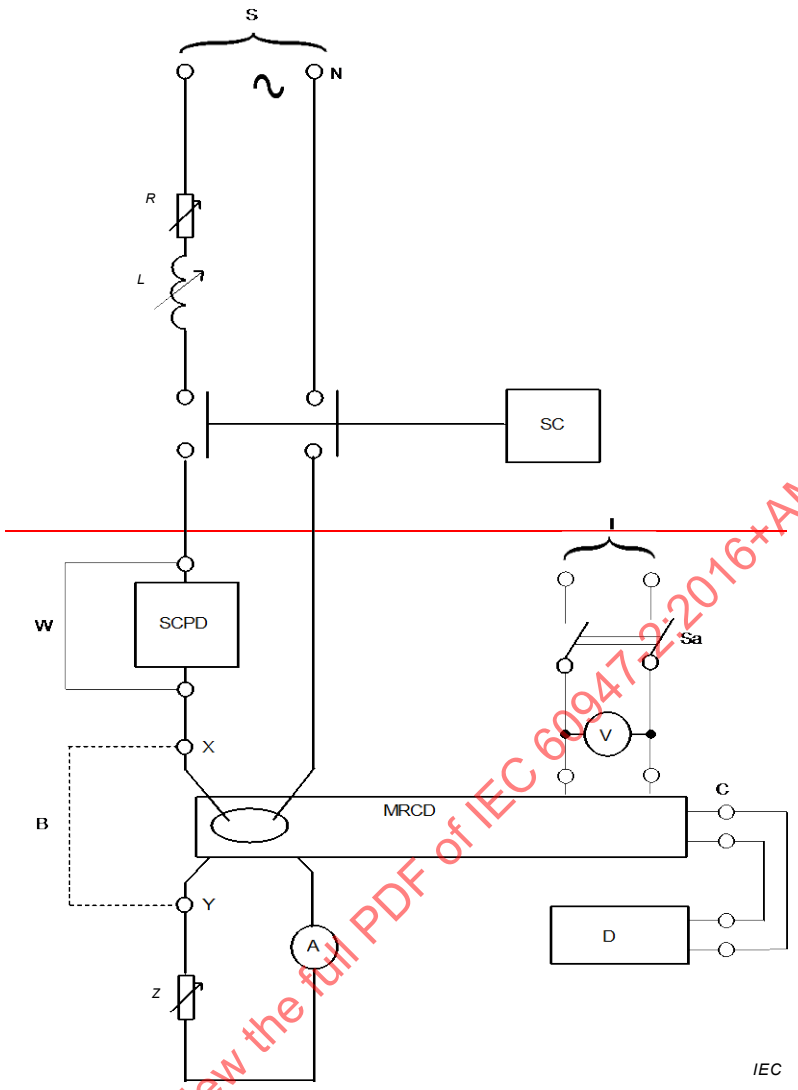
C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.17 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions

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Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistance

Z variable impedance

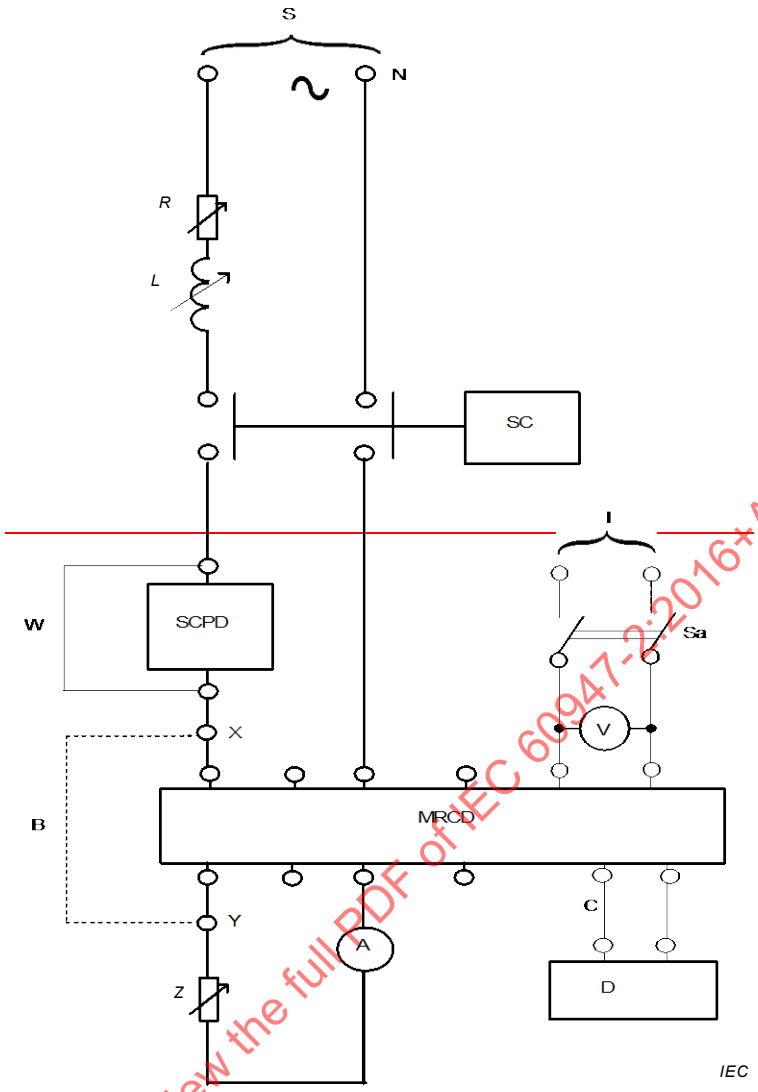
C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.18 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions

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Key

S power supply

A ammeter

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L variable reactor

R variable resistor

Z variable impedance

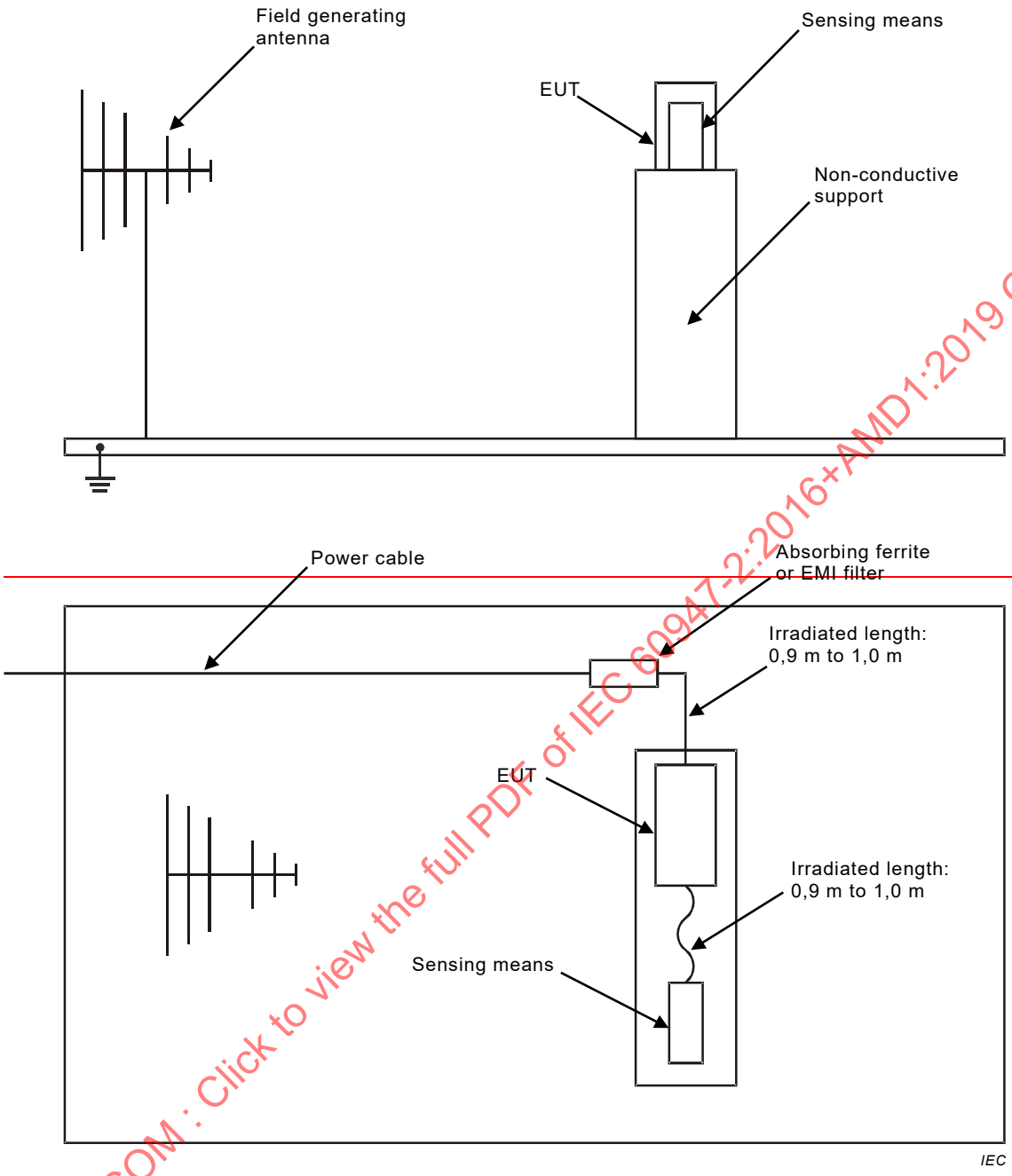
C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

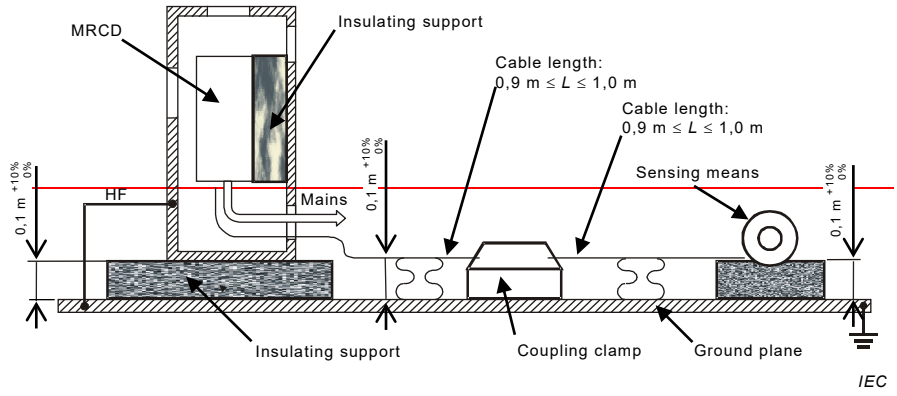
Figure M.19 – Test circuit for the verification of the behaviour of terminal type MRCD under short-circuit conditions

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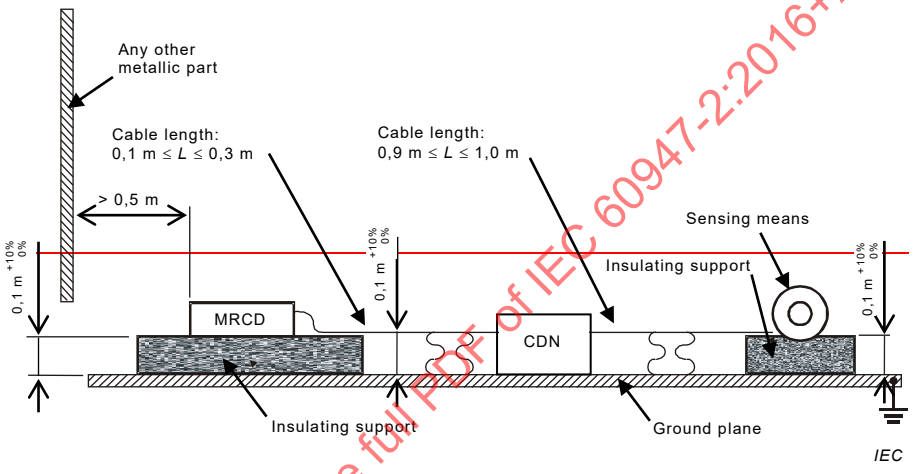


~~Figure M.20 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCD with separate sensing means (additional to the test of Annex B)~~

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~~Figure M.21 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (additional to the test of Annex B)~~



~~Figure M.22 – Verification of immunity to conducted disturbances induced by RF fields – Test set up for MRCD with separate sensing means (additional to the test of Annex B)~~

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M.1 General

M.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Residual current devices, where the current-sensing means and the processing device are mounted together with the circuit-breaker, are covered in Annex B.

The provisions of Annex B apply to this annex, adapting, amending or supplementing Annex B as necessary to cover its applicability to equipment where the current-sensing means and/or the processing device are mounted separately from the current-breaking device.

Throughout this annex, "CBR" as used in Annex B (see B.2.3.1) is replaced by "MRCD" (see M.2.2.1).

Wherever relevant, reference is made to the corresponding subclause of Annex B. In other cases, reference is made to the relevant subclause of the main body of this document, or, where applicable, of IEC 60947-1.

Since the equipment covered by this annex does not include a current-breaking device, certain conventional phrases used in Annex B have been adapted accordingly in this annex, e.g. "ON position" is replaced by "ready condition", meaning "ready to operate".

M.1.2 Scope and object

This annex applies to residual current operated devices which do not incorporate a current-breaking device, hereinafter called "Modular Residual Current Device (MRCD)". They are primarily intended to be used in conjunction with circuit-breakers in accordance with this document.

They may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements that shall be complied with by the MRCD in association with the specified current-breaking device(s).

M.2 Terms and definitions

The terms and definitions of Annex B apply.

The following additional terms and definitions apply to this annex.

M.2.1 Terms and definitions relating to the energization of an MRCD

M.2.1.1
voltage source
source intended to supply the energizing quantity that may consist of:

– the line voltage;
– a voltage other than the line voltage

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M.2.2 Terms and definitions relating to the operation and the functions of an MRCD

M.2.2.1
modular residual current device
MRCD
device or an association of devices comprising a current-sensing means and a processing device designed to detect and to evaluate the residual current and to control the opening of the contacts of a current-breaking device

M.2.2.2 Terms and definitions relating to time

M.2.2.2.1
operating time of an MRCD
time that elapses between the instant when the residual operating current is suddenly applied and the instant when the MRCD output changes status

M.2.2.2.2
combination time
time that elapses between the instant when the residual operating current is suddenly applied and the instant of the arc extinction of the associated current-breaking device

M.2.2.2.3
limiting non-operating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the MRCD without actually bringing it to operate

M.2.3
conditional residual short-circuit current
prospective residual current that an MRCD, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions

M.2.4
residual short-time withstand current
residual current that an MRCD in the closed position can carry during a specified short time under specified conditions

M.3 Classification

M.3.1 Classification according to the configuration of the primary conductors

M.3.1.1 Terminal type: MRCD with incoming and outgoing terminals and integral primary conductors

M.3.1.2 Through-conductor type

M.3.1.2.1 MRCD with sensing means and processing device combined

M.3.1.2.2 MRCD with sensing means and processing device separated

M.3.2 Classification according to the method of operation

M.3.2.1 MRCD without voltage source (see Figure M.22)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in the case of failure of the voltage source

M.3.2.2.2 Not operating automatically after failure of the voltage source but able to operate as intended in the case of a residual current fault

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M.3.3 Classification according to the possibility of adjusting the residual operating current

Subclause B.3.2 applies.

M.3.4 Classification according to time delay of the residual current function

Subclause B.3.3 applies.

M.3.5 Classification according to behaviour in presence of a d.c. component

M.3.5.1 MRCD of type AC (see M.4.2.2.1)

M.3.5.2 MRCD of type A (see M.4.2.2.2)

M.3.5.3 MRCD of type B (see M.4.2.2.3)

M.4 Characteristics of MRCDs

M.4.1 General characteristics

M.4.1.1 Characteristics of the monitored circuit

M.4.1.1.1 Rated frequency range

Range of frequency values of the monitored circuit for which the MRCD is designed and for which it operates correctly under specified conditions.

M.4.1.1.2 Rated voltage (U_n)

Value of the voltage assigned by the manufacturer to the MRCD.

M.4.1.1.3 Rated current (I_n)

M.4.1.1.3.1 Terminal type

Subclause 4.3.3.3 applies.

M.4.1.1.3.2 Through-conductor type

Value of current, assigned to the MRCD by the manufacturer and marked in accordance with Table M.1, item M1.4, which the MRCD can monitor in uninterrupted duty under specified conditions (see M.8.6).

M.4.1.1.4 Rated insulation voltage (U_i)

Voltage, assigned by the manufacturer, to which the dielectric tests and the MRCD creepage distances are referred with respect to the monitored circuit.

M.4.1.1.5 Rated impulse withstand voltage (U_{imp})

Peak value of the impulse voltage that the MRCD can withstand without failure and to which the values of the clearances are referred with regard to the monitored circuit.

M.4.1.2 Characteristics of the voltage source of MRCDs

M.4.1.2.1 Rated values of the voltage source of MRCDs (U_s)

Values of the voltage source to which the operating functions of the MRCD are referred.

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M.4.1.2.2 Rated values of the frequencies of the voltage source of MRCDs

Values of the frequencies of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.3 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

NOTE In the case of a specified power supply, the requirement applies to the incoming connections.

M.4.1.3 Characteristics of auxiliary contacts

Subclause 4.6 of IEC 60947-1:2007 applies.

M.4.2 Characteristics of MRCDs concerning their residual current function

M.4.2.1 General

Subclause B.4.2.4 applies, replacing "non-actuating time" by "non-operating time", and with the following additions.

The maximum values of the MRCD operating time shall be stated by the manufacturer for residual current values equal to $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (or 0,25 A for $I_{\Delta n} \leq$ 30 mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n} \leq$ 30 mA).

The maximum combination time shall comply with Table B.1 for a non-time-delay type MRCD and with Table B.2 for a time-delay type MRCD having a limiting non-operating time of 0,06 s.

MRCDs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type.

M.4.2.2 Operating characteristic in the case of residual current with d.c. component

M.4.2.2.1 Type AC MRCD

Subclause B.4.4.1 applies.

M.4.2.2.2 Type A MRCD

Subclause B.4.4.2 applies.

M.4.2.2.3 Type B MRCD

Subclause B.4.4.3.applies

M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

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M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 4.3.6.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.4 Peak withstand current

Subclause 2.5.28 of IEC 60947-1:2007 applies to the primary circuit of the MRCD.

M.4.3.5 Rated residual short-time withstand current ($I_{\Delta w}$)

The rated residual short-time withstand current of an equipment is the value of residual short-time withstand current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in this document.

M.4.4 Preferred and limiting values

M.4.4.1 Preferred values of the rated residual operating current ($I_{\Delta n}$)

Subclause B.4.2.1 applies.

M.4.4.2 Minimum value of the rated residual non-operating current ($I_{\Delta no}$)

Subclause B.4.2.3 applies.

M.4.4.3 Limiting value of the non-operating overcurrent in the case of a single-phase load in a multiphase circuit

Subclause B.4.2.4 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

Subclause 4.5.1 applies.

M.5 Product information

The MRCD, processing device or sensing means, as applicable, shall be provided with the information as given in Table M.1. Any marking shall be durable. The marking shall be on the MRCD itself or on one or more nameplates.

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Table M.1 – Product information

Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M1.1	operating characteristic in the case of residual currents in the presence or absence of a d.c. component: – MRCDs of type AC with the symbol (IEC 60417-6148:2012-01) – MRCDs of type A with the symbol (IEC 60417-6149:2012-01) – MRCDs of type B with the symbol (IEC 60417-6398:2017-12) or (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	-	Visible
M1.2	rated residual operating current (value(s) or range, as applicable) ($I_{\Delta n}$)	Visible	-	Visible
M1.3	limiting non-operating time (value or range) at 2 $I_{\Delta n}$ for time-delay type, as applicable (Δt)	Visible	-	Visible
M1.4	maximum rated current of the monitored circuit (I_n)	Visible	Marked	Visible [a]
M1.5	test device with the letter "T"	Visible	-	Visible
M2.1	manufacturer's name or trade mark	Marked	Marked	Marked
M2.2	type designation or catalogue reference	Marked	Marked	Marked
M2.3	IEC 60947-2	Marked	-	Marked
M2.4	rated voltage of the voltage source (U_s)	Marked	-	Marked
M2.5	rated voltage of the monitored circuit (U_n)	Marked	Marked	-
M2.6	rated impulse voltage of the monitored circuit (U_{imp})	Marked	Marked	-
M3.1	rated frequency of the voltage source	Literature	-	Literature
M3.2	rated impulse withstand voltage of the voltage source (U_{imp})	Literature	-	Literature
M3.3	output characteristics and/or specified current-breaking device(s)	Literature	-	Literature
M3.4	rated residual non-operating current if it differs from 0,5 $I_{\Delta n}$ ($I_{\Delta no}$)	Literature	-	Literature
M3.5	rated frequency of the monitored circuit	Literature	Literature	-
M3.6	lowest residual current setting at 6 I_n for MRCDs with separate sensing means	-	Literature	Literature
M3.7	rated conditional short-circuit current (I_{cc}) and/or rated short-time withstand current (I_{cw}), and rated conditional residual short-circuit current ($I_{\Delta c}$)	Literature	Literature	Literature
M3.8	IP code, where applicable (see Annex C of IEC 60947-1:2007)	Literature	Literature	Literature
M3.9	position of use and mounting precautions	Literature	Literature	Literature
M3.10	wiring diagram	Literature	Literature	Literature
M3.11	connection of the sensing means to the processing device (cable type, length, etc.)	-	Literature	-

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Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M3.12	for a through conductor type MRCD, dimensions of the conductor aperture (s) and the position relative to the sensing means	Literature	Literature	-
M3.13	for a terminal type MRCD, the maximum cross-sectional area of the conductors to be connected	Literature	-	-
M3.14	distances to be respected with regard to nearby conductors	Literature	Literature	Literature
M3.15	conditions to be observed for the connections between the processing device and the current-breaking device	Literature	-	Literature
M3.16	the SCPDs to be associated with the MRCD	Literature	-	Literature
M3.17	for a non-time-delay type, the current-breaking device(s) to be associated with MRCD to meet the maximum combination times of Table B.1	Literature	-	Literature
M3.18	for a time-delay type having a limiting non-operating time of 0,06 s, the current-breaking device(s) to be associated with the MRCD to meet the combination times of Table B.2	Literature	-	Literature
Key Visible: visible from the front when the MRCD is installed as in service and the test device is accessible Marked: marked on the product Literature: provided in the manufacturer's literature				
[a] Only applicable if the residual current is marked as a percentage of I_n.				

M.6 Normal service, mounting and transport conditions

Clause 6 applies.

M.7 Design and operating requirements

M.7.1 Design requirements

It shall not be possible to modify the operating characteristic of an MRCD except by means which are specifically provided for setting the rated residual operating current or the definite time delay. Changing from one setting to another shall only be possible through a deliberate action, such as the use of a tool, a password or equivalent means.

NOTE MRCDs can be provided with means indicating the status of the outputs.

M.7.2 Operating requirements

M.7.2.1 Operation in the case of a residual current

Subclause B.7.2.1 applies.

Compliance shall be checked by the tests of M.8.3.

M.7.2.2 Operation under short-circuit conditions

MRCDs shall have a rated conditional short-circuit current (I_{cc}) or a rated short-time withstand current (I_{cw}), but may have both. They shall also have a rated conditional residual short-circuit current ($I_{\Delta c}$) or a rated residual short-time withstand current ($I_{\Delta w}$), but may have both.

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MRCDs shall meet the requirements of the relevant tests of M.8.14.

M.7.2.3 Mechanical and electrical endurance

MRCDs shall meet the requirements of the tests of M.8.11.

M.7.2.4 Effects of environmental conditions

MRCDs shall meet the requirements of the test of M.8.15.

M.7.2.5 Dielectric properties

MRCDs shall be capable of withstanding the impulse withstand voltage declared by the manufacturer in accordance with 7.2.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

MRCDs shall meet the requirements of the tests of M.8.4.

Clearances from the live parts of the monitored circuit to:

– the live parts of the MRCD,
– the parts intended to be grounded,
– the clearances between the current paths, for terminal-type MRCDs,

shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 according to the rated impulse withstand voltage.

M.7.2.6 Test device

MRCDs shall be provided with a test device to simulate the passing through the detecting device of a residual current, in order to allow periodic testing of the ability of MRCDs to operate.

The test device shall satisfy the tests of M.8.5.

The protective conductor, if any, shall not become live when the test device is operated.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; the use of a light colour is recommended.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

M.7.2.7 Value of the non-operating overcurrent in the case of a single phase load

MRCDs shall meet the requirements of the test of M.8.6.

M.7.2.8 Resistance of MRCDs to unwanted tripping due to surge currents resulting from impulse voltages

MRCDs shall withstand the test of M.8.7.

M.7.2.9 Behaviour of MRCDs of types A and B in the case of an earth fault current comprising a d.c. component

MRCDs of type A and type B shall meet the requirements of the tests of M.8.8, as applicable.

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M.7.2.10 Requirements for MRCDs with voltage source

MRCDs functionally dependent on a voltage source shall operate correctly at any value of the voltage between 0,85 and 1,1 times the rated value U_s (see Figure M.22 and M.4.1.2.1).

According to their classification, MRCDs functionally dependent on a voltage source shall comply with the requirements given in Table M.2.

Table M.2 – Requirements for MRCDs with voltage source

Classification of the device according to M.3.2.2	Behaviour in the case of failure of the voltage source
MRCD operating automatically without delay in the case of voltage source failure (M.3.2.2.1)	Operating without delay according to M.8.12
MRCD operating automatically with delay in the case of voltage source failure (M.3.2.2.1)	Operating with delay according to M.8.12
MRCD not operating automatically after failure of the voltage source but able to operate as intended in the case of a residual-current fault arising (M.3.2.2.2)	Operating according to M.8.13

M.7.2.11 Temperature-rise of terminal-type MRCDs

M.7.2.11.1 General

The temperature rise of the parts of terminal-type MRCDs shall not exceed the values specified in 7.2.2 of IEC 60947-1:2007/AMD2:2014.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014 are only applicable if the ambient air temperature remains between the limits given in M.6.

M.7.2.11.3 Main circuit of terminal type MRCDs

The main circuit of the MRCD, to which the monitored circuit is connected, shall be able to carry the rated current as defined in M.4.1.2.3, without the temperature-rises exceeding the limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014.

M.7.2.12 Electromagnetic compatibility

Requirements of Annex J apply to the sensing means and the processing device of the MRCD, connected in accordance with the manufacturer's instructions.

Tests shall be carried out in accordance with M.8.16.

Immunity to voltage variations is covered by the requirements of M.7.2.10.

M.7.2.13 Behaviour of MRCDs in the case of failure of the sensing means connection

For MRCDs with separate sensing means, if the sensing means are disconnected, then:

– the MRCD shall operate, or
– the MRCD shall provide a signal to indicate such disconnection, or
– it shall be possible to verify the disconnection by operating the test device.

Compliance is verified by the tests of M.8.9.

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M.7.2.14 Behaviour of MRCDs according to the rated frequency

The MRCD shall operate correctly within its rated frequency range.

Compliance is verified by the tests of M.8.3.3 and M.8.5.

M.8 Tests

M.8.1 General

M.8.1.1 Type tests

Type tests are grouped together in a number of sequences, as shown in Table M.3.

In the case of MRCDs with adjustable residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of MRCDs with adjustable time delays (see B.3.3.2.2), the tests shall be carried out at the highest setting, unless otherwise stated.

The release of the associated current breaking device, when applicable, shall be supplied at its lowest rated voltage.

Table M.3 – Test sequences

Sequences	Tests	Subclause
M I	Verification of the operating characteristics	M.8.3
	Verification of dielectric properties	M.8.4
	Verification of the operation of the test device at the limits of rated voltage	M.8.5
	Verification of the limiting value of the non-operating current under overcurrent conditions, in the case of a single phase load	M.8.6
	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	M.8.7
	Verification of the behaviour in the case of an earth fault current comprising a d.c. component	M.8.8
	Verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensing means connection	M.8.9
	Verification of temperature rise of terminal type MRCDs	M.8.10
	Verification of mechanical and electrical endurance	M.8.11
	Verification of the behaviour of MRCDs classified under M.3.2.2.1 in the case of failure of the voltage source	M.8.12
	Verification of the behaviour of MRCDs classified under M.3.2.2.2 in the case of failure of the voltage source	M.8.13
M II	Verification of the behaviour of MRCDs under short-circuit conditions	M.8.14
M III	Verification of the effects of environmental conditions	M.8.15
M IV	Verification of electromagnetic compatibility	M.8.16

For terminal-type MRCDs having variants with different numbers of poles, tests shall be carried out on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants' construction is not identical to the variant tested, then those variants shall also be tested.

One sample shall be tested for each of the test sequences M I, M II and M III.

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For test sequence M IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Unless otherwise specified, each type test (or sequence of type tests) shall be carried out on the MRCD in new and clean condition, the influencing quantities having their normal reference values.

The MRCD shall be installed individually, according to the manufacturer's instructions, in free air, unless otherwise specified. Ambient air temperature shall be between 15 °C and 30 °C, unless otherwise specified. Connections and mounting shall comply with the manufacturer's instructions.

M.8.1.2 Routine tests

Subclause 8.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except in so far as 7.1 applies.

M.8.3 Verification of the operating characteristics

M.8.3.1 General

The MRCD shall be installed, mounted and wired according to the manufacturer's instructions. Unless otherwise specified, it shall be connected to test equipment, as specified by the manufacturer, representing normal service conditions for the output circuit in order to verify the change in the status of the output. For the measurement of the combination time (see M.2.2.2.2), the MRCD shall be connected to a current-breaking device, specified by the manufacturer, and installed in the monitored circuit. The characteristics of this device shall be given in the test report.

M.8.3.2 Test conditions for MRCDs without voltage source

Subclause B.8.2.2 applies.

M.8.3.3 Test conditions for MRCDs with voltage source

The tests shall be carried out at the following values:

– 0,85 times the minimum rated value of the source voltage for tests specified in M.8.3.4 and M.8.3.5.2;

– 1,1 times the maximum rated value of the source voltage for tests specified in M.8.3.5.3.

MRCDs with a range of rated frequencies shall be tested at the highest and lowest frequencies. However, for MRCDs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover both frequencies.

M.8.3.4 Off-load tests at 20 °C ± 5 °C

M.8.3.4.1 General

With the connections as shown in Figure M.1, Figure M.2 or Figure M.3, the MRCD shall comply with the tests of M.8.3.4.2, M.8.3.4.3 and M.8.3.4.4 as well as with the test of M.8.3.4.5 where applicable; all these tests are carried out on a single current path.

Unless otherwise specified:

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– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time delay shall be set to its minimum value.

M.8.3.4.2 Verification of operation in the case of a steady increase of the residual current (Figure M.1)

The switches S_1 and S_2, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current shall be steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, up to $I_{\Delta n}$ in approximately 30 s. The value of current causing the change in status of the output is recorded. The test shall be carried out three times.

The three values measured shall be situated between the rated residual non-operating current $I_{\Delta no}$ and $I_{\Delta n}$.

M.8.3.4.3 Verification of operation in the case of closing on residual current (Figure M.2)

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or at each specific setting of the residual operating current if applicable), the switch S_2 and the current breaking device being closed, switches S_1 and S_a (if applicable) are closed simultaneously. The combination time shall be measured three times.

No measurements shall exceed the limiting value specified for $I_{\Delta n}$ in M.4.2.

M.8.3.4.4 Verification of operation in the case of a sudden appearance of residual current (Figure M.2 and Figure M.3)

The MRCD shall be connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in M.4.2, the switches S_1, and S_a if applicable, and the test equipment being in the closed position, and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}:

– none of the values of operating time shall exceed the values stated by the manufacturer,

– none of the values of combination time shall exceed the limits specified in M.4.2.

M.8.3.4.5 Verification of the limiting non-operating time of time-delayed type MRCDs (Figure M.3)

The MRCD shall be connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at the value 2 $I_{\Delta n}$, the switches S_1, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S_2 for a time equal to the limiting non-operating time declared by the manufacturer in accordance with M.4.2.

The test shall be carried out 3 times. The MRCD shall not operate.

If the MRCD has an adjustable current setting and/or an adjustable time delay, the test shall be carried out, as applicable, at the lowest setting of the residual operating current and at the maximum and minimum settings of the time delay.

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M.8.3.5 Tests at the temperature limits

M.8.3.5.1 General

Subclause B.8.2.5 applies.

M.8.3.5.2 Off-load test at −5 °C

Subclause B.8.2.5.2 applies, but in accordance with M.8.3.4.4 and M.8.3.4.5 if applicable.

M.8.3.5.3 On-load test at +40 °C

Subclause B.8.2.5.3 applies.

After reaching thermal steady-state conditions, the MRCD shall be submitted to the tests described in M.8.3.4.4 and in M.8.3.4.5 if applicable.

M.8.4 Verification of dielectric properties

M.8.4.1 Verification of rated impulse withstand voltage

M.8.4.1.1 General

The MRCD shall comply with the requirements stated in M.7.2.5. The tests shall be carried out in all the auxiliary contact positions.

The tests are carried out in accordance with 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 with the additions listed in M.8.4.1.2 and M.8.4.1.3.

M.8.4.1.2 Verification of rated impulse withstand voltage with respect to the monitored circuit

M.8.4.1.2.1 Tests for terminal type MRCD

The test voltage, defined in M.7.2.5, shall be applied as indicated in 8.3.3.4.1 item 2), of IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Tests for MRCDs of through-conductor type

The test shall be carried out on a sensing means through which runs an uninsulated busbar, installed according to the manufacturer's instructions.

The test voltage, defined in M.7.2.5, shall be applied as follows:

a) between all the conductors of the monitored circuit connected together and the mounting plate if the sensing means are separate;

b) between all the conductors of the monitored circuit connected together and the processing device enclosure or its mounting plate if the sensing means are combined;

c) between each auxiliary circuit and
   - the monitored circuit;
   - the enclosure or mounting plate of the MRCD.

M.8.4.1.3 Verification of rated impulse withstand voltage of the voltage source circuit (if applicable)

If the voltage source circuit is supplied directly from the monitored circuit, the tests are carried out in accordance with M.8.4.1.2.1.

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If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2007 shall be applied as follows:

a) between all the supply terminals of the voltage source circuit connected together and the enclosure or mounting plate of the MRCD;

b) between each supply terminal of the voltage source circuit and the other supply terminals connected together and connected to the enclosure or mounting plate of the MRCD.

M.8.4.2 Capability of any circuits connected to the monitored circuit in respect of withstanding d.c. voltages due to insulation measurements

The need for this verification of MRCDs that cannot be disconnected in service is under consideration.

M.8.5 Verification of the operation of the test device at the limits of the rated voltage

Subclause B.8.4 applies, but by replacing "rated voltage" with "rated voltage of the voltage source". The MRCD shall be tested in association with the test equipment specified in M.8.3.1.

M.8.6 Verification of the limiting value of non-operating current under overcurrent conditions, in the case of a single phase load

The MRCD shall be connected in accordance with Figure M.4 a), b) or c), as applicable, paying particular attention to the positioning of the conductors in the case of a through-conductor type in accordance with the manufacturer's instructions, the switch S_1 being open. The switch S_a, where applicable, is then closed and the voltage U_s is applied.

The test shall be made in accordance with B.8.5 at a current of 6 I_n. For MRCDs with separate sensing means, the test shall be carried out at the lowest residual current setting value declared by the manufacturer.

No change of state of the MRCD shall occur.

M.8.7 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

M.8.7.1 General

For MRCDs with adjustable time delays, the time delay shall be set at its minimum.

M.8.7.2 Verification of the resistance to unwanted tripping in the case of loading of the network capacitance

Subclause B.8.6.2 applies with Figure M.5 replacing Figure B.5.

No change of state of the MRCD shall occur.

M.8.7.3 Verification of the resistance to unwanted tripping in the case of flashover without follow-on current

Subclause B.8.6.3 applies with Figure M.6 replacing Figure B.7.

No change of state of the MRCD shall occur during the test at 250 A. During the test at 3 000 A, the MRCD may operate.

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M.8.7.4 Verification after the tests

After the tests of M.8.7.2 and M.8.7.3, the operation of the MRCD shall be verified in accordance with M.8.3.4.4, with one measurement of operating time, at $I_{\Delta n}$ only.

M.8.8 Verification of the behaviour in the case of an earth fault current comprising a d.c. component

M.8.8.1 General

The test conditions of M.8.3.1, M.8.3.2 and M.8.3.3 apply.

For MRCDs, the operation of which depend on a voltage source, the tests shall be carried out at 1,1 and 0,85 times the rated voltage of the voltage source (U_s).

Unless otherwise specified:

– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time delay shall be set to its minimum value.

M.8.8.2 Type A MRCD

M.8.8.2.1 Verification of the correct operation in the case of a continuous rise of a residual pulsating direct current

Subclause B.8.7.2.1 applies with Figure M.7 replacing Figure B.8.

The switches S_1 and S_2, and S_a if applicable, are closed, the MRCD being ready to operate.

M.8.8.2.2 Verification of the correct operation in the case of a suddenly appearing residual pulsating direct current

B.8.7.2.2 applies with the following modifications.

The test circuit shall be in accordance with Figure M.8 or Figure M.9, as applicable.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement instrument indicating the change in status of the output;

– for the second step, the MRCD is connected to a current-breaking device, specified by the manufacturer, and installed in the monitored circuit. The characteristics of this current-breaking device shall be stated in the test report.

The switches S_1, and S_a if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

The test shall be carried out at each value of the residual current specified:

– for the first step, none of the operating times measured shall exceed the values stated by the manufacturer;

– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

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M.8.8.2.3 Verification of the correct operation with load at the reference temperature

The tests of M.8.8.2.2 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current, the current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure M.7 c).

M.8.8.2.4 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a smooth direct current of 6 mA

B.8.7.2.4 applies with the following modifications.

The test circuit shall be in accordance with Figure M.10 a), b) or c), as applicable.

M.8.8.3 Type B MRCD

M.8.8.3.1 Verification of the correct operation in the case of a steady increase of composite residual current

Subclause B.8.8.1 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

M.8.8.3.2 Verification of the correct operation in the case of sudden appearance of composite residual current

Subclause B.8.8.2 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}.

None of the operating times measured shall exceed the values stated by the manufacturer for the response time at 5 $I_{\Delta n}$ of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.3 Verification of the correct operation in the case of residual sinusoidal alternating currents up to 1 000 Hz

Subclause B.8.8.3 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time at $I_{\Delta n}$ of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1 for $I_{\Delta n}$.

M.8.8.3.4 Verification of the correct operation in the case of a residual alternating current superimposed by a residual smooth direct current

Subclause B.8.8.4 applies, but "MRCD" replaces "CBR", and with the following modification:

The tests shall be performed in accordance with Figure M.17.

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M.8.8.3.5 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a residual smooth direct current

Subclause B.8.8.5 applies, but "MRCD" replaces "CBR", and with the following modification:

The tests shall be performed in accordance with Figure M.10.

M.8.8.3.6 Verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from two phases

Subclause B.8.8.6 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.15.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.7 Verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from three phases

Subclause B.8.8.7 applies, but "MRCD" replaces "CBR", with the following modifications:

The tests shall be performed in accordance with Figure M.14.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.8 Verification of the correct operation in the case of residual smooth direct current

M.8.8.3.8.1 Verification of the correct operation in the case of residual smooth direct current without load

Verification is carried out in two steps:

a) The test circuit shall be in accordance with Figure M.11, switches S_1 and S_2, and S_a if applicable, being closed.

One current path, chosen at random, shall be tested twice in position I and twice in position II of switch S_3.

The residual current, starting from zero, shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. The MRCD shall operate between 0,5 $I_{\Delta n}$ and 2 $I_{\Delta n}$.

b) The test circuits shall be in accordance with Figure M.12 and Figure M.13.

The circuit being successively calibrated at the values specified hereafter, the switch S_1 or S_a, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S_2.

The test shall be carried out at each value of residual current specified in Table B.1, multiplied by two.

Two operating time measurements are performed for each value, the switch S_3 being in position I for the first measurement and in position II for the second measurement.

None of the operating times shall exceed the values stated by the manufacturer, and no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

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M.8.8.3.8.2 Verification of the correct operation in the case of residual smooth direct current with load

The test of M.8.8.3.8.1 a) shall be repeated, the current path under test and another current path of the MRCD being loaded with the rated current.

M.8.8.3.9 Tests at the temperature limits

The MRCD shall perform the tests specified in M.8.8.3.6 and M.8.8.3.7 (but, in each case, only the verification of the operating time) and M.8.8.3.8.1 b), under the following conditions successively:

a) ambient air temperature: −5 °C, without load;

b) ambient air temperature: +40 °C, and, for terminal-type MRCDs, the MRCD having been previously loaded with its rated current until it has attained thermal steady-state conditions. In practice, these conditions are reached when the variation of temperature-rise, measured at one of the main terminals, does not exceed 1 K per hour. The loading of the main circuit may be carried out at reduced voltage but auxiliary circuits shall be supplied with their rated operating voltage, particularly for components depending on the line voltage.

In the case of MRCDs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

M.8.9 Verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensing means connection

M.8.9.1 General

For MRCDs with a range of rated values of the voltage source, tests shall be carried out for each rated value, in accordance with M.8.9.2 or M.8.9.3, as applicable, and in accordance with the manufacturer's instructions.

M.8.9.2 Test method 1

The MRCD shall be connected to the external sensing means and shall be supplied successively with each rated voltage, as shown in Figure M.18. There shall be no fault current flowing in the sensing means and the test circuit shall not be activated.

The sensing means are disconnected and the MRCD shall operate or provide a signal to indicate such disconnection.

The time interval between the disconnection and the output status change is measured.

Three measurements are carried out; no value shall exceed 5 s.

M.8.9.3 Test method 2

Tests shall be carried out as follows:

a) the test device is actuated. The MRCD shall operate;

b) the sensing means are disconnected and the test device is actuated. The MRCD shall not operate.

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M.8.10 Verification of temperature-rise of terminal type MRCDs

M.8.10.1 General

Unless otherwise specified, the MRCD shall be connected with the appropriate conductors whose cross-sections are specified in Tables 9, 10 and 11 of IEC 60947-1:2007, and fixed on a mat black painted plywood board of about 20 mm in thickness.

The test shall be carried out in an atmosphere protected against abnormal external heating or cooling.

M.8.10.2 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 8.3.3.3.4 of IEC 60947-1:2007, at the rated current I_n.

During this test, temperature-rise shall not exceed the values listed in Table 2 of IEC 60947-1:2007 and Table 3 of IEC 60947-1:2007/AMD2:2014.

M.8.11 Verification of mechanical and electrical endurance

The MRCD output shall be subjected to mechanical and electrical endurance tests including:

– 500 off-load operations controlled by the test device;
– 500 off-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path;
– 500 on-load operations controlled by the test device;
– 500 on-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path.

The on-load tests are carried out on a circuit corresponding to the output rating given by the manufacturer.

After the tests, the MRCD shall show no damage impairing its further use. The output shall be able to withstand in the open position a voltage equal to twice its maximum rated value given by the manufacturer.

NOTE 1 This verification is not applicable if the output is designed for a specific load and does not have a rated output voltage.

For MRCDs having more than one output rating, two tests shall be carried out:

– a test at the highest rated current at the corresponding voltage;
– a test at the highest rated voltage at the corresponding current.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.11.4 b).

NOTE 2 If the MRCD output has an appropriate AC-15 rating, in accordance with IEC 60947-5-1, the tests of this subclause are not necessary.

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M.8.12 Verification of the behaviour of MRCDs classified under M.3.2.2.1 in the case of failure of the voltage source

M.8.12.1 General

For MRCDs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For MRCDs having an adjustable time-delay, the test shall be carried out at any one of the time-delay settings.

The voltage applied shall be the rated voltage of the voltage source (U_s).

For MRCDs having a range of rated voltages of the voltage source, the tests shall be carried out at the maximum and minimum values of the voltage range.

M.8.12.2 Determination of the limiting value of the voltage source

Tests shall be carried out in accordance with B.8.9.2, with "voltage source" replacing "line voltage" and "voltage source terminals" replacing "line terminals".

M.8.12.3 Verification of automatic opening in the case of voltage source failure

Tests are carried out in accordance with B.8.9.3, with "voltage source" replacing "line voltage" and "voltage source terminals" replacing "line terminals". The time interval between the switching off and the change in status of the output shall be measured.

Three measurements are carried out:

– for instantaneous MRCDs, no value shall exceed 1 s;

– for time-delayed MRCDs, no value shall exceed 1 s plus the set time delay.

M.8.13 Verification of the behaviour of MRCDs classified under M.3.2.2.2 in the case of failure of the voltage source

The provisions of B.8.10 apply in the case where the voltage source is the line voltage of the monitored circuit. In the case where the voltage source is other than the line voltage, a test shall be carried out as follows.

For MRCDs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For MRCDs having an adjustable time delay, the test shall be made at any one of the time-delay settings.

The MRCD shall be connected according to Figure M.3 and supplied with its rated voltage, or in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_a or S_1, as applicable; the MRCD shall not operate.

The switch S_a or S_1, as applicable, is then reclosed and the voltage is reduced to 70 % of the lowest rated voltage. The rated residual current $I_{\Delta n}$ is then applied by closing S_2; the MRCD shall operate.

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M.8.14 Verification of the behaviour of MRCDs under short-circuit conditions

M.8.14.1 General

Since an MRCD is not a switching device, where it has been tested with a given SCPD in accordance with M.8.14.3 and M.8.14.5, tests with other SCPDs of a lower peak current and lower I^2t are considered to be also covered.

M.8.14.2 General conditions for the test

M.8.14.2.1 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies, except Figures 9, 10, 11 and 12. The test shall be carried out in accordance with Figure M.19, Figure M.20 or Figure M.21, as applicable.

For short-time withstand tests, the SCPD shall be omitted.

M.8.14.2.2 Tolerances on the test quantities

Table 8 of IEC 60947-1:2007 applies.

M.8.14.2.3 Power factor of test circuit

Table 11 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 8.3.2.2.3, item a), of IEC 60947-1:2007/AMD2:2014 applies.

M.8.14.2.5 Calibration of the test circuit

The SCPD and the MRCD, if of the terminal type, are replaced by temporary connections of impedance negligible compared with that of the test circuit. For other MRCDs, the conductors through the sensing means are part of the calibrating circuit.

For the test at rated conditional short-circuit current I_{cc}, the resistors R and the reactors L are adjusted so as to obtain at the test voltage, a current equal to I_{cc}, at the prescribed power factor. The test circuit shall be energized simultaneously in all poles.

For the tests at rated residual conditional short-circuit current $I_{\Delta c}$, the additional impedance Z is used so as to obtain the required current values.

M.8.14.2.6 Condition of the MRCD for tests

The wiring and the fixing of the MRCD shall be in accordance with the manufacturer's instructions.

This is particularly the case for MRCDs of the through-conductor type for installing conductors that pass through the sensing means.

The MRCD shall be mounted on a metal plate.

M.8.14.2.7 Condition of the MRCD after tests

After each test of M.8.14.3, M.8.14.4 and M.8.14.5, the MRCD shall show no damage impairing its further use and, in the case of a terminal type MRCD, shall be capable of withstanding a voltage equal to twice its rated voltage under the conditions of 8.3.3.6.

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The MRCD shall perform satisfactorily the tests specified in B.8.11.4b) and M.8.12.3, if applicable, and limited to one measurement.

M.8.14.3 Verification of the rated conditional short-circuit current (I_{cc})

M.8.14.3.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated short-time withstand current I_{cw}.

M.8.14.3.2 Test conditions

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal-type MRCD.

M.8.14.3.3 Test procedure

The rated voltage of the voltage source, if applicable, shall be applied.

The following sequence of operations is performed:

O – *t* – O

M.8.14.3.4 Behaviour of the MRCD during the tests

During the tests, the MRCD may operate.

M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 8.3.4.3 of IEC 60947-1:2007 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of Figure M.17, Figure M.18 and Figure M.19 shall be omitted for the test.

M.8.14.5 Verification of the rated conditional residual short-circuit current ($I_{\Delta c}$)

M.8.14.5.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated residual short-time withstand current $I_{\Delta w}$.

M.8.14.5.2 Test conditions

The MRCD shall be tested under the conditions prescribed in M.8.14.2.1 but shall be connected so that the short-circuit current is a residual current. For residual short-circuit tests, the connection B, indicated by the dashed line in Figure M.19, Figure M.20 and Figure M.21, replaces the connection through the sensing means, between X and Y.

The test shall be carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

M.8.14.5.3 Test procedure

The following sequence shall be performed without synchronisation with respect to the voltage wave:

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O – *t* – O

M.8.14.5.4 Behaviour of the MRCD during the tests

During the tests, the MRCD may operate.

M.8.14.6 Verification of rated residual short-time withstand current ($I_{\Delta w}$)

Subclause M.8.14.4 applies, except that the MRCD shall be connected so that the short-circuit current is a residual current.

M.8.15 Verification of the effects of environmental conditions

The tests conditions of B.8.12 apply.

At the end of the tests, the MRCD shall be capable of performing satisfactorily the tests specified in B.8.11.4 b).

M.8.16 Verification of electromagnetic compatibility

M.8.16.1 Immunity tests

M.8.16.1.1 General

Subclause B.8.13.1 applies, but with "CBR" replaced by "MRCD" where necessary, except that the verifications after the tests shall be a measurement of the operating time (see M.2.2.2.1) at $I_{\Delta n}$, which shall not exceed the value declared by the manufacturer (see M.4.2). The test circuit for the verification shall be in accordance with Figure M.3.

M.8.16.1.2 Electrostatic discharges

Subclause B.8.13.1.2 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.3 Radiated RF electromagnetic fields

Subclause B.8.13.1.3 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.4, and Figure M.22 for MRCDs with separate sensing means.

M.8.16.1.4 Electrical fast transients/bursts (EFT/B)

Subclause B.8.13.1.4 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.5 and Figure J.6, and Figure M.23 for MRCDs with separate sensing means.

M.8.16.1.5 Surges

Subclause B.8.13.1.5 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.6 Conducted disturbances induced by RF fields (common mode)

Subclause B.8.13.1.6 applies with the additional specifications given in M.8.16.1.1.

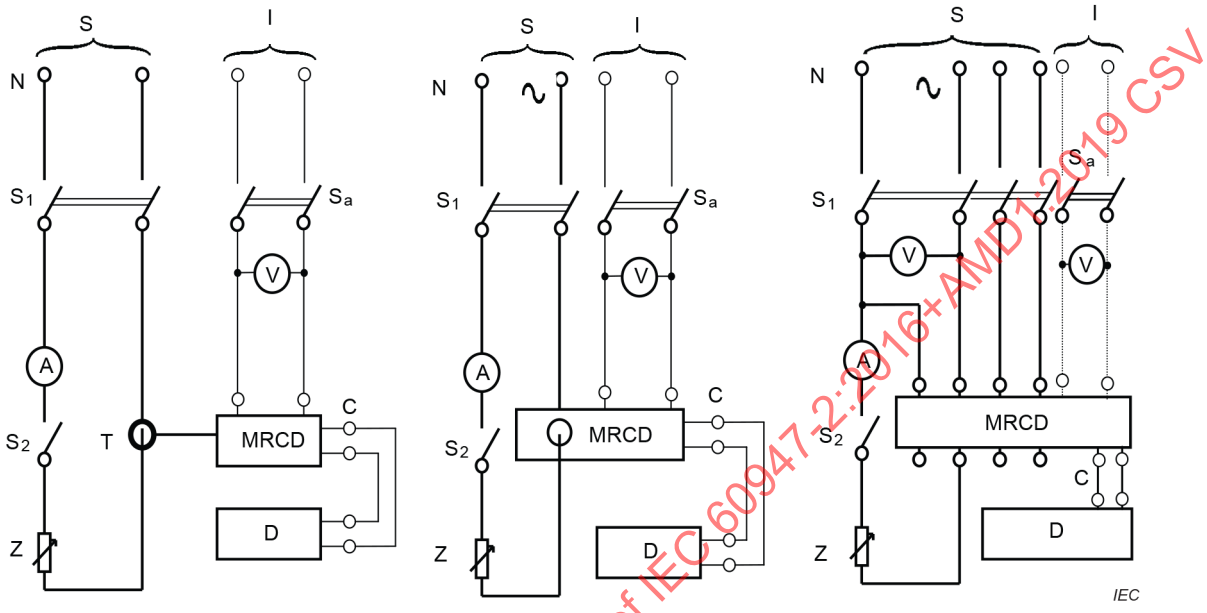
The test set-up shall be in accordance with Figure M.24 for MRCDs with separate sensing means.

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An EM clamp may be used when normal functioning cannot be achieved because of the impact of the CDN on the MRCD.

M.8.16.2 Emission tests

Subclause B.8.13.2 applies.



a) MRCD with separate sensing means

b) MRCD with integral sensing means

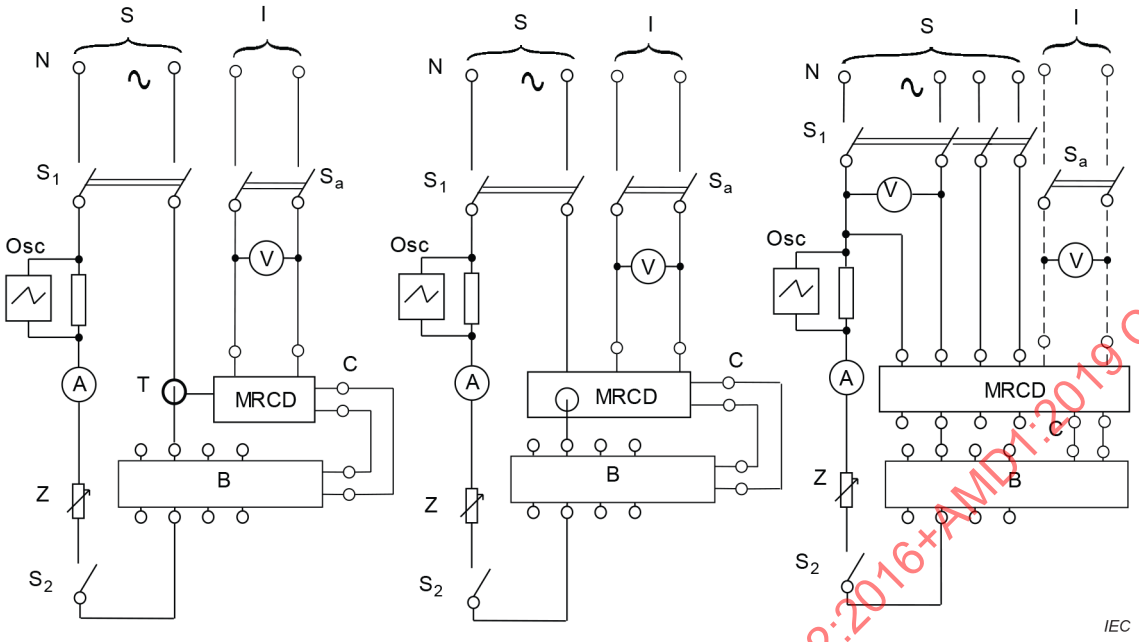
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	single-pole switch		

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

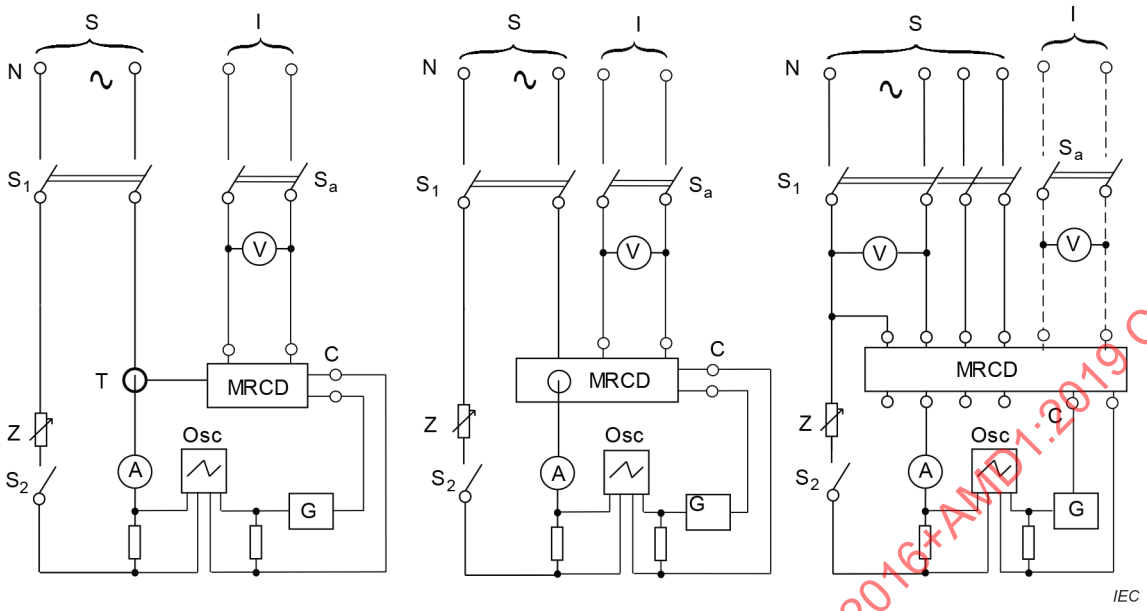
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope

Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with current breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

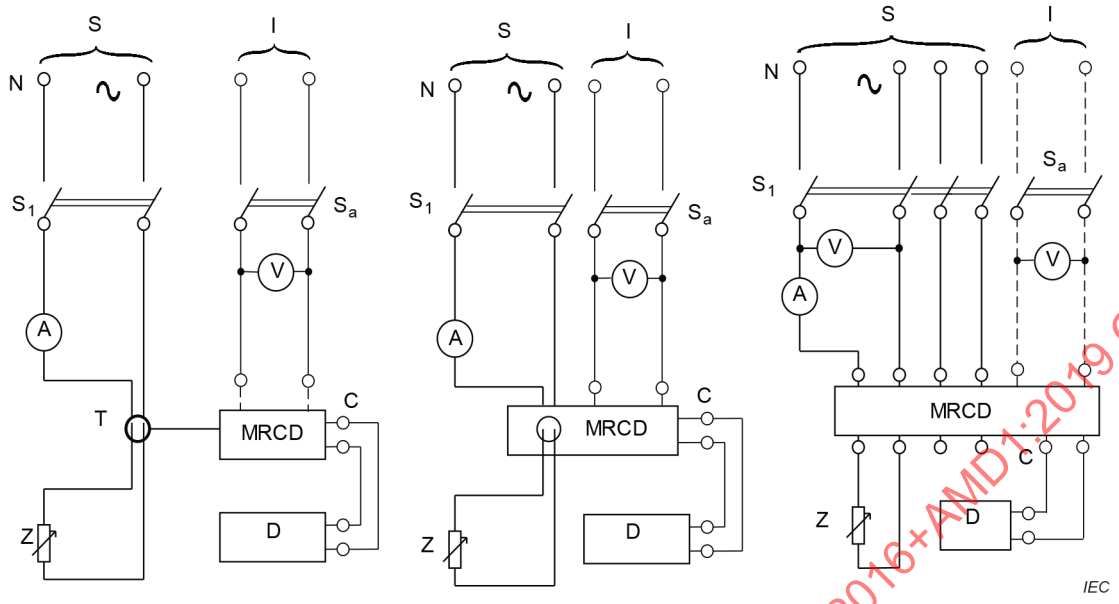
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope

Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without current breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_1 multi-pole switch

S_a auxiliary switch

Z adjustable impedance

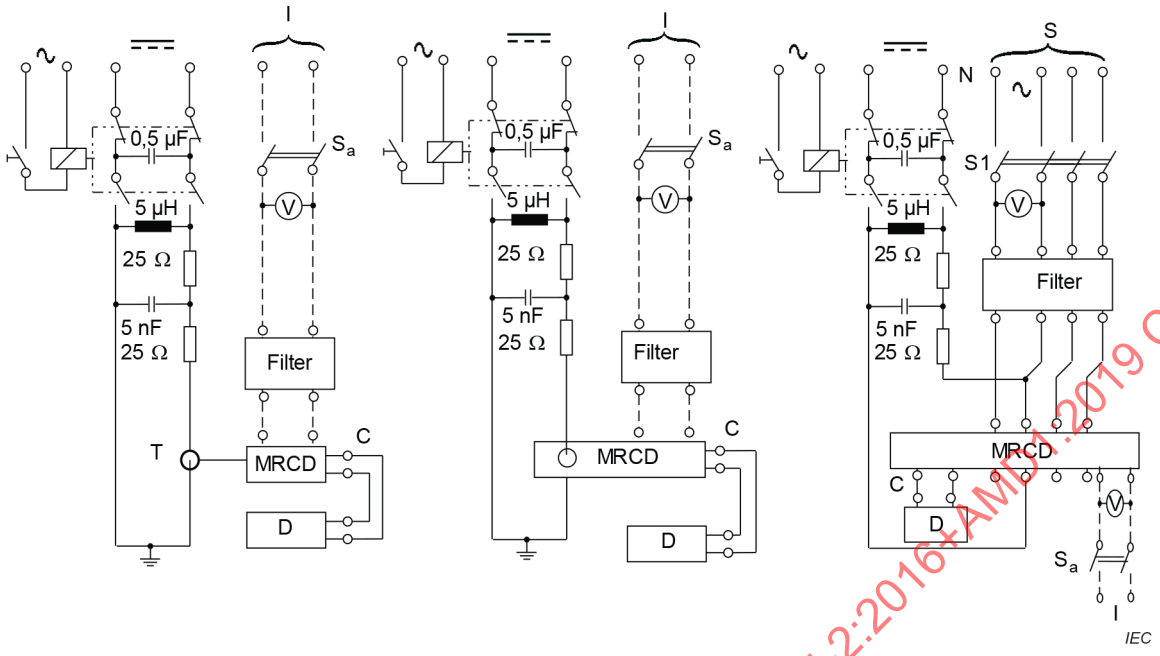
T sensing means

C output circuit

D instrument indicating the change of status

Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

S	power supply	T	sensing means
V	voltmeter	C	output circuit
I	separate voltage source, if applicable	D	instrument indicating the change of status
S_1	multi-pole switch	S_a	auxiliary switch

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

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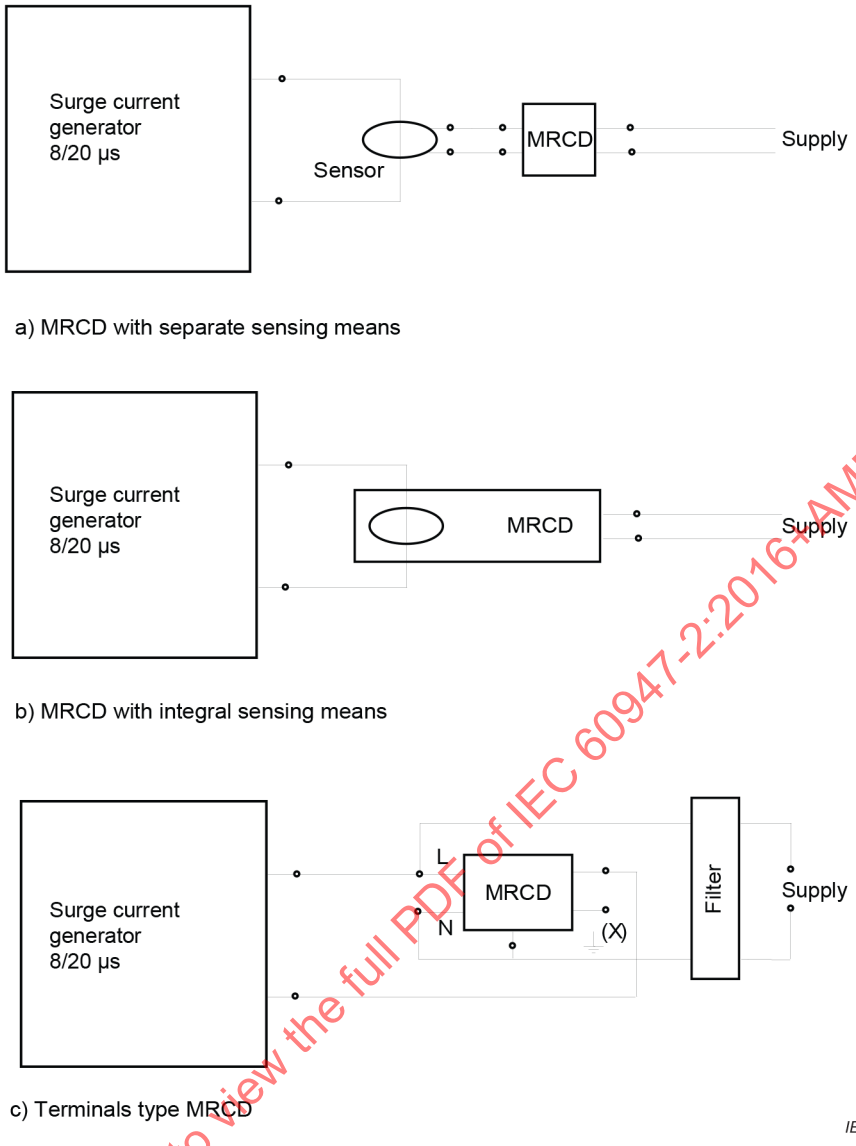
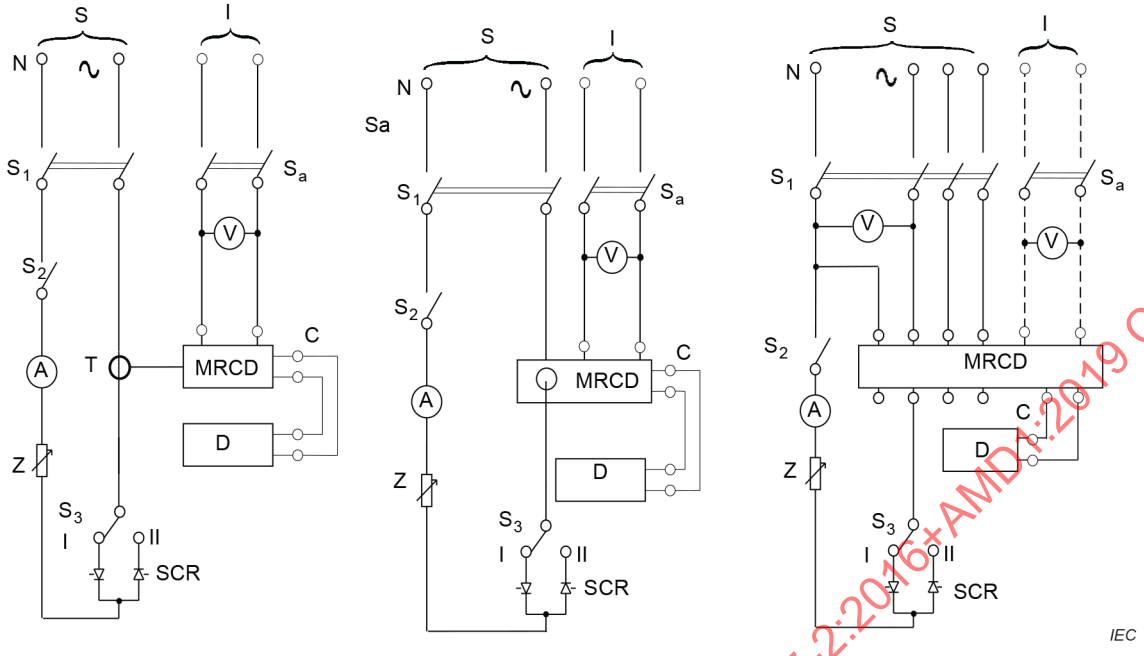


Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

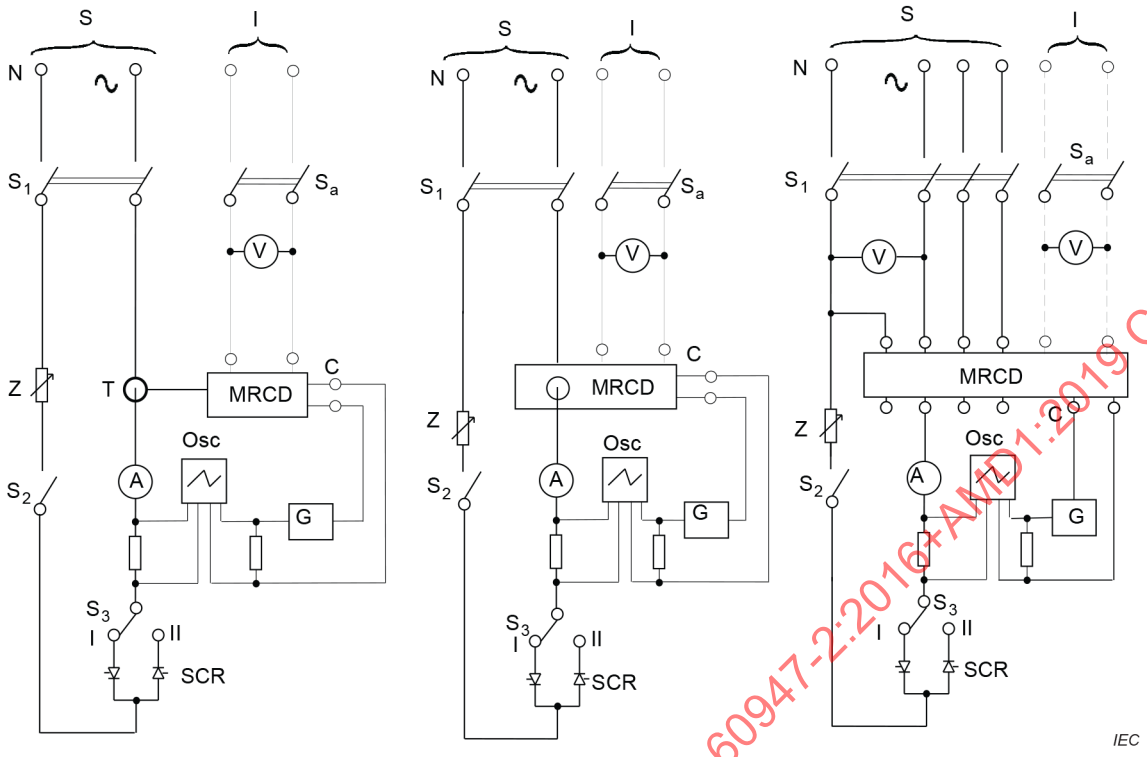
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	single-pole switch	SCR	thyristors
S_3	inverter switch		

Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

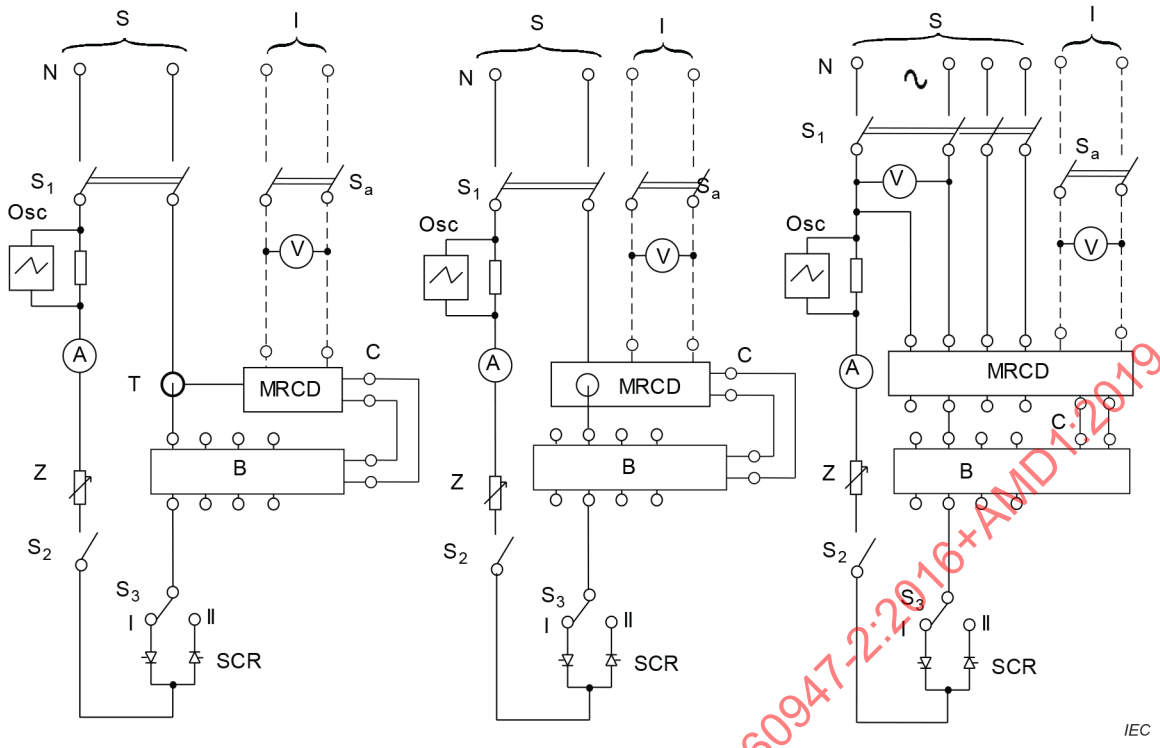
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristors

Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without current-breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

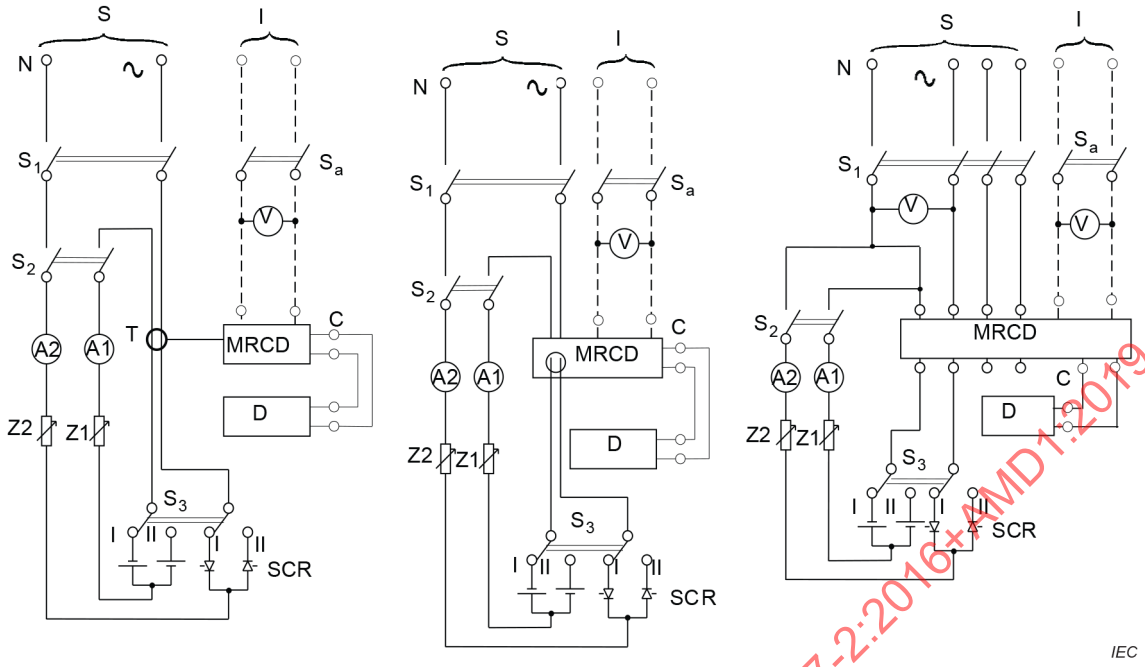
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristors

Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with current-breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

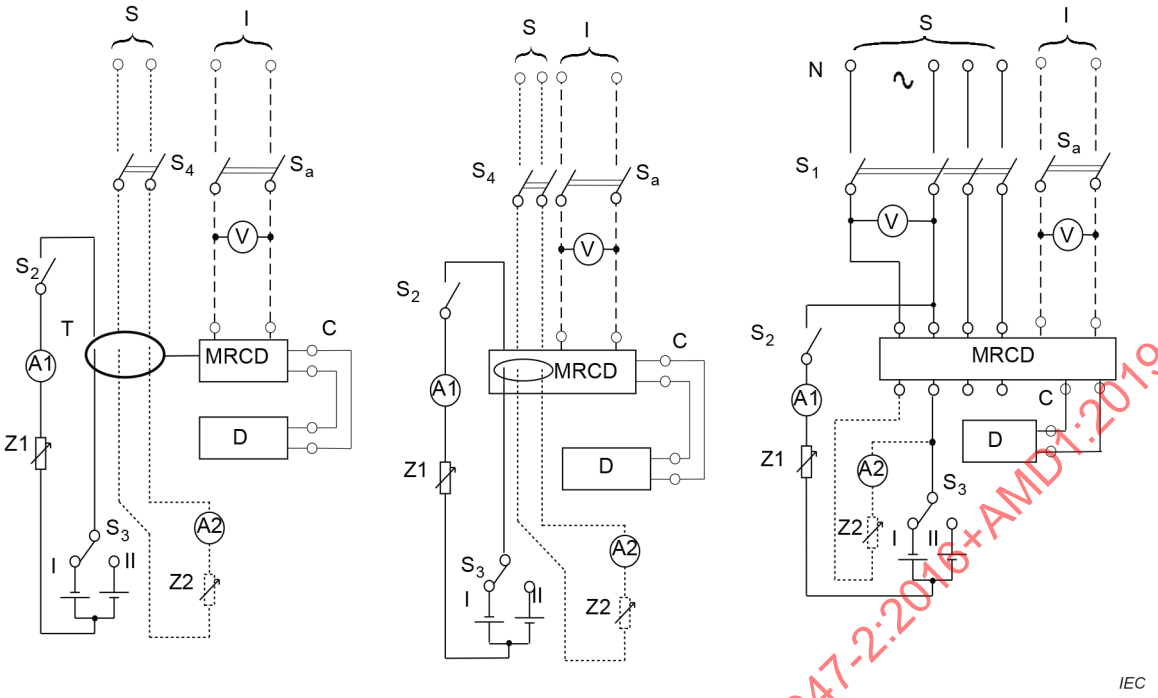
c) Terminal-type MRCD

Key

S	power supply	S_3	double inverter switch
I	separate voltage source if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A1	ammeter measuring d.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	two-pole switch	SCR	thyristors

Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by a smooth direct current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

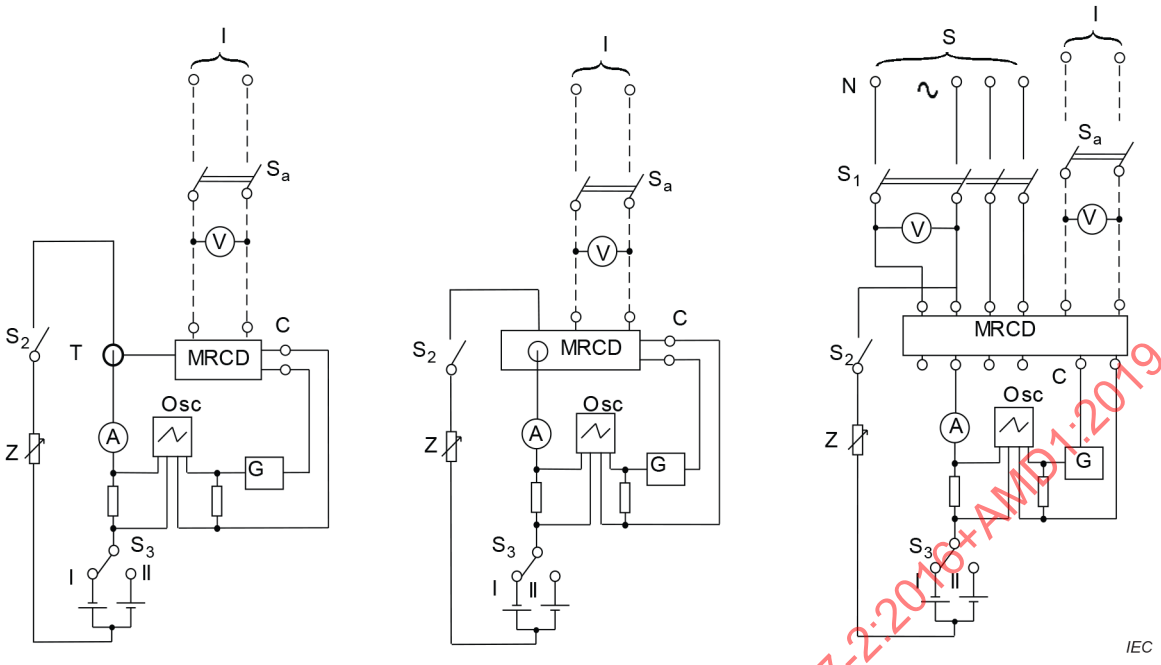
c) Terminal-type MRCD

Key

S	power supply	S_3	double inverter switch
I	separate voltage source, if applicable	S_4	two-pole switch
V	voltmeter	S_a	auxiliary switch
A1	ammeter measuring d.c. current	Z1, Z2	adjustable impedances
A2	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

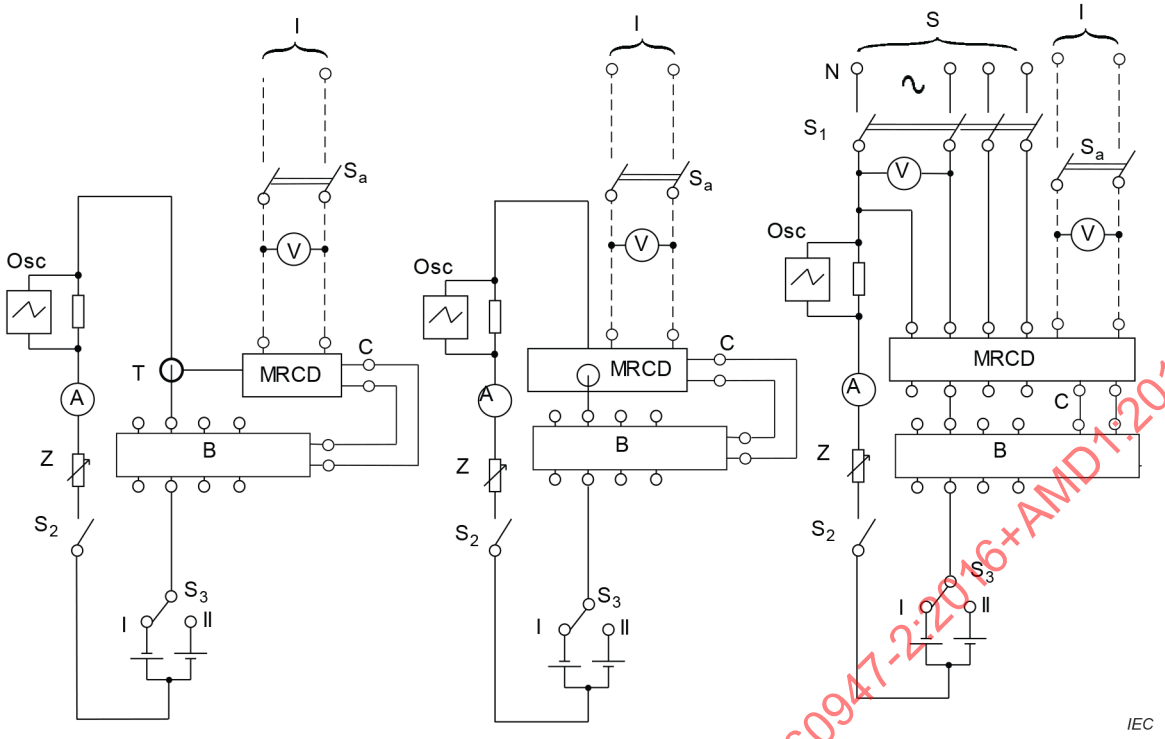
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without current-breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

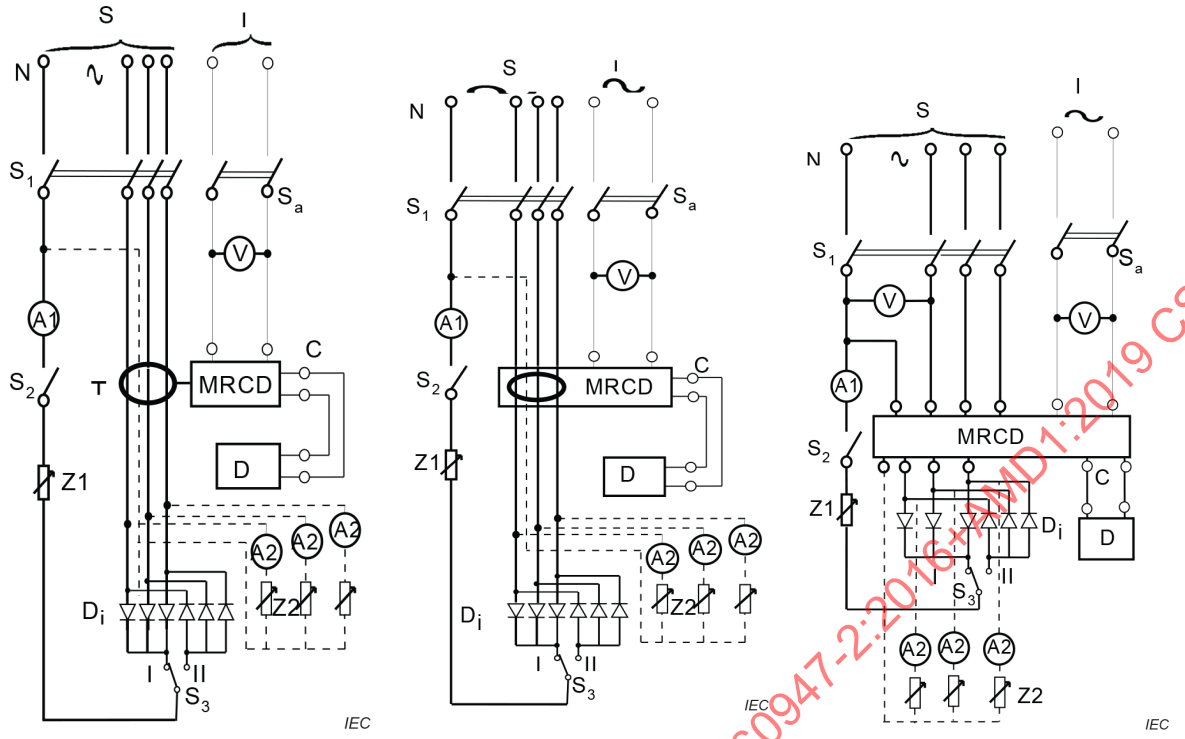
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with current-breaking device)

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a) MRCD with separate sensing mean

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

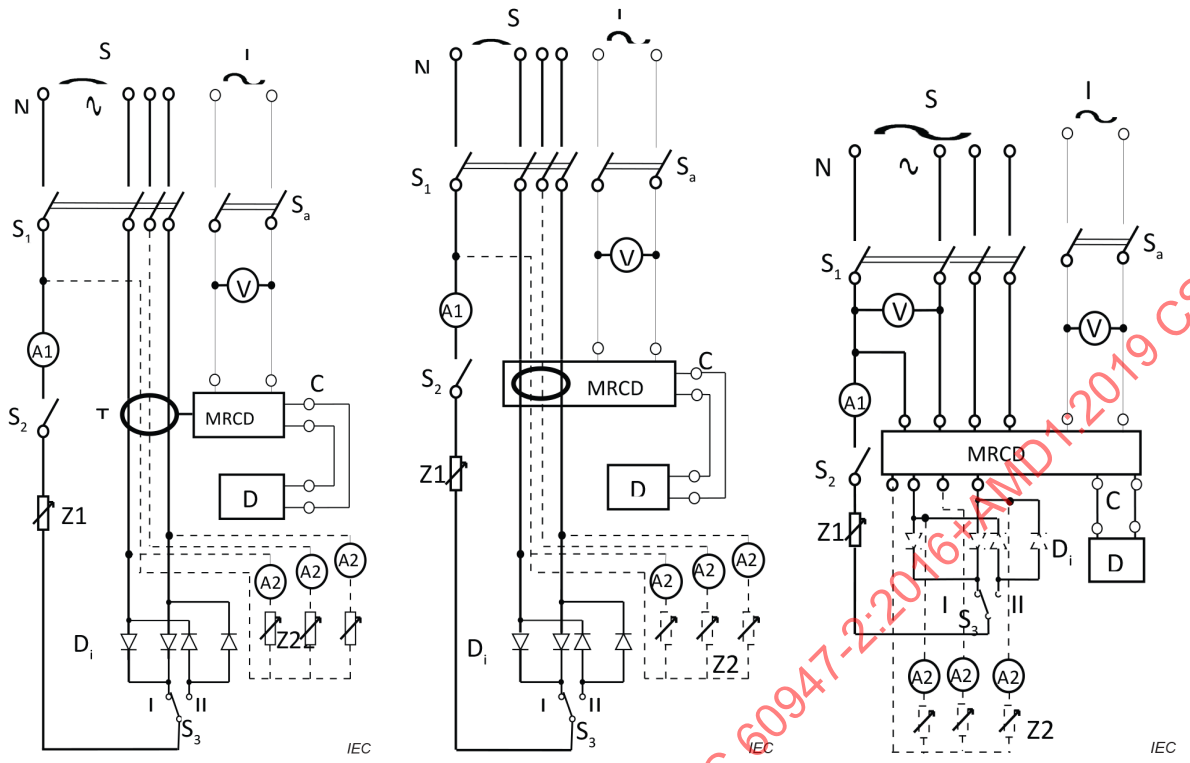
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z1, Z2	adjustable impedances
A1	ammeter measuring a.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
		D_i	diodes

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.14 – Test circuits for the verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from three phases

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

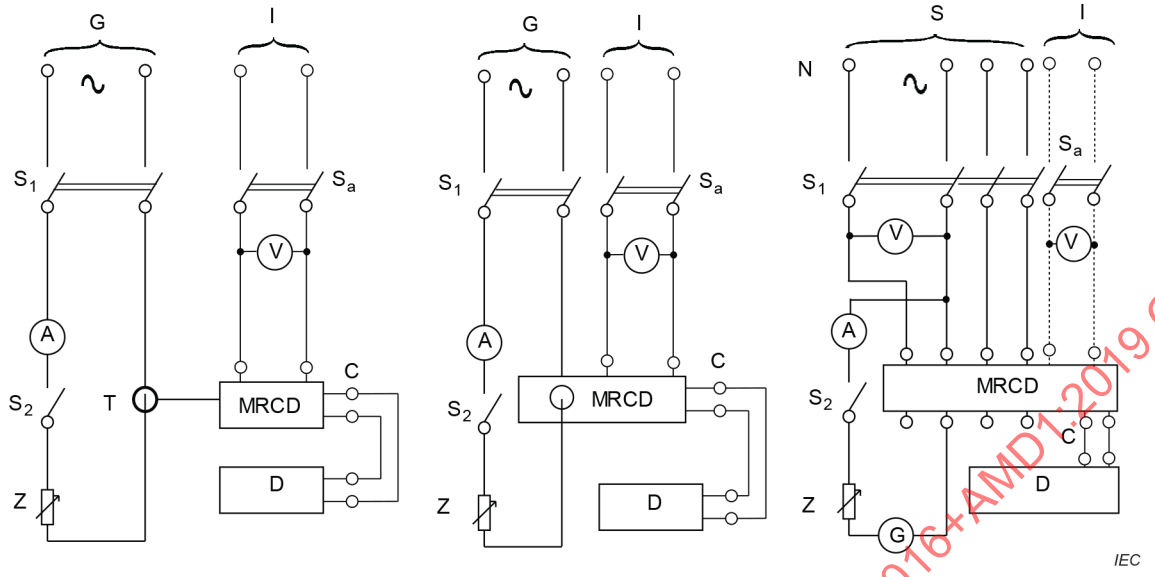
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z1, Z2	adjustable impedances
A1	ammeter measuring a.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
D_i	diodes		

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.15 – Test circuits for the verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from two phases

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

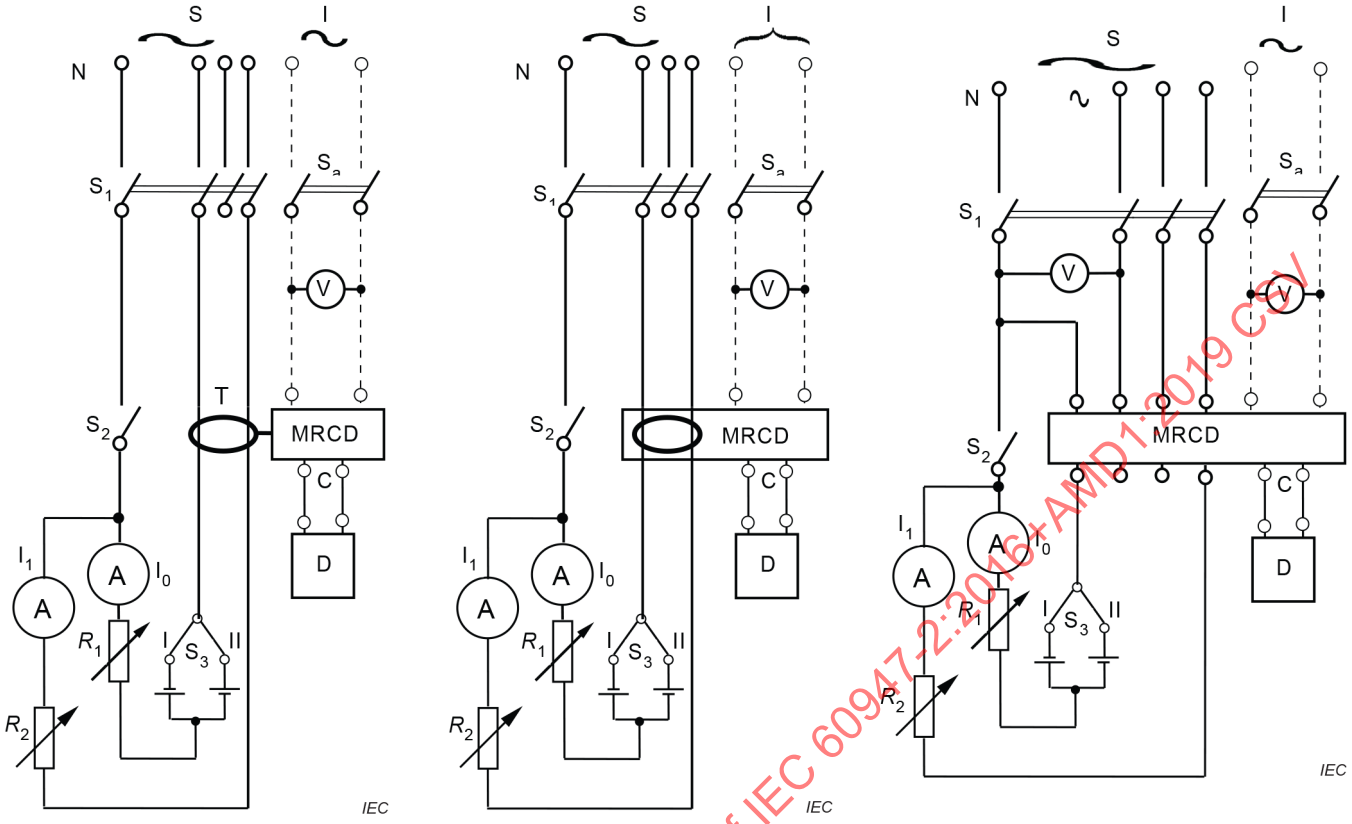
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
G	generator	D	instrument indicating the change of status

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.16 – Test circuits for the verification of correct operation in the case of composite residual currents and residual sinusoidal alternating current up to 1 000 Hz

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

c) **Terminal-type MRCD**

Key

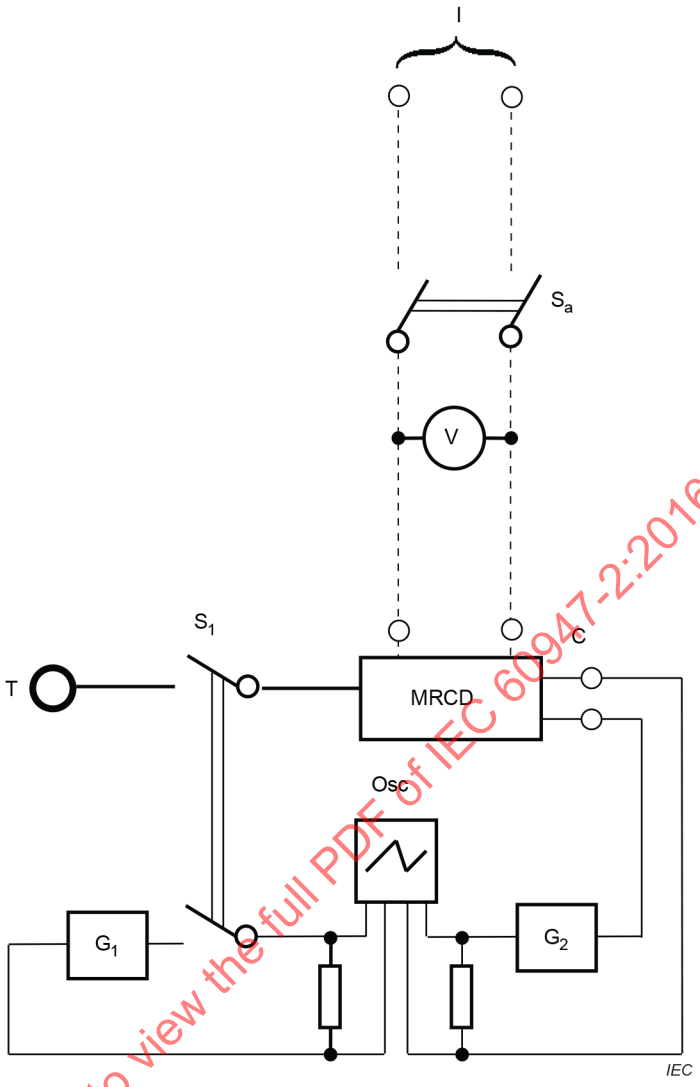
S	power supply	S_3	two-way switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	R_1, R_2	adjustable resistors
A	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.17 – Test circuits for the verification of the correct operation in the case of a residual alternating current superimposed on a smooth direct current

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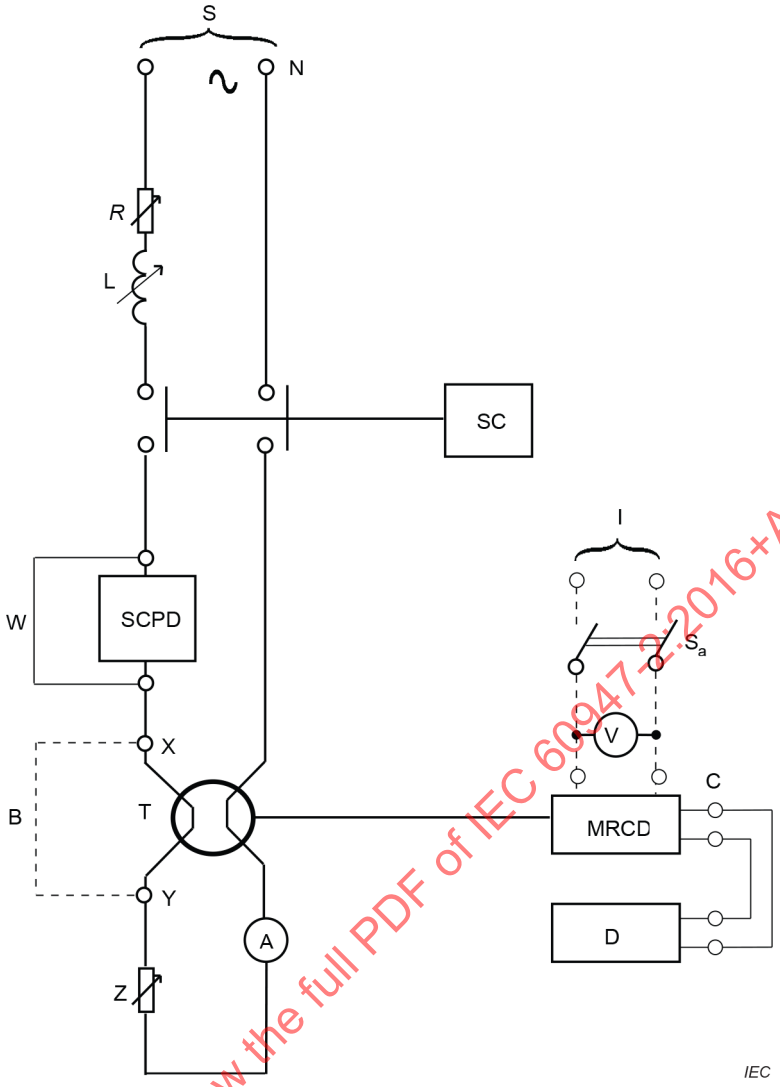


Key

I separate voltage source, if applicable
V voltmeter
S_1 multi-pole switch
S_a auxiliary switch
T sensing means
C output circuit
G_1, G_2 generators
Osc oscilloscope

Figure M.18 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the connection of the sensing means

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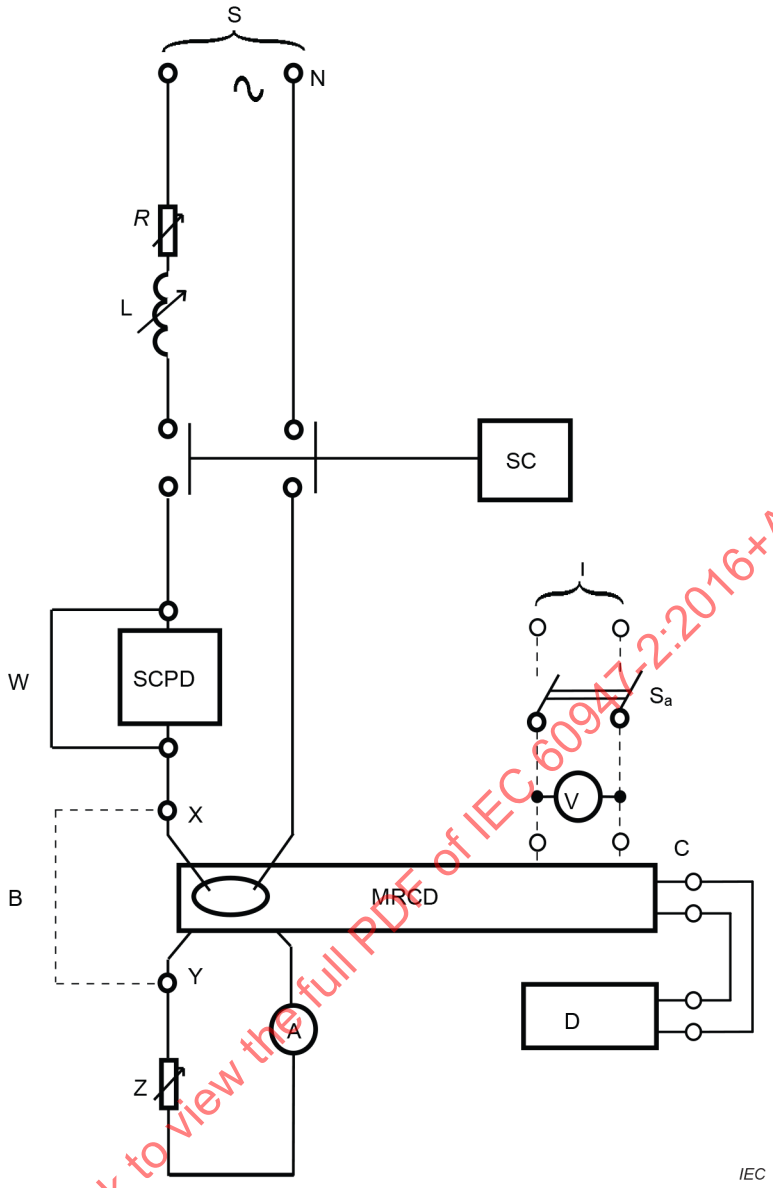


Key

S power supply
I separate voltage source, if applicable
V voltmeter
A ammeter
S_a auxiliary switch
SC short-circuit switch
W temporary connection
B connection for residual short-circuit test, replacing the connection through the sensing means
L adjustable reactor
R adjustable resistor
Z adjustable impedance
T sensing means
C output circuit
D instrument indicating the change of status
SCPD short-circuit protective device

Figure M.19 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions

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Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L adjustable reactor

R adjustable resistor

Z adjustable impedance

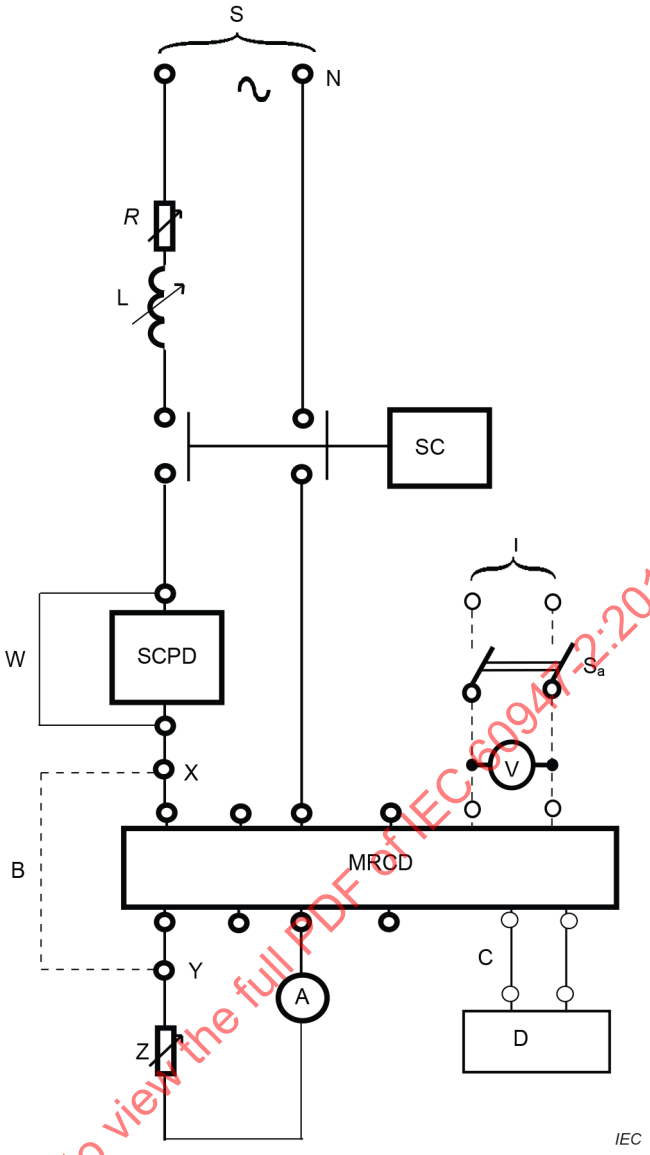
C output circuit

D instrument indicating the change of status SCPD

shortcircuit protective device

Figure M.20 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions

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Key

S	power supply	L	adjustable reactor
A	ammeter	*R*	adjustable resistor
S_a	auxiliary switch	Z	adjustable impedance
SC	short-circuit switch	C	output circuit
W	temporary connection	D	instrument indicating the change of status
B	connection for residual short-circuit test, replacing the connection through the sensing means	SCPD	short-circuit protective device

Figure M.21 – Test circuit for the verification of the behaviour of terminal-type MRCDs under short-circuit conditions

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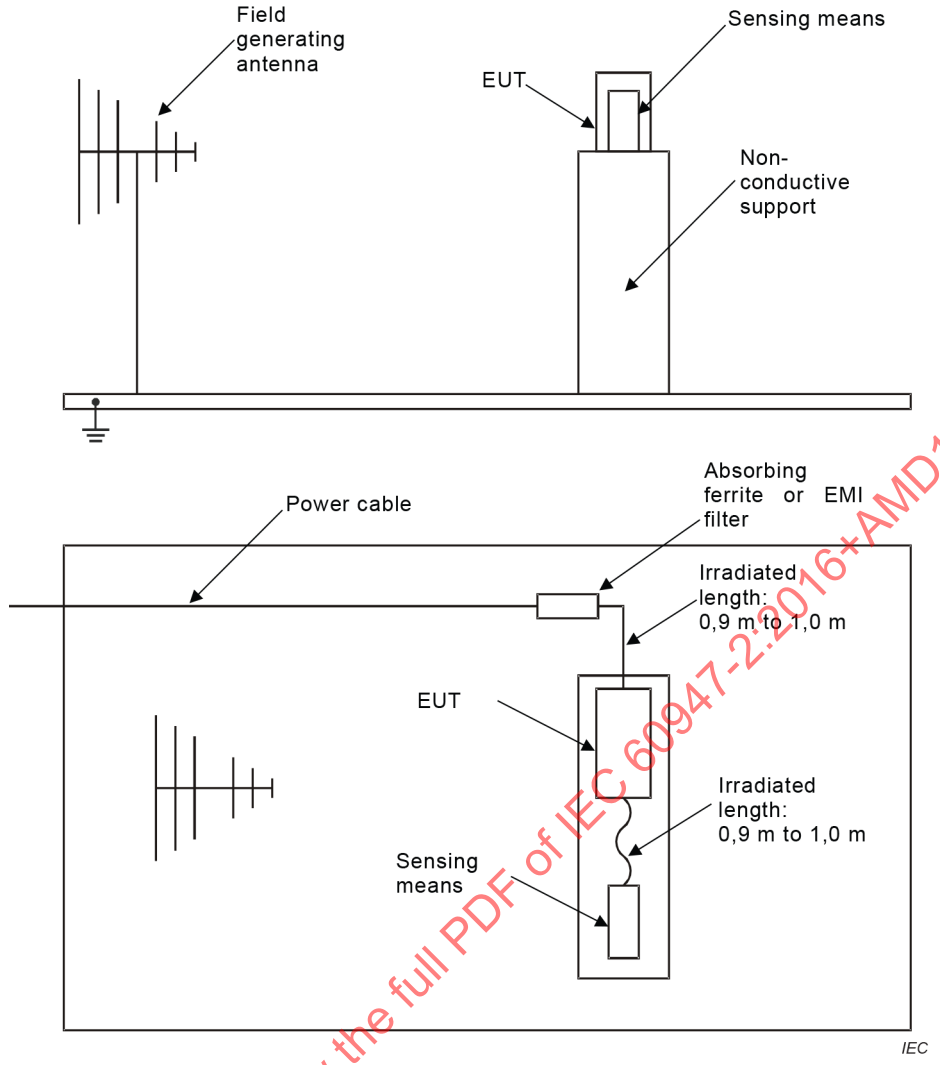


Figure M.22 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCDs with separate sensing means (in addition to the test of Annex B)

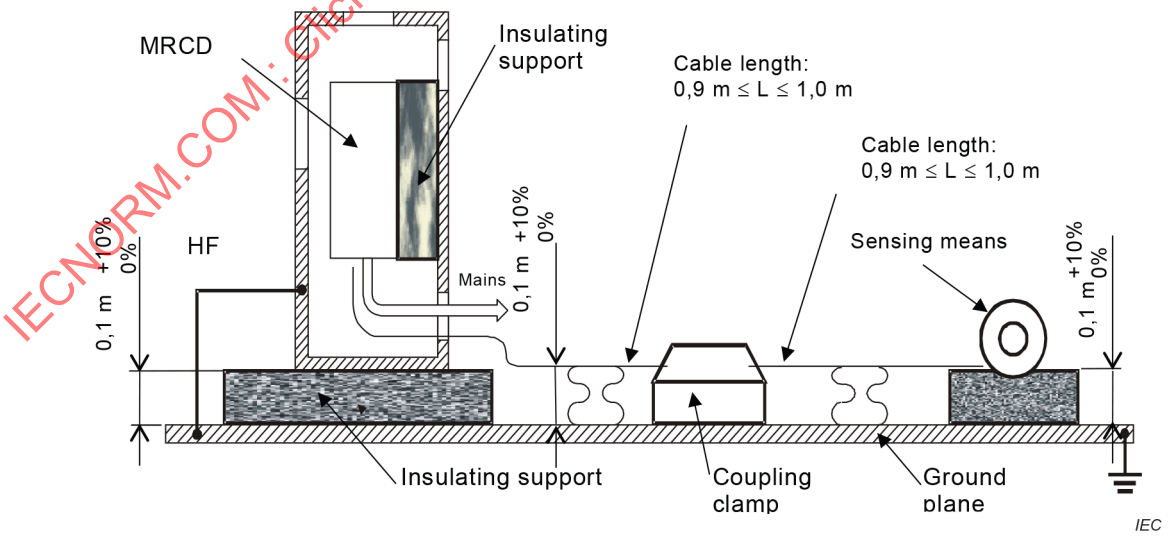
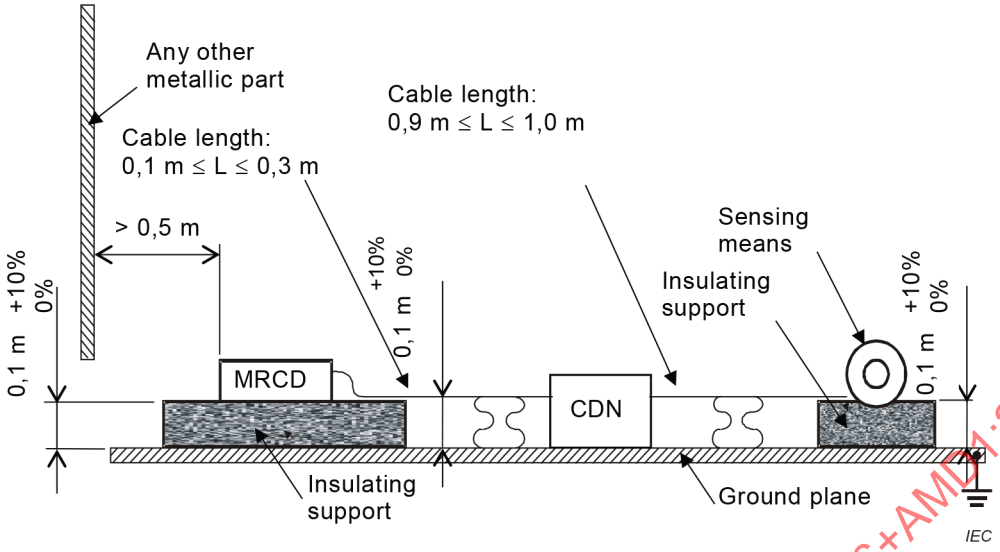


Figure M.23 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (in addition to the test of Annex B)

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Key

CDN coupling-decoupling network

Figure M.24 – Verification of immunity to conducted disturbances induced by RF fields – Test setup for MRCD with separate sensing means (in addition to the test of Annex B)

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Annex N
(normative)

Electromagnetic compatibility (EMC) – Additional requirements and test methods for devices not covered by Annex B, Annex F and Annex M

N.1 General

N.1.1 General

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 7.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014), and not covered by Annex B (circuit-breakers incorporating residual current protection), Annex F (circuit-breakers with electronic overcurrent protection) and Annex M (modular residual current devices).

It covers circuit-breaker auxiliaries such as undervoltage releases, shunt releases, closing ~~coils~~ releases, motor-operators, remote status indicators, etc. Communication modules are not covered by these requirements.

It supplements Annex J, for test conditions and acceptance criteria specific to these devices.

N.1.2 General test conditions

Tests according to this annex may be performed separately from the test sequences of Clause 8.

A new device may be used for each test, or one device may be used for several tests, at the manufacturer's discretion.

For devices with different voltage supply ratings, one device of each rating shall be tested.

Tests on closing ~~coils~~ releases are not necessary if their construction (coil and electronic control) is identical to the equivalent shunt trips.

The devices shall be mounted in or on the circuit-breaker, in accordance with the manufacturer's instructions.

Undervoltage releases and power ports intended to be permanently connected to a power supply shall be supplied with the rated voltage. In case of a range of rated voltages, they shall be supplied at any convenient voltage within this range.

Devices rated from 50 Hz to 60 Hz may be tested at either one of the rated frequencies.

N.2 Immunity

N.2.1 General

N.2.1.1 Test conditions

Immunity tests may be performed on a circuit-breaker fitted with different devices, and may be combined with the corresponding tests of Annex B and Annex F, where applicable (e.g. electrostatic discharges, radiated RF electromagnetic fields, etc.).

Devices, except closing ~~coils~~ releases, shall be tested with the circuit-breaker closed.

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Closing ~~coils~~ releases, if applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

N.2.1.2 Performance criteria

Criterion A: during the test, the status of the circuit-breaker shall not change and the status of the outputs of remote indication modules shall not change.

Criterion B: during the test, the status of the circuit-breaker shall not change while the status of the outputs of remote indication modules may change temporarily, but shall indicate the correct status of the circuit-breaker after the test.

After the tests, the simplified functional verification of N.2.1.3 shall be made.

N.2.1.3 Simplified functional verification

For both criteria, after the test, the operation of the device shall be checked at the rated voltage, or, in the case of a range of rated voltages, at any convenient voltage within this range:

a) An undervoltage release, when energized, shall not prevent the circuit-breaker from being closed; when the voltage is removed, the circuit-breaker shall trip.

b) A shunt trip, when energized, shall trip the circuit-breaker.

c) A closing ~~coil~~ release, when energized, shall close the circuit-breaker.

d) A motor-operator, when energized in accordance with the manufacturer's instructions, shall be capable of closing and opening the circuit-breaker.

NOTE This test is intended only to check that the device has not been damaged during the immunity tests. It is not intended to check the full compliance with the requirements of the main body of this standard.

N.2.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

Performance criterion B of N.2.1.2 applies.

N.2.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test connections shall be in accordance with Figures 5 or 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer’s instructions for installation. The type of cable used shall be stated in the test report.

For step 1 (see J.2.3), the performance criterion A applies.

For step 2 (see J.2.3), at each of the frequencies listed in J.2.3, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figures 11, 12, 13 and 14 of IEC 61000-4-4:2012, taking into consideration the manufacturer’s instructions for installation.

Performance criterion A applies.

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N.2.5 Surges

Annex J applies, in particular J.2.5.

The test connections shall be in accordance with Figures 5, 6, 7, 8, 9, 10 or 11 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

N.2.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

For step 1 (see J.2.6), the performance criterion A applies.

For step 2 (see J.2.6), at each of the frequencies listed in J.2.6, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.7 Voltage dips and interruptions

These tests are applicable to devices with permanent a.c. power supply only.

Tests shall be performed in accordance with IEC 61000-4-11, at test levels of Table 23 of IEC 60947-1:2007/AMD1:2010.

During the test, the status of the circuit-breaker may change. The status of the outputs of remote indication modules may change, but shall indicate the correct status of the breaker after the test. After the test, the correct operation of the device shall be checked in accordance with N.2.1.3.

N.3 Emission

N.3.1 General

These tests are applicable to devices incorporating electronic circuits with fundamental switching frequencies greater than 9 kHz (see 7.3.3.2.1 of IEC 60947-1:2007/AMD2:2014), and intended for continuous operation (e.g. undervoltage releases).

They are not applicable to shunt trips intended only for use with a clearing switch, either built-in or separate.

They are not applicable to motor-operators not incorporating permanently energized electronic circuits, because these devices are operated at very infrequent intervals and the duration of the operations (closing, opening or resetting) is very short (a few hundreds of milliseconds to a few seconds).

Each device shall be submitted to separate emission tests, these tests shall not be combined with the corresponding tests of Annex B and Annex F.

Closing ~~coils~~ releases, when applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

Undervoltage releases and closing ~~coils~~ releases shall be tested with the circuit-breaker closed.

Shunt trips and motor-operators shall be tested with the circuit-breaker open.

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Remote status indicators shall be tested with the circuit-breaker closed.

N.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

N.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

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Annex O
(normative)

Instantaneous trip circuit-breakers (ICB)

O.1 General

This annex covers circuit-breakers which fulfil only the short-circuit portion of overcurrent protection specified in the main part of this standard, hereinafter referred to as ICBs. They comprise instantaneous short-circuit releases which may be adjustable but not overload releases. These devices are generally used in conjunction with other equipment such as motor- starters, overload relays, etc. In combination with specified overload relays, they offer complete overcurrent protection (overload and short-circuit) to both the circuit and specified equipment.

An ICB forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (see O.2.1) by omitting the overload releases and incorporating a short-circuit release, which may be adjustable, designed to provide co-ordinated overcurrent protection when associated with specified motor-starters or overload relays.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

O.2.1
equivalent circuit-breaker
circuit-breaker from which the ICB has been derived, which has been tested according to this standard and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 4 apply with the exception of the reference to overload releases and with the following additions.

O.3.2 Rated current (I_n)

The rated current of an ICB shall not exceed the rated current of the equivalent circuit-breaker.

O.3.3 Rated short-circuit making capacity

ICBs may be assigned a rated short-circuit making capacity different to the equivalent circuit-breaker.

NOTE ICBs can be assigned a rated short-circuit making capacity equal to or greater than that of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

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NOTE ICBs can be assigned a rated short-circuit breaking capacity equal to or greater than I_{cu} of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.4 Product information

An ICB shall be marked according to 5.2 as relevant.

Rated short-circuit making and breaking capacities shall be marked, where applicable (see O.6.1.1). When the ICB is only rated for short-circuit performance in association with a motor-starter or overload relay (see O.6.2), the short-circuit ratings of the association shall not be marked on the ICB.

~~In addition the ICB shall be marked as follows:~~

~~– for 5.2, item a), add the marking "ICB";~~

~~– for 5.2, item b), add the rated instantaneous short-circuit current settings I_i (see 2.20) (actual values or multiples of rated current).~~

In addition, the ICB shall be marked in accordance with Table O.1.

Table O.1 – Product information

Item	Information	Marking location
O1.1	Initialism "ICB"	Visible
O2.1	Rated instantaneous short-circuit current setting I_i (see 2.20) (actual values or multiples of rated current)	Marked
Key Visible: visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked: marked on the product		

Manufacturers' instructions shall draw attention to the fact that, below the rated instantaneous short-circuit current settings, an ICB provides no overcurrent protection to itself or to the circuit. Such protection shall be provided separately.

When an ICB is not associated with a specified protected device (see O.6.2), the manufacturer shall provide data to permit the selection of suitable overload protection, e.g. withstand characteristics of the ICB up to its maximum instantaneous setting.

O.5 Constructional and performance requirements

An ICB, being derived from the equivalent circuit-breaker (see O.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4, item b).

O.6 Tests

O.6.1 Test sequence of the ICB alone

O.6.1.1 General

The tests of this subclause are not required if

– the short-circuit characteristics of the short-circuit releases and the main current paths of the ICB are the same as those of the equivalent circuit-breaker, or

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– the ICB is only rated and tested as an association (see O.6.2).

A sample of each of the maximum and minimum values of the rated current I_n of each frame size shall be tested.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample shall be tested at the maximum rated current corresponding to each construction.

O.6.1.2 Test sequences

Tests shall be made according to sequences II and III of this standard without the verification of overload releases.

For ICBs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. The other variant(s) shall be submitted to the tests of sequence III only (without the verification of overload releases).

O.6.1.3 Verification of short-circuit releases

Following the test of O.6.1.2, a tripping test is made in accordance with 8.3.3.2.2 on each phase pole in turn, at the maximum setting of the rated instantaneous short-circuit current. The test is made at the value of the tripping current declared by the manufacturer for individual poles. The ICB shall trip.

O.6.2 ICB associated with a specified protected device (i.e. motor-starter or overload relay)

The applicable test requirements for these associations are covered in the relevant sections of IEC 60947-4-1, specifically the following clauses:

– co-ordination with short-circuit protective devices;
– additional requirements for combination starters and protected starters suitable for isolation;
– performance under short-circuit conditions;
– co-ordination at the crossover current between the starter and associated SCPD.

NOTE The symbol SCPD in IEC 60947-4-1 applies to various short-circuit protective devices, including the ICB.

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Annex P
(normative)

DC circuit-breakers for use in photovoltaic (PV) applications

P.1 Field of application

This annex applies to d.c. circuit-breakers, rated up to 1 500 V d.c., intended for use with photovoltaic (PV) systems, and hereafter referred to as "PV circuit-breakers".

Circuit-breakers used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of this standard.

The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

– the requirements for circuit-breakers to be used on the d.c. side of PV applications;
– the tests intended to verify the product performances and their maintaining after exposure to the PV service environmental conditions.

P.2 Terms and definitions

Clause 2 applies.

P.3 Classification

Clause 3 applies.

P.4 Characteristics of PV circuit-breakers

Clause 4 applies with the following modification:

A PV circuit-breaker rated for use not only in PV applications shall have only one rated current.

~~The~~ Rated impulse withstand voltage (U_{imp}) of PV circuit-breakers shall comply with Table P.1.

Table P.1 – Rated impulse withstand levels for PV circuit-breakers

Maximum value of rated operational voltage (V)	**Value of rated impulse withstand voltage** (V)
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II, as defined in IEC 60664-1 and IEC/TR 60664-2-1:2011, Annex D.	

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P.5 Product information

~~Subclause 5.2 applies with the following additions:~~

~~A PV circuit-breaker shall be marked "IEC 60947-2, Annex P" under the conditions of item 5.2 b).~~

~~A circuit-breaker rated for use not only in PV applications shall have the ratings U_e and corresponding I_{cu} / I_{cs} according to this annex clearly separated from the ratings according to the body of this standard.~~

~~A PV circuit-breaker shall have method and diagram of series connection of poles (as necessary for each rating) marked under the conditions of item 5.2 c).~~

Clause 5 applies with the modifications and additions listed in Table P.3.

Circuit-breakers rated for use not only in PV applications shall have the ratings U_e and corresponding I_{cu}/I_{cs} in accordance with this annex clearly separated from the ratings in accordance with the body of this document.

Table P.3 – Product information

Item	Information	Marking location
P2.1	IEC 60947-2:2016 – Annex P,	Marked
P3.1	Method and diagram of series connection of poles, as necessary for each rating	Literature
Key Marked: marked on the product Literature: provided in the manufacturer's literature		

P.6 Normal service, mounting and transport conditions

Clause 6 applies with the following addition:

Guidance on de-rating for ambient air temperature up to 70 °C may be provided. In addition guidance on operation at temperature lower than -5 °C may also be given.

P.7 Constructional and performance requirements

P.7.1 Constructional requirements

Subclause 7.1 applies.

P.7.2 Performance requirements

Subclause 7.2 applies with the following modifications:

PV circuit-breakers shall be capable of interrupting any current up to their rated short-circuit breaking capacity, including critical load current, if exists, in both forward and reverse directions.

Compliance with these requirements is checked by the tests of P.8.3.

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With reference to 7.2.4.1, such overload conditions do not arise in the case of PV applications. Overcurrent conditions can only result from a short-circuit. Therefore, no tests to this clause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 7.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.2.

Table P.2 – Number of operating cycles

Rated current [a] (A)	Number of operating cycles per hour [b]	Number of operating cycles		
		Without current	With current [c]	Total
$I_n \leq 100$	120	9 700	300	10 000
$100 < I_n \leq 315$	120	7 800	200	8 000
$315 < I_n \leq 630$	60	4 800	200	5 000
$630 < I_n \leq 2\,500$	20	2 900	100	3 000
$2\,500 < I_n$	10	1 900	100	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

Due to the installation rules defined in IEC 60364-7-712, the risk of a double fault to earth does not need to be taken in consideration. Therefore, Annex H of this standard is not applicable to PV circuit-breakers.

NOTE The case of a PV circuit-breaker having to interrupt a small fault current on one pole only is under consideration.

P.7.3 Electromagnetic compatibility (EMC)

Subclause 7.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 8.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 8.2 applies.

P.8.3 Type tests

Subclause 8.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 8.3.1.2, tests omitted from test sequence I need not be made if the PV circuit-breaker is derived from a circuit-breaker on which identical or more severe tests have already been conducted, except that tripping characteristics conducted in a.c. do not cover d.c. characteristics.

With reference to 8.3.1.4, alternative test programmes do not apply to PV circuit-breakers.

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P.8.3.2 General test conditions

For all tests, the series connection of poles of the circuit-breaker shall be in accordance with the manufacturer instructions.

Samples shall be selected and tested according to column "Terminals marked line/load-No" of Table 10.

With reference to 8.3.2.2.5, the time constant for operational performance capability, short-circuit tests and critical d.c. load current test shall be equal to 1 ms. At the discretion of the manufacturer, a higher value may be used. In this case, it shall be stated in the test report.

P.8.3.3 Test sequence I

Subclause 8.3.3 applies with the following modifications:

With reference to 8.3.3.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.2.

With reference to 8.3.3.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.2, and the time constant shall comply with P.8.3.2. Half of the operations shall be made with the currents flowing in one direction, the other half with the other direction.

With reference to 8.3.3.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 8.3.4 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 8.3.5 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 8.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 8.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 8.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.9 Critical d.c. load current test

Subclause 8.3.9 applies with the following modifications:

The circuit-breaker shall be closed and opened 10 times on to each of the test currents, 5 times with the current flowing in the forward direction, and 5 times with the current flowing in the reverse direction.

The time constant shall comply with P.8.3.2.

During the operational performance verification, if applicable, the breaker shall be subjected to 100 operations instead of 50.

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P.8.3.10 Thermal cycling test

PV circuit-breakers shall be subjected to temperature cycling according to IEC 60068-2-14, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at + 85 °C. Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

– a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
– the verification of overload releases according to 8.3.3.2.3;
– a verification of temperature rise at the main terminals in accordance with 8.3.3.5. The temperature rise shall not exceed the values given in Table 7;
– a verification of dielectric withstand according to 8.3.3.6.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I.

P.8.3.11 Climatic test

PV circuit-breakers shall be subjected to the climatic tests of IEC 60947-1:2007/AMD1:2010/AMD2:2014 Annex Q, category B: environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of P.8.3.10.

Where Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I. At the discretion of the manufacturer, this test may be combined with the thermal cycling test and made on the same samples.

P.8.4 Routine tests

Subclause 8.4 applies.

P.8.5 Special tests

Subclause 8.5 applies.

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Annex Q

Vacant

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Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic re-closing functions

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this standard are used as protective devices to provide protection against the effects of electric shock hazards.

CBRs according to Annex B need to be manually reset after tripping.

CBRs may be installed at remote, unmanned locations such as telecommunication stations or traffic signaling sites. Where such a CBR is tripped due to a lightning surge or temporary earth leakage there will be a delay and cost in travel to site to effect rectification and restoration of the supply.

The results of this tripping by temporary faults such as the blackout of a mobile telecommunication station or malfunction of a traffic light system could cause inconvenience or danger to life.

CBRs with automatic reclosing functions are intended to improve the efficiency of operating unmanned facilities.

This annex is essentially based on the relevant requirements of Annex B of this standard.

R.1.2 Field of application

This annex applies to CBRs, hereinafter referred to as CBARs, which restore the power supply through automatic reclosing without manual operation, in the case of tripping due to the residual current function.

This annex also applies to automatic reclosing devices supplied separately which, when combined with a CBR, fulfils the requirements of a CBAR. For the purpose of this annex, the term CBAR also covers an automatic reclosing device combined with a CBR.

This annex also covers the requirements for CBARs concerning electromagnetic compatibility (EMC).

This annex applies only to CBARs intended for use in a.c. circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs depending on an alternative supply source for the residual current function are not covered by this annex.

The object of this annex is to state:

a) specific features of the automatic reclosing function;
b) specific requirements which shall be complied with by the CBAR:
   – under normal circuit conditions;
   – under abnormal circuit conditions;
   – under temporary fault conditions.

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c) tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;

d) relevant product information.

R.2 Terms and definitions

As a complement to Clause 2 and Clause B.2 of this standard, the following additional terms and definitions apply:

R.2.1
automatic reclosing
operating sequence of a mechanical switching device whereby, following its opening, it closes automatically depending on specific conditions

[SOURCE: IEC 60050-441:1984, 441-16-10, modified – term and supplemented by "depending on specific conditions"]

R.2.2
rated automatic reclosing operating residual current
$I_{\Delta ar}$
maximum value of the residual current at which a type M CBAR recloses automatically under the specified conditions (see R.3.2.1)

R.2.3
selector switch
switch for selecting automatic reclosing or manual reclosing mode

R.2.4
reset time
maximum period of time, declared by the manufacturer, during which consecutive reclosing operations may be made

R.2.5
blocked state
state of the CBAR in which the automatic reclosing function is inhibited and a manual reset is necessary

R.2.6
reclosing time-delay
for type TD CBAR, maximum time between the tripping of the device and the reclosing of the contacts

Note 1 to entry: For definition of type TD CBAR, see R.3.2.2.

R.2.7
reclosing time
for type M CBAR, maximum time between the instant when the reclosing condition is fulfilled and the reclosing of the contacts

Note 1 to entry: For definition of type M CBAR, see R.3.2.1.

R.2.8
monitoring time
for type M CBARs, time during which the monitoring is effective after operation of the residual current tripping function

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R.3 Classification

As a complement to Clause 3 and Clause B.3 of this standard, the following additional classifications apply.

R.3.1 According to the method of construction

R.3.1.1 Integral CBAR

CBAR as a single unit comprising an automatic reclosing function integrated by the manufacturer with the circuit-breaker.

R.3.1.2 External automatic reclosing device

An automatic reclosing device externally connected to a CBR without modification of its internal circuits or components.

R.3.2 According to the method of automatic reclosing

R.3.2.1 Earth leakage monitoring type (M)

CBAR, hereafter called "type M", which monitors the downstream circuit to assess the presence of an earth fault, and does not allow reclosing when the assessed earth leakage current exceeds $I_{\Delta ar}$.

The monitoring shall be achieved through the use of the line voltage. It may be either continuous or intermittent.

Type M CBARs with limitation of test voltage monitors the downstream circuit by means of a non-hazardous voltage, hereinafter called "monitoring voltage".

Type M CBARs with limitation of test current monitors the downstream circuit by means of a non-hazardous current, hereinafter called "monitoring current".

R.3.2.2 Time-delay type (TD)

CBAR, hereafter called "type TD", for which the automatic re-closing takes place after a time-delay without consideration of the circuit conditions.

R.4 Characteristics

Clause 4 and Clause B.4 of this standard apply with the following addition.

R.4.1 Rated automatic reclosing operating residual current ($I_{\Delta ar}$)

The value of the rated automatic reclosing operating residual current shall be declared by the manufacturer, without exceeding $I_{\Delta n}$. The manufacturer may declare different values of $I_{\Delta ar}$ for different rated voltages.

R.4.2 Maximum number of consecutive reclosing operations

The reset time and the maximum number of consecutive reclosing operations within the reset time shall be declared by the manufacturer.

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R.5 Marking and instructions

As a complement to Clause 5 and Clause B.5 of this standard, the following additional marking shall apply:

a) The following data shall be marked on the device, in addition to the marking specified in 5.2 a) and B.5, and be clearly visible in the installed position:
   - indication of mode selection of the selector switch: "automatic reclosing" and "manual reclosing";

b) The following data shall also be marked externally on the device, as specified in item a), except that they need not be visible when the device is installed. This data shall also be made available in the manufacturer's literature:
   - rated control circuit supply voltage (U_s) of the CBAR, if applicable;
   - rated automatic reclosing operating residual current ($I_{\Delta ar}$);
   - meaning of the indicators (e.g. lamps), if applicable;

c) The following data shall either be marked on the device as specified in item b), or made available in the manufacturer's literature:
   - procedure for replacement of any built-in fuse;
   - procedure for the connection of the earth terminal when necessary for the automatic reclosing function;
   - reset time and corresponding maximum number of reclosing operations;
   - monitoring time and reclosing time for type M CBARs;
   - reclosing time-delay for type TD CBARs.

Clause 5 and Clause B.5 apply with the additions listed in Table R.2.

Table R.2 – Product information

Item	Information	Marking location
R1.1	Indication of the two positions of the selector switch: "automatic reclosing" and "manual reclosing"	Visible
R2.1	Rated control circuit supply voltage (U_s) of the CBAR, if applicable	Marked
R2.2	Rated automatic reclosing operating residual current ($I_{\Delta ar}$)	Marked
R2.3	Meaning of the indicators (e.g. lamps), if applicable	Marked
R3.1	Procedure for replacement of any built-in fuse	Literature
R3.2	Procedure for the connection of the earth terminal when necessary for the automatic reclosing function	Literature
R3.3	Reset time and corresponding maximum number of reclosing operations	Literature
R3.4	Monitoring time and reclosing time for type M CBARs	Literature
R3.5	Reclosing time delay for type TD CBARs	Literature

Key

Visible: visible from the front when the circuit-breaker is installed as in service and the actuator is accessible

Marked: marked on the product

Literature: provided in the manufacturer's literature

R.6 Normal service, mounting and transport conditions

Clause 6 applies.

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R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 7.1 and B.7.1 of this standard, the following additional requirements apply:

R.7.1.1 Mode selection

The device shall be equipped with a selector switch (see R.2.3).

Compliance is checked by the tests of R.8.4.4.

R.7.1.2 Indicators

The device shall be provided with an indicator showing the blocked state.

All indicators shall be visible in the installed position.

R.7.1.3 Type M CBARs

It shall be ensured that no hazardous voltage or current is applied to the load terminals. One of the following methods shall be employed:

– The monitoring voltage (see R.3.2.1) shall be supplied by a transformer providing Class II isolation between primary and secondary circuits. The monitoring voltage shall not exceed 25 V a.c. or 60 V d.c.; or

– The monitoring current (see R.3.2.1) shall be supplied from a current-limiting source or a protective impedance device complying with IEC 61140. The steady-state current shall not exceed 1 mA a.c. or 2 mA d.c.

R.7.2 Operating requirements

As a complement to 7.2 and B.7.2 of this standard, the following additional requirements apply:

R.7.2.1 General

CBARs shall only reclose automatically after tripping due to the residual current function. Compliance is checked by the tests of R.8.2.

CBARs shall not reclose automatically after intentional opening of the circuit-breaker. Compliance is checked by the tests of R.8.3.

When the maximum number of automatic reclosing operations within the reset time is reached, the automatic reclosing function shall be blocked until a manual reset is performed.

The reset time shall be not less than 5 s.

R.7.2.2 Type M CBARs

After tripping of the residual current release, if the assessed earth leakage current is lower than $I_{\Delta ar}$, a type M CBAR shall automatically reclose within the reclosing time declared by the manufacturer.

After tripping of the residual current release, if the assessed earth leakage current is higher than $I_{\Delta ar}$, the automatic reclosing shall be inhibited. In this case, the monitoring shall not be effective for a period of time longer than the monitoring time declared by the manufacturer. After this time, the automatic reclosing function shall be blocked.

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The monitoring time shall be less than 1 h.

Compliance is checked by the tests of R.8.4.2.

R.7.2.3 Type TD CBAR

After tripping due to the residual current function, a type TD CBAR shall automatically reclose within the reclosing time-delay declared by the manufacturer, unless it has reached the maximum number of consecutive reclosing operations within the reset time.

Compliance is checked by the tests of R.8.4.3.

NOTE A type TD CBAR will not reclose on a phase-to-phase short-circuit, but can potentially reclose on a phase-to-ground fault.

R.7.2.4 Residual short-circuit making and breaking capacity

CBARs shall make, carry for a specified time and break residual short-circuit currents.

Compliance is checked by the tests of R.8.7.

R.7.2.5 Effects of environmental conditions

CBARs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the tests of R.8.8.

R.8 Tests

R.8.1 General conditions

As a complement to Clause 8 and Clause B.8 of this standard, the following additional requirements apply.

Integral CBARs shall meet the test requirements from R.8.2 to R.8.8 except that the tests of R.8.6 only apply to CBARs suitable for isolation.

One sample shall be submitted to the tests of R.8.2, R.8.3 and R.8.4 in sequence.

The tests from R.8.5 to R.8.8 may be made during the test sequences of Clause 8.

External CBARs shall meet the test requirements of R.8.9.

Tests shall be performed in automatic reclosing mode, unless otherwise stated, the CBAR being supplied with the maximum rated voltage and the rated control circuit supply voltage, if applicable.

The CBAR shall be connected as per the manufacturer's instructions.

EMC tests of B.8.12 shall be performed in both automatic re-closing mode and manual re-closing mode.

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R.8.2 Verification of the non-reclosing after tripping under over-current conditions

R.8.2.1 Tripping under short-circuit conditions

The circuit-breaker shall be tripped through its short-circuit release by applying a test current higher or equal to 120 % of the short-circuit current setting on one combination of two poles in series chosen at random (see 8.3.3.2.2). In case of adjustable current setting, the test shall be performed at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker short-circuit release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.2.2 Tripping under overload conditions

The circuit-breaker shall be tripped through its overload release by applying a test current higher than 130 % of the overload current setting and lower than 80 % of the short circuit current setting. This test may be performed at any ambient temperature and in case of adjustable current setting, at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker overload release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.3 Verification of the non-reclosing after intentional opening

The selector switch being in the "automatic reclosing" position and the control circuit supply voltage normally applied, the circuit-breaker is opened manually. The device shall not reclose automatically after opening. The test duration shall be twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

This test shall be repeated for opening through shunt trip or undervoltage release as applicable, using any convenient rated control voltage variant.

R.8.4 Verification of the automatic reclosing function after tripping on earth fault

R.8.4.1 General

The devices shall be installed as in normal use.

The test circuit shall be in accordance with Figure R.1.

R.8.4.2 Verification of the correct operation of type M CBARs

R.8.4.2.1 In case of continuous residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

The switch S_2 shall be maintained in the closed position for the monitoring time declared by the manufacturer (see R.7.2.2).

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The monitoring voltage or current shall comply with the requirements of R.7.1.3.

The CBAR shall not reclose automatically.

At the end of the monitoring time, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.2.2 In case of temporary residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.The CBAR shall trip.

After tripping, the residual current is reduced to the value of $I_{\Delta ar}$ corresponding to the applied voltage.

The CBAR shall reclose automatically within the reclosing time declared by the manufacturer.

The test is repeated as many times as necessary to verify the maximum number of consecutive reclosing operations within the reset time, as declared by the manufacturer. At the end of the test, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.3 Verification of the correct operation of type TD CBARs

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay (Δt) as applicable.

The test circuit being calibrated at $2 \times I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall reclose automatically within the reclosing time-delay, repeated for the maximum number of consecutive reclosings within the reset time, as declared by the manufacturer.

At the end of the test, the CBAR shall be in the blocked state.

R.8.4.4 Verification of the correct operation of the selector switch

The test is made on one pole only chosen at random, with the selector switch in the "manual reclosing" position, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit being calibrated at $2 \times I_{\Delta n}$, and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

Immediately after tripping, the switch S_2 is re-opened; the CBAR shall not reclose automatically within twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

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R.8.5 Verification of mechanical endurance

R.8.5.1 External automatic reclosing device combined with a CBR previously tested to Annex B or CBAR previously tested to Annex B

The test circuit is in accordance with Figure R.1.

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit is calibrated at $2 \times I_{\Delta n}$. With the switch S_1 and the CBAR in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall be reclosed automatically.

The test shall be repeated for one-third of the number of "operations with current" specified in Table 8. No failure to trip or to reclose shall be permitted.

NOTE Depending on the reset time and corresponding maximum number of consecutive reclosing operations, it may be necessary to manually reset the CBAR or inhibit the blocking function.

R.8.5.2 CBAR not previously tested to Annex B

The test of R.8.5.1 may be carried out separately or during the operational performance test of B.8.1.1.1, replacing the operations performed by applying a residual current.

R.8.6 Verification of the isolation function

R.8.6.1 General

This verification only applies to CBARs suitable for isolation.

The tests of R.8.6.2 and R.8.6.3 shall be performed in all positions of the selector switch and in the blocked state.

R.8.6.2 Leakage current between open contacts

The following requirements apply:

a) Following the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA.

b) Following the test of 8.3.3.6 (Test sequence I, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

c) Following the test of 8.3.4.4 (Test sequence II, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

d) If applicable, following the test of 8.3.5.4 (Test sequence III, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 6 mA.

R.8.6.3 Impulse voltage between open contacts

During the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the test voltage shall be applied between the line terminals being connected together and load terminals being connected together of CBARs with the contacts in the open position and its value shall be as specified in Table 14 of IEC 60947-1:2007.

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There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

B.8.10 applies, with the following additional requirements:

The tests shall be performed in automatic reclosing mode, if applicable, with the line voltage (i.e. control circuit supply voltage) connected to the CBAR.

The following additional requirements shall be met after test:

– The CBAR shall comply with the test of ~~B.8.10.4.2~~ B.8.11.4 b) regardless of the operation of the protection devices (fuse, etc.);

– In case of operation of the protection devices (fuse, etc.), this operation shall be shown by the appropriate indication means, if provided. If no indication mean is provided, it shall not be possible to reclose the CBAR, even manually, when the protection devices have operated.

R.8.8 Verification of the automatic reclosing function after the test sequences of Clause B.8

Following each of the verifications of ~~B.8.1.1.2~~ B.8.1.2.1 (verification of the withstand capability to short-circuit currents), a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

Following each of the test sequences B I to B IV of Annex B, a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

R.8.9 Test items for external type automatic reclosing devices

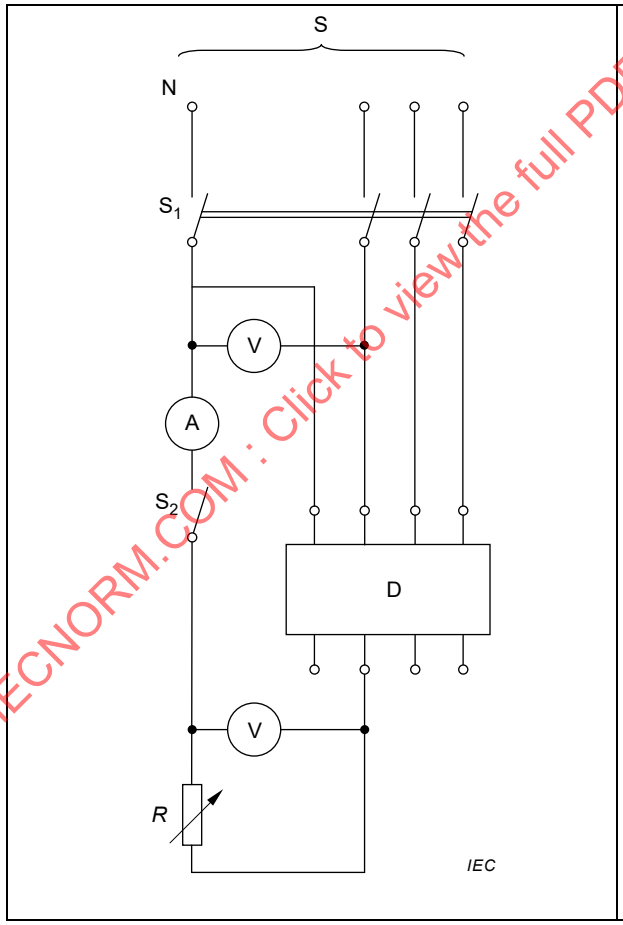
The following test sequences shall be performed on CBARs classified under R.3.1.2, in accordance with Figure R.1.

These tests are applicable to an automatic reclosing device assembled to a CBR and do not replace the tests of Clause B.8 made on the CBR.

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Table R.1 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under over-current conditions	R.8.2
	Verification of the non-reclosing after intentional opening	R.8.3
	Verification of the automatic reclosing function after tripping on earth faults	R.8.4
	Verification of mechanical endurance	R.8.5
	Verification of the isolation function	R.8.6
2	Verification of the residual short-circuit making and breaking capacity	R.8.7
3	Rated ultimate short-circuit breaking capacity	8.3.5
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
4	Verification of the effects of environmental conditions	B.8.11
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
5	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Verification of electromagnetic compatibility	B.8.12
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8



Key:

S = power supply
N = neutral connection
S_1 = multipole switch
S_2 = single-pole switch
V = voltmeter
A = r.m.s. ammeter
D = CBAR under test
R = adjustable resistor

Figure R.1 – Test circuit for the verification of the automatic reclosing functions

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2 This publication was withdrawn.

3 "DB" refers to the IEC on-line database.

4 "DB" refers to the IEC on-line database.

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UL 486E, *Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors*

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5 IS 13947-1 has been withdrawn.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

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Cette version consolidée de la Norme IEC officielle et de son amendement a été préparée pour la commodité de l'utilisateur.

L'IEC 60947-2 édition 5.1 contient la cinquième édition (2016-06) [documents 121A/71/FDIS et 121A/83/RVD], son corrigendum (2016-11) et son amendement 1 (2019-07) [documents 121A/286/FDIS et 121A/302/RVD].

Dans cette version Redline, une ligne verticale dans la marge indique où le contenu technique est modifié par l'amendement 1. Les ajouts sont en vert, les suppressions sont en rouge, barrées. Une version Finale avec toutes les modifications acceptées est disponible dans cette publication.

La Norme internationale IEC 60947-2 a été établie par le sous-comité 121A: Appareillages à basse tension, du comité d'études 121 de l'IEC: Appareillage et ensembles d'appareillages basse tension.

Cette cinquième édition constitue une révision technique.

Cette édition inclut les additions techniques majeures suivantes par rapport à l'édition précédente:

- essais pour la vérification de la sélectivité dans l'Annexe A (voir A.5.3),
- essais de courants de charge critiques pour disjoncteurs à courant continu (voir 8.3.9),
- nouvelle Annexe P relative aux disjoncteurs pour utilisation dans des applications photovoltaïques,
- nouvelle Annexe R relative aux disjoncteurs de courant différentiel résiduel avec fonctions de refermeture automatique.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60947, publiées sous le titre général *Appareillage à basse tension*, peut être consultée sur le site web de l'IEC.

Cette Norme internationale doit être utilisée conjointement avec l'IEC 60947-1:2007 et ses Amendement 1:2010 et Amendement 2:2014.

Les dispositions des règles générales qui font l'objet de l'IEC 60947-1 sont applicables à la présente norme lorsque celle-ci le précise. Les articles, paragraphes, tableaux, figures et annexes des règles générales qui sont ainsi applicables sont identifiés par référence à l'IEC 60947-1 et ses amendements le cas échéant, par exemple: 1.2.3 de l'IEC 60947-1:2007, Tableau 4 de l'IEC 60947-1:2007/AMD1:2010, ou Annexe A de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

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Le contenu du corrigendum d'octobre 2019 a été pris en considération dans cet exemplaire.

APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

1 Généralités

1.1 Domaine d'application et objet

La présente partie de la série IEC 60947 est applicable aux disjoncteurs destinés à être installés et utilisés par des personnes qualifiées ou compétentes, et dont les contacts principaux sont destinés à être reliés à des circuits dont la tension assignée ne dépasse pas 1 000 V en courant alternatif ou 1 500 V en courant continu; elle contient aussi des exigences supplémentaires pour les disjoncteurs à fusibles incorporés.

Les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif mais ne dépassant pas 1 500 V en courant alternatif peuvent également être soumis à essai selon la présente norme.

Elle est applicable quels que puissent être les courants assignés, les méthodes de construction et l'emploi prévu des disjoncteurs.

Les exigences pour les disjoncteurs qui sont aussi prévus pour assurer une protection contre les courants différentiels résiduels font l'objet de l'Annexe B.

Les exigences supplémentaires pour les disjoncteurs à protection électronique contre les surintensités font l'objet de l'Annexe F.

Les exigences supplémentaires relatives aux disjoncteurs pour réseaux IT font l'objet de l'Annexe H.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des disjoncteurs font l'objet de l'Annexe J.

Les exigences pour les disjoncteurs ne satisfaisant pas aux exigences concernant les protections contre les surintensités font l'objet de l'Annexe L.

Les exigences pour les appareils modulaires à courant différentiel résiduel (non intégrés à un appareil de coupure de courant) font l'objet de l'Annexe M.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des auxiliaires de disjoncteurs font l'objet de l'Annexe N.

Les exigences et les méthodes d'essai pour les disjoncteurs à courant continu utilisables dans les applications photovoltaïques (PV) font l'objet de l'Annexe P.

Les exigences et les méthodes d'essai pour les disjoncteurs incorporant une protection par courant différentiel résiduel avec fonctions de refermeture automatique font l'objet de l'Annexe R.

Les exigences supplémentaires pour les disjoncteurs utilisés comme démarreurs directs sont données dans l'IEC 60947-4-1, applicable aux contacteurs et aux démarreurs à basse tension.

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Les exigences concernant les disjoncteurs destinés à la protection des installations électriques des bâtiments et à des emplois analogues et prévus pour être utilisés par des personnes non averties figurent dans l'IEC 60898.

Les exigences relatives aux disjoncteurs pour le matériel (par exemple pour les appareils électriques) figurent dans l'IEC 60934.

Des exigences particulières ou ~~complémentaires~~ supplémentaires peuvent être nécessaires pour certaines applications spécifiques (par exemple: traction, laminoirs, service à bord des navires, circuits en aval de dispositifs d'entraînement à fréquence variable, utilisation dans des atmosphères explosives).

NOTE Les disjoncteurs, objet de la présente norme, peuvent être munis d'appareils provoquant l'ouverture automatique dans des conditions prédéterminées autres que la surintensité et la chute de tension, telles que, par exemple, l'inversion de la puissance ou du courant. La présente norme ne traite pas de la vérification du fonctionnement dans de telles conditions prédéterminées.

La présente norme a pour objet de fixer:

a) les caractéristiques des disjoncteurs;

b) les conditions auxquelles doivent répondre les disjoncteurs concernant:

   1) leur fonctionnement et leur tenue en service normal;

   2) leur fonctionnement et leur tenue en cas de surcharge et en cas de court-circuit, y compris la coordination en service (sélectivité et protection d'accompagnement);

   3) leurs propriétés diélectriques;

c) les essais destinés à vérifier si ces conditions sont remplies et les méthodes à adopter pour ces essais;

d) les informations à marquer sur les appareils ou à fournir avec ceux-ci.

1.2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-14, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60068-2-30, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60228, *Ames des câbles isolés*

IEC 60269-1:2006, *Fusibles basse tension – Partie 1: Exigences générales*

~~IEC 60364 (toutes les parties), *Installations électriques à basse tension*~~

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60947-1:2007, *Appareillage à basse tension – Partie 1: Règles générales*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

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~~IEC 61000-3-2, *Compatibilité électromagnétique (CEM) – Partie 3-2: Limites – Limites pour les émissions de courant harmonique (courant appelé par les appareils ≤ 16 A par phase)*~~

~~IEC 61000-3-3, *Compatibilité électromagnétique (CEM) – Partie 3-3: Limites – Limitation des variations de tension, des fluctuations de tension et du papillotement dans les réseaux publics d'alimentation basse tension, pour les matériels ayant un courant assigné ≤16 A par phase et non soumis à un raccordement conditionnel*~~

IEC 61000-4-2:2008, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2006, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5:2014, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6:2013, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-11, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61545, *Dispositifs de connexion – Dispositifs pour la connexion des câbles en aluminium dans un organe de serrage en matière quelconque et des câbles en cuivre dans des organes de serrage en aluminium*

IEC 62475:2010, *Techniques des essais à haute intensité – Définitions et exigences relatives aux courants d'essai et systèmes de mesure*

CISPR 11:2015, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
CISPR 11:2015/AMD1:2016

~~CISPR 22, *Appareils de traitement de l'information – Caractéristiques des perturbations radioélectriques – Limites et méthodes de mesure*~~

CISPR 32:2015, *Compatibilité électromagnétique des équipements multimédia – Exigences d'émission*

2 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60947-1 ainsi que les suivants s'appliquent.

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NOTE Lorsque ces définitions sont identiques à celles du *Vocabulaire Electrotechnique International (VEI)*, IEC 60050-441, la référence à cette publication est donnée entre crochets.

2.1
disjoncteur
appareil mécanique de connexion capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, ainsi que d'établir, de supporter pendant une durée spécifiée et d'interrompre des courants dans des conditions anormales spécifiées du circuit telles que celles du court-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
taille
terme désignant un groupe de disjoncteurs dont les dimensions extérieures physiques sont communes à une plage de courants assignés

Note 1 à l'article: La taille est exprimée en ampères correspondant au courant assigné le plus élevé du groupe.

Note 2 à l'article: Dans une taille, la largeur de l'appareil peut varier selon le nombre de pôles.

Note 3 à l'article: Cette définition n'implique pas de normalisation dimensionnelle.

2.1.2
différence de construction
différence significative de construction entre des disjoncteurs d'une taille donnée, nécessitant d'effectuer des essais supplémentaires de type

2.2
disjoncteur à fusibles incorporés
combinaison en un seul appareil d'un disjoncteur et de fusibles, un fusible étant placé en série avec chaque pôle du disjoncteur destiné à être relié à un conducteur de phase

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
disjoncteur à limitation du courant
disjoncteur qui, à l'intérieur d'une plage de courants spécifiée, empêche le courant coupé limité d'atteindre la valeur crête présumée et qui limite l'énergie limitée (I^2t) à une valeur inférieure à l'énergie limitée d'une demi-période du courant présumé symétrique

Note 1 à l'article: Il peut être fait référence à la valeur crête présumée symétrique ou asymétrique du courant coupé limité.

Note 2 à l'article: Le courant coupé limité (let-through current) est aussi nommé «cut-off current» (voir IEC 60050-441:1984, 441-17-12).

Note 3 à l'article: Les modèles de représentation graphique des caractéristiques de courant coupé limité et d'énergie limitée sont illustrés de la Figure K.2 à la Figure K.5 et les exemples d'utilisation des modèles de la Figure K.6 à la Figure K.7.

2.4
disjoncteur enfichable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts permettant le retrait du disjoncteur

Note 1 à l'article: Certains disjoncteurs peuvent être de type enfichable sur le côté d'alimentation uniquement, les bornes de sortie étant les bornes utilisées habituellement pour le raccordement par conducteurs.

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2.5
disjoncteur débrochable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts de sectionnement lui permettant d'être retiré du circuit principal et, en position débrochée, de présenter une distance de sectionnement conforme à des exigences spécifiées

2.6
disjoncteur en boitier moulé
disjoncteur dont le châssis et l'enveloppe sont en matériau isolant moulé et font partie intégrante du disjoncteur

[SOURCE: IEC 60050-441:1984, 441-14-24]

2.7
disjoncteur à air
disjoncteur dont les contacts s'ouvrent et se ferment dans l'air à la pression atmosphérique

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
disjoncteur à vide
disjoncteur dont les contacts s'ouvrent et se ferment dans une enceinte où règne un vide poussé

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
disjoncteur à gaz
disjoncteur dont les contacts s'ouvrent et se ferment dans un gaz autre que l'air à une pression égale ou supérieure à la pression atmosphérique

2.10
déclencheur sous courant de fermeture
déclencheur qui permet l'ouverture d'un disjoncteur sans retard intentionnel, pendant une manœuvre de fermeture, si le courant établi dépasse une valeur prédéterminée, et qui est rendu inopérant lorsque le disjoncteur est en position fermée

2.11
déclencheur de court-circuit
déclencheur à maximum de courant destiné à la protection contre les courts-circuits

2.12
déclencheur de court-circuit à retard de courte durée
déclencheur à maximum de courant prévu pour fonctionner au bout d'un retard de courte durée

2.13
interrupteur de défaut
interrupteur auxiliaire ne fonctionnant que lors du déclenchement du disjoncteur auquel il est associé

2.14
disjoncteur à fermeture empêchée
disjoncteur dont chacun des contacts mobiles est empêché de se fermer suffisamment pour être capable de laisser passer le courant si l'ordre de fermeture est donné alors que demeurent maintenues des conditions spécifiées

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2.15
pouvoir de coupure (ou de fermeture) en court-circuit
pouvoir de coupure (ou de fermeture) pour lequel les conditions spécifiées comprennent un court-circuit

2.15.1
pouvoir de coupure ultime en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée ne comprennent pas l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

2.15.2
pouvoir de coupure de service en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée comprennent l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

2.16
durée d'ouverture
intervalle de temps entre l'instant spécifié de début de la manoeuvre d'ouverture et l'instant de la séparation des contacts d'arc sur tous les pôles

Note 1 à l'article:

– dans le cas d'un disjoncteur actionné directement, l'instant de début de la durée d'ouverture est l'instant de début d'un courant assez fort pour provoquer la manœuvre du disjoncteur;

– dans le cas d'un disjoncteur actionné par toute forme d'énergie auxiliaire, l'instant de début de la durée d'ouverture est l'instant de début de l'application ou du retrait de l'énergie auxiliaire au déclencheur d'ouverture.

Note 2 à l'article: Pour les disjoncteurs, la «durée d'ouverture» est couramment appelée «durée de déclenchement», bien que, à proprement parler, la durée de déclenchement comprenne le délai entre l'instant où commence la durée d'ouverture et celui où la commande de l'ouverture devient irréversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modifiée – ajout de Notes à l'article.]

2.17
coordination de la protection contre les surintensités

2.17.1
sélectivité lors d'une surintensité
coordination entre les caractéristiques de fonctionnement de plusieurs appareils de protection à maximum de courant de telle façon qu'à l'apparition de surintensités comprises dans des limites données, l'appareil prévu pour fonctionner dans ces limites fonctionne, tandis que le ou les autres ne fonctionnent pas

2.17.2
sélectivité totale
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection sans provoquer le fonctionnement de l'autre appareil de protection

2.17.3
sélectivité partielle
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection jusqu'à un niveau donné de surintensité sans provoquer le fonctionnement de l'autre appareil de protection

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2.17.4
courant limite de sélectivité
I_s
valeur de courant correspondant à l'intersection de la caractéristique totale temps-courant de l'appareil de protection placé en aval avec la caractéristique temps-courant de préarc (pour les fusibles) ou de déclenchement (pour les disjoncteurs) de l'autre appareil de protection

Note 1 à l'article: Le courant limite de sélectivité (voir Figure A.1) est une valeur limite de courant:

– en dessous de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval achève sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité est assurée);

– au-dessus de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval peut ne pas achever sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité n'est pas assurée).

2.17.5
courant d'intersection
I_B
coordonnée du courant correspondant à l'intersection des courbes donnant les caractéristiques de la durée maximale de coupure en fonction du courant pour deux appareils de protection à maximum de courant placés en série

Note 1 à l'article: Cela s'applique à deux appareils de protection à maximum de courant placés en série pour des durées de fonctionnement ≥ 0,05 s. Pour des durées de fonctionnement < 0,05 s, les deux appareils à maximum de courant placés en série sont considérés comme une association (voir Annexe A).

2.18
caractéristique I^2t d'un disjoncteur
information (généralement une courbe) donnant les valeurs maximales de I^2t correspondant à la durée de coupure en fonction du courant présumé (valeur efficace de la composante périodique en courant alternatif) jusqu'à la valeur maximale du courant présumé correspondant au pouvoir assigné de coupure en court-circuit à la tension correspondante

2.19
durée de réarmement
temps écoulé entre le déclenchement du disjoncteur provoqué par une surintensité et l'instant où les conditions sont atteintes pour qu'il puisse être refermé

2.20
courant assigné instantané de réglage de court-circuit
I_i
valeur assignée du courant provoquant le fonctionnement d'un déclencheur sans retard intentionnel

2.21
courant de réglage de surcharge
I_r
courant de réglage pour un déclencheur de surcharge réglable

Note 1 à l'article: Dans le cas d'un déclencheur de surcharge non réglable, cette valeur est égale au courant assigné I_n.

2.22
automate programmable
AP
système électronique numérique conçu pour un usage en environnement industriel et utilisant une mémoire programmable destinée au stockage interne d'instructions orientées utilisateur pour réaliser des fonctions particulières telles que la logique, le séquencement, le décompte du temps, le comptage et l'arithmétique afin de commander, au moyen d'entrées et de sorties analogiques ou numériques, différents types de machines ou de processus. Un AP ainsi que ses périphériques associés sont conçus de sorte qu'ils peuvent aisément être intégrés dans un système de commande industriel et employés dans toutes leurs fonctions prévues

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[SOURCE: IEC 61131-1:2003, 3.5, modifiée – suppression de la note.]

2.23
déclencheur de fermeture
bobine de fermeture
auxiliaire alimenté par une source de tension qui déclenche la fermeture du disjoncteur

Note 1 à l'article: Un déclencheur de fermeture est un appareil auxiliaire du disjoncteur, différent de l'"appareil de fermeture" mentionné dans les figures de l'Annexe A et dans l'IEC 60947-1, qui fait partie du montage d'essai et qui est destiné à établir le courant de court-circuit.

3 Classification

Les disjoncteurs peuvent être classés:

3.1 Suivant leur catégorie de sélectivité, A ou B (voir 4.4)

3.2 Suivant le milieu de coupure, par exemple:

– coupure à air,
– coupure sous vide,
– coupure à gaz.

3.3 Suivant le type de conception, par exemple:

– construction ouverte,
– construction en boîtier moulé.

3.4 Suivant le mode de commande du mécanisme de manœuvre, c'est-à-dire:

– manœuvre dépendante à main,
– manœuvre indépendante à main,
– manœuvre dépendante à source d'énergie extérieure,
– manœuvre indépendante à source d'énergie extérieure,
– manœuvre à accumulation d'énergie.

3.5 Suivant l'aptitude au sectionnement:

– apte au sectionnement,
– inapte au sectionnement.

3.6 Suivant les possibilités d'entretien:

– conçu pour être entretenu,
– non conçu pour être entretenu.

3.7 Suivant le mode d'installation, par exemple:

– fixe,
– enfichable,
– débrochable.

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3.8 Suivant le degré de protection procuré par l'enveloppe (voir 7.1.12 de l'IEC 60947-1:2007).

4 Caractéristiques des disjoncteurs

4.1 Enumération des caractéristiques

Les caractéristiques d'un disjoncteur doivent, selon le cas, être indiquées de la façon suivante:

– type du disjoncteur (4.2),
– valeurs assignées et valeurs limites du circuit principal (4.3),
– catégories de sélectivité (4.4),
– circuits de commande (4.5),
– circuits auxiliaires (4.6),
– déclencheurs (4.7),
– fusibles incorporés (disjoncteurs à fusibles incorporés) (4.8).

4.2 Type du disjoncteur

Les éléments suivants doivent être indiqués:

– le nombre de pôles,
– la nature du courant (courant alternatif ou courant continu) et, dans le cas du courant alternatif, le nombre de phases et la fréquence assignée.

4.3 Valeurs assignées et valeurs limites du circuit principal

4.3.1 Généralités

Les valeurs assignées relatives à un disjoncteur doivent être indiquées conformément aux 4.3.2 à 4.4, mais il n'est pas nécessaire de spécifier toutes les valeurs assignées énumérées.

4.3.2 Tensions assignées

4.3.2.1 Tension d'emploi assignée (U_e)

Le paragraphe 4.3.1.1 de l'IEC 60947-1:2007 est applicable avec le développement suivant:

– Disjoncteurs répondant au point a) de la Note 2 (de l'IEC 60947-1 :2007):

U_e est généralement exprimée par la tension entre phases.

NOTE 1 Au Canada et aux Etats-Unis, la tension assignée d'emploi U_e est exprimée par:

a) la tension entre phases et la terre, ainsi que par la tension entre phases (par exemple 277 V/480 V) pour des réseaux triphasés à quatre fils et neutre mis à la terre,

b) la tension entre phases (par exemple 480 V) pour des réseaux triphasés, à trois fils, non reliés à la terre ou reliés à la terre par une impédance.

Les disjoncteurs pour systèmes non reliés à la terre ou pour systèmes reliés à la terre par une impédance requièrent des essais supplémentaires conformément à l'Annexe H.

– Disjoncteurs répondant au point b) de la Note 2:

Ces disjoncteurs demandent des essais supplémentaires conformément à l'Annexe C.

U_e doit s'exprimer par la tension entre phases, précédée de la lettre C.

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NOTE 2 Dans la pratique actuelle au Canada et aux Etats-Unis, les disjoncteurs répondant au point b) de la Note 2 (de l'IEC 60947-1 :2007) ne sont identifiés que par la tension entre phases.

4.3.2.2 Tension d'isolement assignée (U_i)

Le paragraphe 4.3.1.2 de l'IEC 60947-1:2007 est applicable.

4.3.2.3 Tension assignée de tenue aux chocs (U_{imp})

Le paragraphe 4.3.1.3 de l'IEC 60947-1:2007 est applicable.

4.3.3 Courants

4.3.3.1 Courant thermique conventionnel à l'air libre (I_{th})

Le paragraphe 4.3.2.1 de l'IEC 60947-1:2007 est applicable.

4.3.3.2 Courant thermique conventionnel sous enveloppe (I_{the})

Le paragraphe 4.3.2.2 de l'IEC 60947-1:2007 est applicable.

4.3.3.3 Courant assigné (I_n)

Pour les disjoncteurs, le courant assigné est le courant assigné ininterrompu (I_u) (voir 4.3.2.4 de l'IEC 60947-1:2007) et a la même valeur que le courant thermique conventionnel à l'air libre (I_{th}).

4.3.3.4 Courant assigné des disjoncteurs tétrapolaires

Le paragraphe 7.1.9 de l'IEC 60947-1:2007 est applicable.

4.3.4 Fréquence assignée

Le paragraphe 4.3.3 de l'IEC 60947-1:2007 est applicable.

4.3.5 Service assigné

Les services assignés considérés comme normaux sont:

– le service de huit heures (voir le 4.3.4.1 de l'IEC 60947-1:2007),
– le service ininterrompu (voir le 4.3.4.2 de l'IEC 60947-1:2007).

4.3.6 Caractéristiques de court-circuit

4.3.6.1 Pouvoir assigné de fermeture en court-circuit (I_{cm})

Le pouvoir assigné de fermeture en court-circuit d'un disjoncteur est la valeur de pouvoir de fermeture en court-circuit fixée pour ce disjoncteur par le fabricant pour la tension assignée d'emploi, à la fréquence assignée et pour un facteur de puissance spécifié en courant alternatif, ou une constante de temps spécifiée en courant continu. Il s'exprime par la valeur maximale de crête du courant présumé.

En courant alternatif, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur au produit de son pouvoir assigné de coupure ultime en court-circuit multiplié par le facteur *n* figurant au Tableau 2 (voir 4.3.6.3).

En courant continu, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur à son pouvoir assigné de coupure ultime en court-circuit.

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Un pouvoir assigné de fermeture en court-circuit implique que le disjoncteur doit être capable d'établir le courant correspondant à ce pouvoir assigné pour une tension appliquée appropriée à la tension assignée d'emploi.

4.3.6.2 Pouvoirs assignés de coupure en court-circuit

4.3.6.2.1 Généralités

Les pouvoirs assignés de coupure en court-circuit d'un disjoncteur sont les valeurs de pouvoir de coupure en court-circuit assignées par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans des conditions spécifiées.

Un pouvoir assigné de coupure en court-circuit exige que le disjoncteur doit pouvoir couper tout courant de court-circuit de valeur inférieure ou égale à ce pouvoir assigné de coupure, à une tension de rétablissement à fréquence industrielle correspondant aux valeurs spécifiées pour la tension d'essai et:

– en courant alternatif, à tout facteur de puissance supérieur ou égal à celui du Tableau 11 (voir 8.3.2.2.4),
– en courant continu, à toute constante de temps inférieure ou égale à celle du Tableau 11 (voir 8.3.2.2.5).

Aucun pouvoir de coupure en court-circuit n'est garanti pour des tensions de rétablissement à fréquence industrielle supérieures aux valeurs spécifiées pour la tension d'essai (voir 8.3.2.2.6).

En courant alternatif, le disjoncteur doit être capable de couper un courant présumé correspondant à son pouvoir assigné de coupure en court-circuit et le facteur de puissance correspondant donné au Tableau 11, quelle que soit la valeur de la composante continue correspondante, en admettant que la composante périodique est constante.

Les pouvoirs assignés de coupure en court-circuit sont définis comme suit:

– pouvoir assigné de coupure ultime en court-circuit,
– pouvoir assigné de coupure de service en court-circuit.

4.3.6.2.2 Pouvoir assigné de coupure ultime en court-circuit (I_{cu})

Le pouvoir assigné de coupure ultime en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure ultime en court-circuit (voir 2.15.1) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.5. Il est exprimé comme valeur du courant de coupure présumé, en kA (valeur efficace de la composante alternative dans le cas du courant alternatif).

4.3.6.2.3 Pouvoir assigné de coupure de service en court-circuit (I_{cs})

Le pouvoir assigné de coupure de service en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure de service en court-circuit (voir 2.15.2) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.4. Il est exprimé comme valeur du courant de coupure présumé, en kA, ou comme pourcentage de I_{cu} (par exemple I_{cs} = 25 % I_{cu}).

I_{cs} doit être au moins égal à 25 % de I_{cu}.

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Tableau 1 (vide)

4.3.6.3 Relation normale entre les pouvoirs de fermeture et de coupure en court-circuit des disjoncteurs à courant alternatif et les facteurs de puissance correspondants

La relation normale entre le pouvoir de coupure en court-circuit et le pouvoir de fermeture en court-circuit est donnée par le Tableau 2.

Tableau 2 – Rapport *n* entre le pouvoir de fermeture en court-circuit et le pouvoir de coupure en court-circuit et le facteur de puissance correspondant (pour les disjoncteurs à courant alternatif)

Pouvoir de coupure en court-circuit kA eff	Facteur de puissance	Valeur minimale exigée de n $n = \frac{\text{pouvoir de fermeture en court - circuit}}{\text{pouvoir de coupure en court - circuit}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

Les pouvoirs assignés de fermeture et de coupure en court-circuit ne sont valables que si le disjoncteur est manœuvré selon les exigences de 7.2.1.1 et 7.2.1.2.

Pour des exigences spéciales, le fabricant peut fixer une valeur de pouvoir assigné de fermeture en court-circuit supérieure à celle exigée dans le Tableau 2. Les essais de vérification de ces valeurs assignées doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

4.3.6.4 Courant assigné de courte durée admissible (I_{cw})

Le courant assigné de courte durée admissible d'un disjoncteur est la valeur de courant de courte durée admissible fixée pour ce disjoncteur par le fabricant dans les conditions d'essai spécifiées en 8.3.6.3.

En courant alternatif, la valeur de ce courant est la valeur efficace de la composante périodique du courant présumé de court-circuit, étant par hypothèse constante pendant le retard de courte durée.

Le retard de courte durée associé au courant assigné de courte durée admissible doit être d'au moins 0,05 s, les valeurs préférentielles étant les suivantes:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

Le courant assigné de courte durée admissible ne doit pas avoir une valeur moindre que les valeurs figurant au Tableau 3.

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Tableau 3 – Valeurs minimales du courant assigné de courte durée admissible

Courant assigné I_n A	Courant assigné de courte durée admissible I_{cw} – Valeurs minimales kA
$I_n \leq 2\,500$	12 I_n ou 5 kA, selon la valeur la plus élevée
$I_n > 2\,500$	30 kA

4.4 Catégories de sélectivité

Les disjoncteurs conformes à la présente norme sont divisés en deux catégories de sélectivité:

– **catégorie de sélectivité B** comprenant les disjoncteurs assurant la sélectivité en ayant un courant assigné de courte durée admissible et un retard de courte durée associé conformes à 4.3.6.4.

La sélectivité des disjoncteurs de catégorie de sélectivité B n'est pas nécessairement assurée jusqu'au pouvoir de coupure ultime en court-circuit (par exemple, en cas de fonctionnement d'un déclencheur instantané), mais elle l'est au moins jusqu'à la valeur spécifiée au Tableau 3.

– **catégorie de sélectivité A** comprenant tous les autres disjoncteurs.

Ces disjoncteurs peuvent assurer la sélectivité dans des conditions de court-circuit par d'autres moyens.

Un disjoncteur de catégorie de sélectivité A peut avoir un retard de courte durée intentionnel avec un courant de courte durée admissible inférieur à celui spécifié en 4.3.6.4. Dans ce cas, les essais comprennent la séquence d'essai IV (voir 8.3.6) au courant assigné de courte durée admissible.

L'attention est attirée sur les différences entre les essais s'appliquant aux deux catégories de sélectivité (voir Tableau 9 et 8.3.4, 8.3.5, 8.3.6 et 8.3.8).

Tableau 4 (vide)

4.5 Circuits de commande

4.5.1 Circuits de commande électriques

Le paragraphe 4.5.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, avec le complément suivant:

Si la tension assignée d'alimentation de commande est différente de celle du circuit principal, il est recommandé de choisir sa valeur parmi celles du Tableau 5.

Tableau 5 – Valeurs préférentielles de la tension assignée d'alimentation de commande si elle est différente de celle du circuit principal

Courant continu V	Courant alternatif monophasé V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Circuits de commande à air comprimé (pneumatiques ou électropneumatiques)

Le paragraphe 4.5.2 de l'IEC 60947-1:2007 est applicable.

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4.6 Circuits auxiliaires

Le paragraphe 4.6 de l'IEC 60947-1:2007 est applicable.

4.7 Déclencheurs

4.7.1 Types

Pour les besoins de la présente norme, les types suivants de déclencheurs sont considérés:

1) déclencheur shunt,
2) déclencheur à maximum de courant:
   a) instantané,
   b) à retard indépendant,
   c) à temps inverse:
      – indépendant de la charge préalable,
      – dépendant de la charge préalable (par exemple: déclencheur du type thermique).

NOTE 1 Le terme «déclencheur de surcharge» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les surcharges (voir 2.4.30 de l'IEC 60947-1:2007). Le terme «déclencheur de court-circuit» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les courts-circuits (voir 2.11).

NOTE 2 Le terme «déclencheur réglable», utilisé dans la présente norme, comprend aussi les déclencheurs interchangeables.

3) déclencheur à minimum de tension (déclencheur d'ouverture),
4) déclencheur de fermeture;
~~4)~~5) autres déclencheurs.

4.7.2 Caractéristiques

Les caractéristiques suivantes doivent être considérées:

1) déclencheur shunt et déclencheur à minimum de tension (déclencheurs d'ouverture), et déclencheur de fermeture:
   – tension assignée du circuit de commande (U_c),
   – nature du courant,
   – fréquence assignée, dans le cas du courant alternatif.
2) déclencheur à maximum de courant:
   – courant assigné (I_n),
   – nature du courant,
   – fréquence assignée, dans le cas du courant alternatif,
   – courant de réglage (ou plage de réglage),
   – temps de réglage (ou plage de réglage) le cas échéant.

Le courant assigné d'un déclencheur à maximum de courant est la valeur du courant (valeur efficace dans le cas du courant alternatif) correspondant au courant de réglage maximal qu'il doit être capable de supporter dans les conditions d'essai spécifiées en 8.3.2.5 sans que l'échauffement dépasse les valeurs spécifiées au Tableau 7.

4.7.3 Courant de réglage des déclencheurs à maximum de courant

Pour les disjoncteurs équipés de déclencheurs réglables (voir Note 2 de 4.7.1, point 2)), le courant de réglage (ou la plage des courants de réglage, le cas échéant) doit être marqué ou affiché sur le déclencheur ou sur son échelle de réglage. L'indication ou l'affichage peut être donné(e) soit directement en ampères, soit en multiples de la valeur du courant. Des moyens

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doivent être disponibles auprès du fabricant pour lire l'affichage indépendamment de l'état du disjoncteur.

Pour les disjoncteurs équipés de déclencheurs non réglables, l'indication peut figurer sur le disjoncteur. Si les caractéristiques de fonctionnement du déclencheur de surcharge satisfont aux exigences du Tableau 6, il suffit d'indiquer sur le disjoncteur son courant assigné (I_n).

Pour les déclencheurs indirects fonctionnant à l'aide d'un transformateur de courant, les indications peuvent se rapporter soit au courant au primaire du transformateur de courant qui les alimente, soit au courant de réglage du déclencheur de surcharge. Dans l'un et l'autre cas, le rapport de transformation du transformateur de courant doit être indiqué.

Sauf spécification contraire,

– la valeur de fonctionnement des déclencheurs de surcharge autres que ceux du type thermique est indépendante de la température de l'air ambiant dans les limites de – 5 °C à + 40 °C;
– pour les déclencheurs du type thermique, les valeurs indiquées correspondent à une température de référence de + 30 °C ± 2 °C. Le fabricant doit être en mesure de préciser l'influence des variations de la température de l'air ambiant (voir 7.2.1.2.4, point b)).

4.7.4 Réglage du temps de déclenchement des déclencheurs à maximum de courant

Le temps de déclenchement doit être défini comme suit, selon le type de déclencheur à maximum de courant:

1) Déclencheurs à maximum de courant à retard défini

   Le retard de ces déclencheurs est indépendant de la surintensité. Le réglage du temps de déclenchement doit être défini comme égal à la valeur en secondes de la durée d'ouverture du disjoncteur si le retard n'est pas réglable, ou aux valeurs extrêmes de la durée d'ouverture si le retard est réglable.

2) Déclencheurs à maximum de courant à temps inverse

   Le retard de ces déclencheurs dépend de la surintensité.

   Les caractéristiques temps/courant doivent être données sous forme de courbes fournies par le fabricant. Celles-ci doivent indiquer comment la durée d'ouverture, à partir de l'état froid, varie en fonction du courant dans la plage de fonctionnement du déclencheur. Le fabricant doit indiquer, par des moyens convenables, les tolérances applicables à ces courbes.

   Ces courbes doivent être données pour chacune des valeurs extrêmes du courant de réglage et, si le temps de réglage donné est réglable, il est recommandé qu'elles soient également données pour chacune des valeurs extrêmes du temps de réglage.

   Il est recommandé de porter le courant en abscisses et le temps en ordonnées, en utilisant des échelles logarithmiques. De plus, en vue de faciliter l'étude de la coordination des divers types de protection contre les surintensités, il est recommandé de porter le courant en multiples du courant de réglage et le temps en secondes en utilisant les échelles normalisées données dans les feuilles de courbe normale décrites en 5.6.1 de l'IEC 60269-1:2006.

4.8 Fusibles incorporés (disjoncteurs à fusibles incorporés)

Le paragraphe 4.8 de l'IEC 60947-1:2007/AMD1:2010 est applicable.

Le fabricant doit fournir les informations nécessaires.

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5 Informations sur le matériel

5.1 Nature des informations

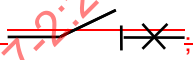
Le paragraphe 5.1 de l'IEC 60947-1:2007 est applicable, dans la mesure où il est approprié pour un modèle particulier.

En supplément le fabricant doit, sur demande, fournir les informations concernant la puissance dissipée typique pour les différentes tailles (voir 2.1.1). Voir Annexe G.

5.2 Marquage

Chaque disjoncteur doit être marqué de façon indélébile; les données à stipuler et les emplacements correspondants sont indiqués dans le Tableau 13.

~~a) Les indications suivantes doivent se trouver sur le disjoncteur lui-même ou sur une ou plusieurs plaques signalétiques fixées au disjoncteur, et ces marques doivent être à un endroit tel qu'elles soient visibles et lisibles lorsque le disjoncteur est en place;~~

- ~~courant assigné (I_n);~~
- ~~aptitude au sectionnement, s'il y a lieu, avec le symbole  ;~~
- ~~indications des positions d'ouverture et de fermeture respectivement par  et  si des symboles sont utilisés (voir 7.1.6.1 de l'IEC 60947-1:2007).~~

~~b) Les indications suivantes doivent également être marquées sur le disjoncteur, comme spécifié au point a), excepté qu'il n'est pas nécessaire qu'elles soient visibles lorsque le disjoncteur est en place:~~

- ~~nom du fabricant ou marque de fabrique;~~
- ~~désignation du type ou numéro de série;~~
- ~~IEC 60947-2 si le fabricant déclare la conformité à la présente norme;~~
- ~~catégorie de sélectivité;~~
- ~~tension(s) assignée(s) d'emploi U_e (voir 4.3.2.1 et le cas échéant, l'Annexe H);~~
- ~~tension assignée de tenue aux chocs (U_{imp});~~
- ~~valeur (ou plage) de la fréquence assignée (par exemple 50 Hz) et/ou indication «courant continu» (ou le symbole ⎓);~~
- ~~pouvoir assigné de coupure de service en court-circuit (I_{cs}) à la tension assignée correspondante (U_e);~~
- ~~pouvoir assigné de coupure ultime en court-circuit (I_{cu}) à la tension assignée correspondante (U_e);~~
- ~~courant assigné de courte durée admissible (I_{cw}) et retard de courte durée correspondant pour la catégorie de sélectivité B;~~
- ~~bornes d'entrée et de sortie, à moins que leur raccordement soit indifférent;~~
- ~~bornes du pôle neutre, le cas échéant, par la lettre N;~~
- ~~borne de terre de protection, le cas échéant, par le symbole  (voir 7.1.10.3 de l'IEC 60947-1:2007);~~
- ~~température de référence pour les déclencheurs thermiques non compensés, si elle est différente de 30 °C;~~
- ~~plage de courant de réglage (I_r) du déclencheur de surcharge réglable;~~
- ~~plage du courant assigné de court-circuit instantané (I_i), pour les déclencheurs réglables.~~

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Le cas échéant, les plages I_r et I_i peuvent être affichées au lieu d'être marquées sur le disjoncteur.

c) Les indications suivantes doivent soit être marquées sur le disjoncteur comme spécifié au point b), soit figurer dans les catalogues ou notices du fabricant:

- pouvoir assigné de fermeture en court-circuit (I_{cm}), s'il est supérieur à celui spécifié en 4.3.6.1;
- tension assignée d'isolement (U_i), si elle est supérieure à la tension assignée d'emploi maximale;
- degré de pollution s'il est autre que 3;
- courant thermique conventionnel sous enveloppe (I_{the}), s'il est différent du courant assigné;
- code IP, le cas échéant (voir Annexe C de l'IEC 60947-1:2007/AMD1:2010);
- taille minimale de l'enveloppe et, s'il y a lieu, données concernant la ventilation, auxquelles s'appliquent les caractéristiques assignées marquées;
- distance minimale entre le disjoncteur et les parties métalliques reliées à la terre pour les disjoncteurs destinés à être utilisés sans enveloppe;
- aptitude à l'environnement A ou l'environnement B, suivant le cas;
- détection sensible à la valeur efficace, le cas échéant, conformément à F.4.1.1;
- section minimale du câble, si différente de la valeur donnée dans le Tableau 9 de l'IEC 60947-1:2007, pour les calibres ≤ 20 A, en fonction du pouvoir assigné de coupure ultime en court-circuit I_{cu};
- valeurs du couple de serrage pour les bornes du disjoncteur.

d) Les indications suivantes concernant les dispositifs d'ouverture et de fermeture du disjoncteur doivent figurer, soit sur leurs propres plaques signalétiques, soit sur la plaque signalétique du disjoncteur; si l'espace disponible est insuffisant, elles doivent figurer dans les catalogues ou notices du fabricant:

- tension assignée du circuit de commande de l'appareil de fermeture (voir 7.2.1.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014) et fréquence assignée dans le cas du courant alternatif;
- tension assignée du circuit de commande du déclencheur shunt (voir 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014) et/ou du déclencheur à minimum de tension (ou du déclencheur à manque de tension) (voir 7.2.1.3 de l'IEC 60947-1:2007), et fréquence assignée dans le cas du courant alternatif;
- courant assigné des déclencheurs indirects à maximum de courant;
- nombre et type des contacts auxiliaires ainsi que nature du courant, fréquence assignée (en cas de courant alternatif) et tensions assignées, si elles diffèrent de celles du circuit principal.

e) Marquage des bornes

Le paragraphe 7.1.8.4 de l'IEC 60947-1:2007 est applicable (voir aussi le point b) ci-dessus).

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Tableau 13 – Informations sur le matériel

Elément	Information	Emplacement du marquage
1.1	courant assigné (I_n)	Visible
1.2	aptitude au sectionnement, s'il y a lieu, avec le symbole  (IEC 60617-S00288:2001-07 combiné avec l'IEC 60617-S00219:2001-07)	Visible
1.3	indications des positions d'ouverture et de fermeture, respectivement par O (IEC 60417-5008:2002-10) et I (IEC 60417-5007:2002-10) si des symboles sont utilisés (voir 7.1.6.1 de l'IEC 60947-1:2007)	Visible
2.1	nom du fabricant ou marque de fabrique	Marqué
2.2	désignation du type ou référence du catalogue	Marqué
2.3	IEC 60947-2 si le fabricant déclare la conformité à la norme	Marqué
2.4	catégorie de sélectivité A ou B	Marqué
2.5	tension(s) assignée(s) d'emploi U_e (voir 4.3.2.1, et le cas échéant, l'Annexe H)	Marqué
2.6	incompatibilité avec les réseaux IT, le cas échéant, avec le symbole  (IEC 60417-6363:2016-07)	Marqué
2.7	tension assignée de tenue aux chocs (U_{imp})	Marqué
2.8	valeur (ou plage) de la fréquence assignée et/ou indication "courant continu" (ou le symbole ⎓ (IEC 60417-5031:2002-10))	Marqué
2.9	pouvoir assigné de coupure de service en court-circuit (I_{cs}) à la tension assignée correspondante (U_e)	Marqué
2.10	pouvoir assigné de coupure ultime en court-circuit (I_{cu}) à la tension assignée correspondante (U_e)	Marqué
2.11	courant assigné de courte durée admissible (I_{cw}) et retard de courte durée correspondant pour la catégorie de sélectivité B	Marqué
2.12	plage de courant de réglage (I_r) du déclencheur de surcharge réglable	Marqué [a]
2.13	plage du courant assigné de court-circuit instantané (I), pour les déclencheurs réglables	Marqué [a]
2.14	température de référence pour les déclencheurs thermiques non compensés, si elle est différente de 30 °C	Marqué
2.15	identification des bornes, conformément au paragraphe 7.1.8.4 de l'IEC 60947-1:2007	Marqué
2.16	bornes d'alimentation et de charge, le cas échéant	Marqué
2.17	bornes du pôle neutre, le cas échéant, par la lettre N	Marqué
2.18	borne de terre de protection, le cas échéant, par le symbole (IEC 60417-5019:2006-08)  (voir 7.1.10.3 de l'IEC 60947-1:2007)	Marqué
3.1	pouvoir assigné de fermeture en court-circuit (I_{cm}), s'il est supérieur à celui spécifié en 4.3.6.1	Documentation
3.2	tension assignée d'isolement (U_i), si elle est supérieure à la tension assignée d'emploi maximale	Documentation
3.3	degré de pollution s'il est autre que 3	Documentation
3.4	courant thermique conventionnel sous enveloppe (I_{the}), s'il est différent du courant assigné	Documentation
3.5	code IP, le cas échéant (voir Annexe C de l'IEC 60947-1:2007/AMD1:2010)	Documentation
3.6	taille minimale de l'enveloppe et, s'il y a lieu, données concernant la ventilation, auxquelles s'appliquent les caractéristiques assignées marquées	Documentation
3.7	distance minimale entre le disjoncteur et les parties métalliques reliées à la terre pour les disjoncteurs destinés à être utilisés sans enveloppe	Documentation
3.8	aptitude à l'environnement A ou B conformément à l'Annexe J, suivant le cas	Documentation

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Elément	Information	Emplacement du marquage
3.9	détection sensible à la valeur efficace, le cas échéant, conformément à F.4.1.1	Documentation
3.10	section minimale du câble, si différente de la valeur donnée dans le Tableau 9 de l'IEC 60947-1:2007, pour les calibres ≤ 20 A en fonction du pouvoir assigné de coupure ultime en court-circuit I_{cu}	Documentation
3.11	valeurs du couple de serrage pour les bornes du disjoncteur	Documentation
3.12	déclassement du courant pour les bornes et les connexions, le cas échéant	Documentation
4.1	pour les déclencheurs de fermeture (voir 2.23) et/ou les commandes motorisées, tension assignée du circuit de commande, type de courant et fréquence assignée dans le cas du courant alternatif	Aux
4.2	tension assignée du circuit de commande du déclencheur shunt et/ou du déclencheur à minimum de tension (ou du déclencheur à manque de tension), type de courant et fréquence assignée dans le cas du courant alternatif	Aux
4.3	courant assigné des déclencheurs indirects à maximum de courant	Aux
4.4	nombre et type des contacts auxiliaires, courants assignés d'emploi aux tensions assignées d'emploi, et fréquence assignée dans le cas du courant alternatif	Aux
Légende		
Visible:	visible depuis le devant lorsque le disjoncteur est installé en configuration de service et que l'organe de commande est accessible	
Marqué:	marqué sur le disjoncteur	
Documentation:	spécifié dans la documentation du fabricant	
Aux:	marqué sur les auxiliaires ou sur le disjoncteur, si l'espace est suffisant pour le marquage; les informations doivent en outre être disponibles dans la documentation du fabricant	
[a] Le cas échéant, les plages I_r et I_i peuvent être affichées au lieu d'être marquées sur le disjoncteur.		

5.3 Instructions d'installation, de fonctionnement et d'entretien

Le paragraphe 5.3 de l'IEC 60947-1:2007/AMD2:2014 est applicable, avec le complément suivant:

Des informations supplémentaires sur la mise hors service et le démantèlement du disjoncteur doivent être fournies à l'utilisateur dans le cas d'une condition dangereuse prévisible, résultant par exemple de l'énergie emmagasinée ou de substances dangereuses.

6 Conditions normales de service, de montage et de transport

L'Article 6 de l'IEC 60947-1:2007/AMD2:2014 est applicable, avec le complément suivant:

Degré de pollution (voir 6.1.3.2 de l'IEC 60947-1:2007).

Sauf spécification contraire du fabricant, un disjoncteur est prévu pour être installé dans les conditions d'environnement du degré de pollution 3.

7 Exigences relatives à la construction et au fonctionnement

7.1 Exigences relatives à la construction

7.1.1 Généralités

~~Le paragraphe 7.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable. Lorsque, dans le paragraphe 7.1.2.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, la température d'essai est à spécifier, la température d'essai exigée par la présente norme est de 960 °C.~~

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Le paragraphe 7.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable avec les modifications suivantes:

Les exigences du paragraphe 7.1.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 ne sont pas applicables aux pièces présentant une masse inférieure à 2 g (masse négligeable, conformément au 3.14 de l'IEC 60695-2-11:2014). Pour les matériels contenant plusieurs petites pièces, la masse totale des pièces non soumises à essai situées à proximité immédiate les unes des autres ne doit pas dépasser 10 g. L'appréciation de la proximité doit être établie par une évaluation technique tenant compte du risque de propagation d'incendie.

Lorsque, dans le paragraphe 7.1.2.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, la température d'essai doit être spécifiée, la valeur exigée par le présent document pour les pièces nécessaires au maintien en position des parties transportant le courant est de:

– 960 °C pour le circuit principal,
– 850 °C pour les autres circuits.

7.1.2 Disjoncteur débrochables

En position débrochée, les contacts de sectionnement du circuit principal et, s'il y a lieu, des circuits auxiliaires des disjoncteurs débrochables doivent avoir des distances de sectionnement répondant aux exigences spécifiées pour la fonction de sectionnement, en tenant compte des tolérances de fabrication et des modifications dimensionnelles causées par l'usure.

Le mécanisme de débrochage doit être équipé d'un dispositif d'indication sûr et robuste indiquant sans équivoque les positions des contacts de sectionnement.

Le mécanisme de débrochage doit être équipé de dispositifs de verrouillage ne permettant au disjoncteur d'être débroché (ou embroché) qu'après l'ouverture des contacts principaux.

En outre, le mécanisme de débrochage doit être équipé de dispositifs de verrouillage ne permettant la fermeture des contacts principaux que:

– lorsque les contacts de sectionnement sont complètement fermés, ou
– lorsque la distance de sectionnement spécifiée est obtenue entre les parties fixes et les parties mobiles des contacts de sectionnement (position débrochée).

Lorsque le disjoncteur est en position débrochée, il doit comporter des dispositifs permettant de s'assurer que les distances spécifiées de sectionnement entre les contacts de sectionnement ne puissent pas être réduites par inadvertance.

7.1.3 Exigences complémentaires pour les disjoncteurs aptes au sectionnement

Pour des exigences supplémentaires concernant le fonctionnement, voir 7.2.7.

Le paragraphe 7.1.7 de l'IEC 60947-1:2007/AMD1:2010 est applicable avec le complément suivant:

Si la position de déclenchement n'est pas la position d'ouverture indiquée, il convient de l'identifier sans ambiguïté.

7.1.4 Distances d'isolement et lignes de fuite

Les valeurs minimales sont données dans le Tableau 13 de l'IEC 60947-1:2007 et dans le Tableau 15 de l'IEC 60947-1:2007/AMD1:2010.

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Pour les valeurs de U_{imp} dépassant les valeurs données dans le Tableau 13 de l'IEC 60947-1:2007, les distances d'isolement doivent être prises dans le Tableau F.2 de l'IEC 60664-1:2007.

7.1.5 Exigences pour la sécurité de l'opérateur

Il ne doit pas y avoir de passage ou d'ouverture permettant aux particules incandescentes de s'échapper de la zone où se trouvent les organes de commande.

La conformité est vérifiée selon les indications données en 8.3.2.6.1, point b).

7.1.6 Liste des différences de construction

Des disjoncteurs d'une taille donnée sont considérés comme ayant une différence de construction (voir 2.1.2) si l'une des caractéristiques suivantes n'est pas la même:

– matériau, revêtement et dimensions des parties internes transmettant le courant, en admettant cependant les différences citées en a), b), c), f) et g) ci-après;

– dimensions, matériau, configuration et mode de fixation des contacts principaux;

– tout mécanisme de manœuvre manuelle intégré, ses matériaux et caractéristiques physiques;

– matériaux moulés et isolants;

– principe de fonctionnement, matériaux et construction du système d'extinction de l'arc;

– conception de base des appareils de déclenchement aux surintensités en admettant, cependant, les différences détaillées en a), b) et c) ci-après.

Les différences suivantes ne constituent pas une différence de construction:

a) les dimensions des bornes, si les distances d'isolement et les lignes de fuites ne sont pas réduites;

b) dans le cas de déclencheurs thermiques et magnétiques, les dimensions et matériaux des composants du déclencheur, y compris les connexions flexibles, qui déterminent le courant assigné;

c) les enroulements du secondaire des déclencheurs avec transformateurs de courant;

d) les moyens de manœuvre externes supplémentaires aux moyens intégrés de manœuvre;

e) la désignation du type et/ou les particularités purement esthétiques (par exemple les étiquettes);

f) dans le cas de variantes bipolaires et tétrapolaires, le remplacement du dispositif de déclenchement d'un pôle par une liaison, pour obtenir un neutre non protégé;

g) la création d'un disjoncteur bipolaire à partir d'un disjoncteur tripolaire en supprimant la ligne de courant du pôle central;

h) une différence dans le logiciel embarqué (micrologiciel) dans les déclencheurs électroniques, n'ayant aucune incidence sur les caractéristiques de fonctionnement exigées, notamment la fonction de déclenchement;

i) le matériel des déclencheurs électroniques, dans le cas d'omission de composants sur des circuits imprimés de configuration identique (par exemple, bouton tournant, affichage, etc.).

7.1.7 Exigences supplémentaires pour les disjoncteurs munis d'un pôle neutre

Le paragraphe 7.1.9 de l'IEC 60947-1:2007 s'applique avec le complément suivant:

Si un pôle ayant un pouvoir de fermeture et de coupure approprié est utilisé comme pôle neutre, alors tous les pôles, y compris le pôle neutre, peuvent fonctionner sensiblement ensemble.

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7.1.8 Entrées et sorties numériques à l'usage des automates programmables (AP)

L'Annexe S de l'IEC 60947-1:2007 s'applique. Pour les besoins de la présente norme, cette exigence ne s'applique pas aux entrées et sorties numériques dédiées à des appareils autres que les automates programmables.

7.2 Exigences relatives au fonctionnement

7.2.1 Conditions de fonctionnement

7.2.1.1 Fermeture

7.2.1.1.1 Généralités

Pour qu'un disjoncteur soit fermé avec sécurité lorsqu'il établit un courant correspondant à son pouvoir assigné de fermeture en court-circuit, il convient pour l'essentiel qu'il soit manœuvré avec la même vitesse et la même force qu'au cours des essais de type de vérification du pouvoir de fermeture en court-circuit.

7.2.1.1.2 Fermeture dépendante manuelle

Pour un disjoncteur muni d'un mécanisme de fermeture dépendante manuelle, il n'est pas possible de fixer une valeur de pouvoir assigné de fermeture en court-circuit sans tenir compte des conditions de manœuvre mécanique.

Il convient de ne pas utiliser un tel disjoncteur dans des circuits pour lesquels la valeur de crête du courant établi présumé dépasse 10 kA.

Cependant, ceci ne s'applique pas dans le cas d'un disjoncteur muni d'un mécanisme de fermeture dépendante manuelle comportant un déclencheur d'ouverture incorporé à action rapide qui fait couper le disjoncteur de façon sûre, quelles que soient la vitesse et la force avec lesquelles il est fermé, à des valeurs de crête de courant présumé supérieures à 10 kA; dans ce cas, un pouvoir assigné de fermeture en court-circuit peut être fixé.

7.2.1.1.3 Fermeture indépendante manuelle

Dans le cas d'un disjoncteur muni d'un mécanisme de fermeture indépendante manuelle, un pouvoir assigné de fermeture en court-circuit peut être fixé sans tenir compte des conditions de manœuvre mécanique.

7.2.1.1.4 Fermeture dépendante à source d'énergie extérieure

Le dispositif de fermeture, y compris, s'il y a lieu, les relais intermédiaires de commande, doit être capable d'assurer la fermeture du disjoncteur dans tous les cas, depuis le fonctionnement à vide jusqu'à celui correspondant au pouvoir assigné de fermeture, quand la valeur de la tension d'alimentation, mesurée pendant la manœuvre de fermeture, demeure dans les limites de 110 % et 85 % de la tension assignée d'alimentation de commande et, dans le cas du courant alternatif, à la fréquence assignée.

A 110 % de la tension assignée d'alimentation de commande, la manœuvre de fermeture, lorsqu'elle est effectuée à vide, ne doit causer aucune détérioration au disjoncteur.

A 85 % de la tension assignée d'alimentation de commande, la manœuvre de fermeture doit être assurée lorsque le courant établi par le disjoncteur est égal à son pouvoir assigné de fermeture dans les limites permises par le fonctionnement de ses relais ou déclencheurs et, si une valeur maximale est indiquée pour la durée de fermeture, en un temps n'excédant pas cette valeur maximale.

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7.2.1.1.5 Fermeture indépendante à source d'énergie extérieure

Un disjoncteur à manœuvre de fermeture indépendante à source d'énergie extérieure peut avoir un pouvoir assigné de fermeture en court-circuit sans tenir compte des conditions de fermeture.

Les organes moteurs des mécanismes d'accumulation, ainsi que les organes de commande de fermeture, doivent pouvoir fonctionner suivant les spécifications du fabricant.

7.2.1.1.6 Fermeture par accumulation d'énergie

Ce type de mécanisme de fermeture doit pouvoir assurer la fermeture du disjoncteur dans toute condition entre le fonctionnement à vide et son pouvoir assigné de fermeture.

Lorsque l'énergie est accumulée dans le disjoncteur, un appareil indiquant que le mécanisme d'accumulation d'énergie est complètement armé doit être prévu.

Les organes moteurs des mécanismes d'accumulation, ainsi que les organes de commande de fermeture, doivent être capables de fonctionner lorsque leur tension d'alimentation auxiliaire est comprise entre 85 % et 110 % de la valeur de la tension assignée d'alimentation de commande.

Les contacts mobiles ne doivent pas pouvoir s'écarter de la position d'ouverture sans que l'énergie soit suffisante pour effectuer entièrement la manœuvre de fermeture de façon satisfaisante.

Lorsque le mécanisme d'accumulation d'énergie est à commande manuelle, le sens dans lequel s'effectue cette manœuvre doit être indiqué.

Cette dernière exigence ne s'applique pas aux disjoncteurs ayant une manœuvre de fermeture indépendante manuelle.

7.2.1.2 Ouverture

7.2.1.2.1 Généralités

Les disjoncteurs dont l'ouverture est automatique doivent être à déclenchement libre (voir 2.4.23 de l'IEC 60947-1:2007) et, sauf accord contraire entre le fabricant et l'utilisateur, l'énergie nécessaire à leur déclenchement doit être emmagasinée automatiquement avant l'achèvement de la manœuvre de fermeture.

7.2.1.2.2 Ouverture par déclencheurs à minimum de tension

Le paragraphe 7.2.1.3 de l'IEC 60947-1:2007 est applicable.

7.2.1.2.3 Ouverture par déclencheurs shunt

Le paragraphe 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

7.2.1.2.4 Ouverture par déclencheurs à maximum de courant

a) Ouverture dans des conditions de court-circuit

Le déclencheur de court-circuit doit provoquer le déclenchement du disjoncteur avec une tolérance de ±20 % de la valeur réglée, pour toutes les valeurs de réglage du déclencheur de courant de court-circuit.

Si cela est nécessaire pour la coordination relative aux surintensités (voir 2.17), le fabricant doit fournir des informations (habituellement des courbes) indiquant:

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– la valeur maximale de crête du courant coupé limité (voir 2.5.19 de l'IEC 60947-1:2007) en fonction du courant présumé (valeur efficace périodique),

– les caractéristiques I^2t (voir 2.18) pour les disjoncteurs de catégorie de sélectivité A et, le cas échéant, de catégorie B pour les disjoncteurs à commande instantanée (voir note de 8.3.5.1).

La conformité à ces informations peut être vérifiée au cours des essais de type pertinents des séquences d'essai II et III (voir 8.3.4 et 8.3.5).

NOTE 1 Il est possible de fournir d'autres sortes de données pour vérifier les caractéristiques de coordination des disjoncteurs, par exemple des essais portant sur des combinaisons d'appareils de protection contre les courts-circuits.

b) Ouverture dans des conditions de surcharge

1) Fonctionnement instantané ou à retard indépendant

Le déclencheur doit fonctionner avec une tolérance de ±10 % de la valeur réglée pour toutes les valeurs de réglage du déclencheur de surcharge.

2) Fonctionnement à temps inverse

Les valeurs conventionnelles de fonctionnement à temps inverse figurent au Tableau 6.

A la température de référence (voir 4.7.3) et à 1,05 fois le courant de réglage (voir 2.4.37 de l'IEC 60947-1:2007), c'est-à-dire au courant conventionnel de non-déclenchement (voir 2.5.30 de l'IEC 60947-1:2007), le déclencheur d'ouverture étant alimenté sur tous les pôles de phase, le déclenchement ne doit pas se produire en un laps de temps inférieur au temps conventionnel (voir 2.5.30 de l'IEC 60947-1:2007) à partir de l'état froid, c'est-à-dire avec le disjoncteur à la température de référence.

De plus, quand, à l'expiration du temps conventionnel, la valeur du courant est immédiatement portée à 1,30 fois le courant de réglage, c'est-à-dire au courant conventionnel de déclenchement (voir 2.5.31 de l'IEC 60947-1:2007), le déclenchement doit se produire dans un laps de temps inférieur au temps conventionnel.

NOTE 2 La température de référence est la température ambiante sur laquelle est fondée la caractéristique temps/courant du disjoncteur.

Tableau 6 – Caractéristiques d'ouverture des déclencheurs d'ouverture à maximum de courant à temps inverse à la température de référence

Tous les pôles en charge		Temps conventionnel h
Courant conventionnel de non-déclenchement	Courant conventionnel de déclenchement	
1,05 fois le courant de réglage	1,30 fois le courant de réglage	2 [a]
[a] 1 h quand $I_n \leq 63$ A		

Si le fabricant déclare qu'un déclencheur est essentiellement indépendant de la température ambiante, les valeurs de courant du Tableau 6 doivent s'appliquer à l'intérieur du domaine de températures annoncé par le fabricant, avec une tolérance ne dépassant pas 0,3 %/K.

L'étendue du domaine de températures doit être au moins égale à 10 K de part et d'autre de la température de référence.

7.2.2 Echauffement

7.2.2.1 Limites d'échauffement

Les échauffements des différents organes d'un disjoncteur, mesurés dans les conditions spécifiées en 8.3.2.5, ne doivent pas dépasser les valeurs limites indiquées dans le Tableau 7, au cours des essais effectués conformément à 8.3.3.7. Les échauffements des bornes ne

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doivent pas dépasser les valeurs limites figurant dans le Tableau 7 durant les essais effectués conformément aux 8.3.4.5 et 8.3.6.4.

7.2.2.2 Température de l'air ambiant

Les limites d'échauffement indiquées au Tableau 7 ne sont valables que si la température de l'air ambiant reste entre les limites indiquées au 6.1.1 de l'IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Circuit principal

Le circuit principal d'un disjoncteur, y compris les déclencheurs à maximum de courant pouvant lui être associés, doit pouvoir supporter son courant assigné I_n, dans les conditions de l'Article 8, sans que les échauffements ne dépassent les limites spécifiées au Tableau 7.

7.2.2.4 Circuits de commande

Les circuits de commande, y compris les appareils pour circuits de commande, utilisés pour les manœuvres de fermeture et d'ouverture d'un disjoncteur, doivent permettre de réaliser le service assigné prévu en 4.3.5 ainsi que d'effectuer les essais d'échauffement dans les conditions spécifiées en 8.3.2.5, sans que les échauffements dépassent les limites spécifiées au Tableau 7.

Les exigences de ce paragraphe doivent être vérifiées sur un disjoncteur neuf. Ou bien, si le fabricant le souhaite, la vérification peut être effectuée pendant l'essai d'échauffement du 8.3.3.7.

7.2.2.5 Circuits auxiliaires

Les circuits auxiliaires, y compris les appareils auxiliaires, doivent pouvoir supporter leur courant thermique conventionnel, sans que les échauffements dépassent les limites spécifiées au Tableau 7 lorsqu'ils sont soumis à essai selon les exigences de 8.3.2.5.

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Tableau 7 – Limites d'échauffement des bornes et des parties accessibles

Description de l'organe [a]	Limites d'échauffement [b] K
– Bornes de raccordement à des connexions extérieures	80
– Organes de manœuvre manuels:	
métalliques	25
non métalliques	35
– Parties destinées à être touchées mais pas à être tenues à la main:	
métalliques	40
non métalliques	50
– Parties pouvant ne pas être touchées en service normal:	
métalliques	50
non métalliques	60

[a] Aucune valeur n'est précisée pour les pièces autres que celles énumérées ci-dessus, mais il convient qu'aucun dommage ne soit occasionné aux pièces voisines en matériau isolant.

[b] Les limites d'échauffement spécifiées ne sont pas celles qui s'appliquent à un échantillon à l'état neuf, mais celles qui s'appliquent aux vérifications de l'échauffement au cours des séquences d'essai appropriées spécifiées à l'Article 8.

7.2.3 Propriétés diélectriques

7.2.3.1 Généralités

Les paragraphes 7.2.3 a) et 7.2.3 b) de l'IEC 60947-1:2007 sont applicables.

Les essais de type doivent être effectués conformément à 8.3.3.3.

La vérification de la tenue diélectrique au cours de toutes les séquences d'essai doit être effectuée conformément à 8.3.3.6.

Les essais individuels de série doivent être effectués conformément à 8.4.6.

7.2.3.2 Tension de tenue aux chocs

Le paragraphe 7.2.3.1 de l'IEC 60947-1:2007 est applicable.

Pour les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif, la tension de tenue aux chocs doit être convenue entre le fabricant et l'utilisateur mais ne doit pas être inférieure aux valeurs correspondant à 1 000 V en courant alternatif.

7.2.3.3 Tension de tenue à fréquence industrielle des circuits principaux, auxiliaires et de commande

Les essais à fréquence industrielle sont utilisés dans les cas suivants:

– essais diélectriques considérés comme essais de type pour la vérification de l'isolation solide,
– vérification de la tenue diélectrique comme critère de défaut après les essais de type de manœuvre ou de court-circuit,
– essais individuels de série.

7.2.3.4 Distance d'isolement

Le paragraphe 7.2.3.3 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

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7.2.3.5 Lignes de fuite

Le paragraphe 7.2.3.4 de l'IEC 60947-1:2007 est applicable.

7.2.3.6 Isolation solide

L'isolation solide doit être vérifiée soit par des essais à fréquence industrielle, selon 8.3.3.4.1, point 3) de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, soit par des essais en courant continu (les tensions d'essai pour les essais en courant continu sont à l'étude).

Pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs doivent être déconnectés pour les essais.

7.2.3.7 Espacements entre circuits distincts

Le paragraphe 7.2.3.6 de l'IEC 60947-1:2007 est applicable.

7.2.4 Aptitude à l'établissement et à la coupure à vide, en charge normale et en surcharge

7.2.4.1 Fonctionnement en surcharge

Cette exigence ne s'applique qu'aux disjoncteurs de courant assigné ne dépassant pas 630 A.

Le disjoncteur doit être capable d'effectuer le nombre de cycles de manœuvres dans les conditions d'essai de 8.3.3.5, le courant dans le circuit principal étant supérieur à son courant assigné.

Chaque cycle de manœuvre consiste en une manœuvre de fermeture suivie d'une manœuvre de coupure.

7.2.4.2 Aptitude au fonctionnement en service

Le paragraphe 7.2.4.2 de l'IEC 60947-1:2007 est applicable avec les compléments suivants:

Le disjoncteur doit être capable de satisfaire aux exigences du Tableau 8:

– pour l'essai de fonctionnement en service sans courant dans le circuit principal dans les conditions d'essai précisées en 8.3.3.4.3,
– pour l'essai de fonctionnement en service avec courant dans le circuit principal dans les conditions d'essai précisées en 8.3.3.4.4.

Chaque cycle de manœuvre consiste, soit en une manœuvre de fermeture suivie d'une manœuvre d'ouverture (essai de fonctionnement en service sans courant), soit en une manœuvre d'établissement suivie d'une manœuvre de coupure (essai de fonctionnement en service avec courant).

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Tableau 8 – Nombre de cycles de manœuvres

1	2	3	4	5
Courant assigné [a]	**Nombre de cycles de manœuvres par heure** [b]	**Nombre de cycles de manœuvres**		
A		**Sans courant**	**Avec courant** [c]	**Total**
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

[a] Indique le courant assigné maximal pour une taille donnée.

[b] La colonne 2 indique la fréquence de manœuvre minimale. Cette fréquence peut être augmentée avec l'accord du fabricant; dans ce cas, la fréquence utilisée doit être indiquée dans le rapport d'essai.

[c] Au cours de chaque cycle de manœuvres, le disjoncteur doit rester fermé pendant un temps suffisant pour assurer l'établissement complet du courant mais ne dépassant pas 2 s.

7.2.5 Aptitude à l'établissement et à la coupure en condition de court-circuit

Le paragraphe 7.2.5 de l'IEC 60947-1:2007 est applicable avec les développements suivants:

Le pouvoir assigné de fermeture en court-circuit doit être conforme aux 4.3.6.1 et 4.3.6.3.

Le pouvoir assigné de coupure en court-circuit doit être conforme à 4.3.6.2.

Le courant assigné de courte durée admissible doit être conforme à 4.3.6.4.

NOTE Le fabricant a la responsabilité d'assurer que la caractéristique de déclenchement du disjoncteur est compatible avec l'aptitude de celui-ci à supporter les contraintes thermiques et électrodynamiques inhérentes.

7.2.6 Disponible

7.2.7 Exigences complémentaires pour les disjoncteurs aptes au sectionnement

Le paragraphe 7.2.7 de l'IEC 60947-1:2007 est applicable et les essais doivent être effectués conformément à 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 et 8.3.7.8, selon le cas.

7.2.8 Exigences particulières pour les disjoncteurs à fusibles incorporés

NOTE Pour la coordination des disjoncteurs et des fusibles séparés associés dans un même circuit, voir 7.2.9.

Un disjoncteur à fusibles incorporés doit être conforme à la présente norme à tous égards jusqu'au pouvoir assigné de coupure ultime en court-circuit. En particulier, il doit répondre aux exigences de la séquence d'essai V (voir 8.3.7).

Le disjoncteur doit fonctionner, sans provoquer le fonctionnement des fusibles, en présence de surintensités ne dépassant pas le courant limite de sélectivité I_s déclaré par le fabricant.

Pour toutes les surintensités jusqu'à et y compris le pouvoir assigné de coupure ultime en court-circuit attribué à l'ensemble, le disjoncteur doit s'ouvrir lorsqu'un ou plusieurs fusibles fonctionnent (pour éviter l'alimentation sur une seule phase). Si le fabricant déclare que le disjoncteur est à fermeture empêchée (voir 2.14), il ne doit pas être possible de refermer le disjoncteur tant que n'auront pas été remplacés, soit les éléments de remplacement fondus, soit tout élément de remplacement manquant, ou bien que les dispositifs de verrouillage n'auront pas été réarmés.

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7.2.9 Coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits

Pour la coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits, voir l'Annexe A.

7.3 Compatibilité électromagnétique (CEM)

Les exigences et les méthodes d'essai sont données à l'Annexe J.

8 Essais

8.1 Nature des essais

8.1.1 Généralités

Le paragraphe 8.1 de l'IEC 60947-1:2007 est applicable avec les compléments suivants:

Les essais destinés à vérifier les caractéristiques des disjoncteurs sont:

– les essais de type (voir 8.3),
– les essais individuels de série (voir 8.4),
– les essais spéciaux (voir 8.5).

8.1.2 Essais de type

Les essais de type comprennent les essais suivants:

Essai	Paragraphe
Echauffement	8.3.2.5
Limites et caractéristiques de déclenchement	8.3.3.2
Propriétés diélectriques	8.3.3.3
Aptitude au fonctionnement en service	8.3.3.4
Fonctionnement en surcharge (le cas échéant)	8.3.3.5
Pouvoirs de coupure en court-circuit	8.3.4 et 8.3.5
Courant de courte durée admissible (le cas échéant)	8.3.6
Fonctionnement des disjoncteurs à fusibles incorporés	8.3.7
Courant continu critique de charge	8.3.9

Les essais de type doivent être effectués par le fabricant dans ses ateliers ou dans un laboratoire approprié de son choix.

8.1.3 Essais individuels de série

Les essais individuels de série comprennent les essais énumérés en 8.4.

8.2 Conformité aux exigences de construction

Le paragraphe 8.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable.

8.3 Essais de type

Pour éviter la répétition de textes identiques concernant les différentes séquences d'essai, les conditions générales d'essai ont été groupées au début du présent paragraphe sous trois titres:

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– conditions d'essai applicables à toutes les séquences (8.3.3 à 8.3.8),

– conditions d'essai applicables aux essais d'échauffement (8.3.2.5),

– conditions d'essai applicables aux essais de court-circuit (8.3.2.6).

Dans la mesure du possible, ces conditions générales d'essai se réfèrent aux règles générales de l'IEC 60947-1 ou sont fondées sur celles-ci.

Chaque séquence d'essai se réfère aux conditions générales d'essai qui sont applicables. Cela demande l'emploi de références, mais permet de présenter chaque séquence d'essai sous une forme très simplifiée.

Le terme «essai» est utilisé dans toute cette section pour chaque essai à effectuer; il convient d'interpréter le terme «vérification» dans le sens de «essai de vérification» et ce terme est utilisé lorsqu'il s'agit de vérifier l'état du disjoncteur après un essai au cours d'une séquence d'essai où le disjoncteur aurait pu être endommagé.

Un index alphabétique est donné ~~en 8.3.1.3~~ ci-après pour situer plus facilement une condition d'essai ou un essai. Cet index comprend les termes qui seront le plus vraisemblablement employés (et pas forcément les termes exacts qui figurent dans le titre des paragraphes correspondants).

8.3.1 Séquences d'essai

8.3.1.1 Généralités

Les essais de type sont regroupés dans plusieurs séquences, comme indiqué au Tableau 9.

Pour chaque séquence, les essais doivent être réalisés dans l'ordre indiqué, sauf spécification contraire dans la présente norme.

8.3.1.2 Essais omis de la séquence I et réalisés séparément

En référence à 8.1.1 de l'IEC 60947-1:2007, les essais suivants de la séquence d'essai I (voir 8.3.3) peuvent être omis de la séquence et réalisés sur des échantillons séparés:

– limites et caractéristiques de déclenchement (8.3.3.2); auquel cas l'échantillon (ou les échantillons) en essai dans la séquence doi(ven)t être soumis aux essais de 8.3.3.2.3, uniquement sur les pôles des phases et au réglage maximal, à la température ambiante de la pièce et sans l'essai supplémentaire du point b) destiné à vérifier la caractéristique temps-courant;

– essai des propriétés diélectriques (8.3.3.3);

– essai des déclencheurs à minimum de tension de 8.3.3.4.2.3 et 8.3.3.4.3, afin de vérifier les exigences de 7.2.1.3 de l'IEC 60947-1:2007, et essais des déclencheurs à minimum de tension aux fréquences alternatives (voir 8.3.2.1);

– essai des déclencheurs shunt de 8.3.3.4.2.4 et 8.3.3.4.3, afin de vérifier les exigences de 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014, et essais des déclencheurs shunt aux fréquences alternatives (voir 8.3.2.1);

– essais supplémentaires d'aptitude au fonctionnement en service sans courant pour les disjoncteurs débrochables (8.3.3.4.5).

8.3.1.3 Applicabilité des séquences selon la relation entre les caractéristiques assignées de court-circuit

L'applicabilité des séquences d'essai en fonction de la relation entre I_{cs}, I_{cu} et I_{cw} est donnée au Tableau 9a.

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Index alphabétique des essais

Conditions générales d'essai	Paragraphe
Constante de temps	8.3.2.2.5
Court-circuit: circuits d'essai	8.3.2.6.2
Court-circuit: mode opératoire	8.3.2.6.4
Disposition des disjoncteurs, généralités	8.3.2.1
Disposition des disjoncteurs pour les essais de court-circuit	8.3.2.6.1
Echauffement	8.3.2.5
Enregistrements (interprétation des)	8.3.2.6.6
Facteur de puissance	8.3.2.2.4
Fréquence	8.3.2.2.3
Rétablissement (tension de)	8.3.2.2.6
Tolérances	8.3.2.2.2
Essais (voir Tableau 9 pour le schéma d'ensemble des séquences d'essai)	**Paragraphe**
Aptitude au fonctionnement en service	8.3.3.4 – 8.3.4.3 – 8.3.4.5
Courant continu critique de charge	8.3.9
Courant de courte durée admissible	8.3.6.3 – 8.3.8.3
Déclencheurs de surcharge (vérification des)	8.3.3.8 ~~– 8.3.4.5~~ 8.3.4.6– 8.3.5.2 – 8.3.5.5 – 8.3.6.2 – 8.3.6.7 – 8.3.7.5 – 8.3.7.9 – 8.3.8.2 – 8.3.8.8
Disjoncteurs à fusibles incorporés (essais de court-circuit)	8.3.7.2 – 8.3.7.6 – 8.3.7.7
Disjoncteurs débrochables (essais supplémentaires)	8.3.3.4.5
Echauffement (vérification d')	8.3.3.7 – 8.3.4.5 – 8.3.6.4 – 8.3.7.3 – 8.3.8.7
Essai de pouvoir de coupure en court-circuit au courant maximal de courte durée admissible	8.3.6.5
Essai en court-circuit sur un pôle séparément (pour réseaux ayant une phase reliée à la terre)	Annexe C
Essai en court-circuit sur un pôle séparément (pour systèmes IT)	Annexe H – voir H.2
Fonctionnement en surcharge	8.3.3.5
Indication de la position des contacts principaux	8.3.3.10
Limites et caractéristiques de déclenchement	8.3.3.2
Pouvoir de coupure de service en court-circuit	8.3.4.2 – 8.3.8.4
Pouvoir de coupure ultime en court-circuit	8.3.5.3
Propriétés diélectriques	8.3.3.3
Tenue diélectrique (vérification de la)	8.3.3.6 – 8.3.4.4 – 8.3.5.4 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.6

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Tableau 9 – Schéma d'ensemble des séquences d'essai [a]

Séquence d'essai	Validité	Essais
I Caractéristiques générales de fonctionnement (8.3.3)	Tous les disjoncteurs	Limites et caractéristiques de déclenchement Propriétés diélectriques Fonctionnement mécanique et aptitude au fonctionnement en service Fonctionnement en surcharge (le cas échéant) Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge Vérification des déclencheurs à minimum de tension et des déclencheurs shunt (le cas échéant) Vérification de la position des contacts principaux (le cas échéant)
II Pouvoir assigné de coupure de service en court-circuit (8.3.4)	Tous les disjoncteurs [b]	Pouvoir assigné de coupure de service en court-circuit Vérification de l'aptitude au fonctionnement Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge
III Pouvoir assigné de coupure ultime en court-circuit (8.3.5)	Tous les disjoncteurs [c] de catégorie de sélectivité A et les disjoncteurs de catégorie de sélectivité B à commande instantanée [d]	Vérification des déclencheurs de surcharge Pouvoir assigné de coupure ultime en court-circuit Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
IV Courant assigné de courte durée admissible (8.3.6)	Disjoncteurs de catégorie de sélectivité B [b] et disjoncteurs de catégorie de sélectivité A avec un courant assigné de courte durée admissible (voir 4.4)	Vérification des déclencheurs de surcharge Courant assigné de courte durée admissible Vérification de l'échauffement Pouvoir de coupure en court-circuit au courant maximal de courte durée admissible Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
V Fonctionnement des disjoncteurs à fusibles incorporés (8.3.7)	Phase 1 Disjoncteurs à fusibles incorporés Phase 2	Court-circuit au courant limite de sélectivité Vérification de l'échauffement Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge Court-circuit à 1,1 fois le courant d'intersection Court-circuit au pouvoir assigné de coupure ultime en court-circuit Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
VI Séquence d'essai combinée (8.3.8)	Disjoncteurs de catégorie de sélectivité B: avec $I_{cw} = I_{cs}$ (remplace les séquences d'essai II et IV) avec $I_{cw} = I_{cs} = I_{cu}$ (remplace les séquences d'essai II, III et IV)	Vérification des déclencheurs de surcharge Courant assigné de courte durée admissible Pouvoir assigné de coupure de service en court-circuit Aptitude au fonctionnement en service Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge
Courant continu critique de charge (8.3.9)	Disjoncteurs à caractéristiques assignées à courant continu	Essais de courant continu critique de charge
Séquence d'essai en court-circuit sur un pôle séparément (Annexe C)	Disjoncteur pour emploi sur des réseaux avec liaison phase-terre	Pouvoir de coupure en court-circuit sur un pôle séparément (I_{su}) Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
Séquence d'essai pour les disjoncteurs pour réseaux IT (Annexe H)	Disjoncteur pour emploi sur réseaux IT	Pouvoir de coupure en court-circuit sur un pôle séparément (I_{IT}) Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge

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[a] Pour le choix des disjoncteurs pour les essais et les différentes séquences d'essai applicables en fonction de la relation entre I_{cs}, I_{cu} et I_{cw}, voir le Tableau 9a.
[b] Sauf lorsque la séquence VI est appliquée.
[c] Sauf
– lorsque $I_{cs} = I_{cu}$ (mais voir 8.3.5),
– lorsque la séquence VI est appliquée,
– pour les disjoncteurs à fusibles incorporés.
[d] Voir la note de 8.3.5.1

Tableau 9a – Applicabilité des séquences d'essai en fonction de la relation entre I_{cs}, I_{cu} et I_{cw} [a]

Relation entre I_{cs}, I_{cu} et I_{cw}	Séquence d'essai	Catégorie de sélectivité			
		A	A Fusibles incorporés	B	B Fusibles incorporés
CAS 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ pour la catégorie de sélectivité A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ pour la	IV	X [d]		X	X
catégorie de sélectivité B	V		X		X
CAS 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ pour la	II			X	X
catégorie de sélectivité B	III			X [b]	
	IV			X	X
	V				X
	VI (combinée)			X [c]	X [c]
CAS 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ pour la catégorie de sélectivité A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ pour la	IV	X [d]		X	X
catégorie de sélectivité B	V		X		X
CAS 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ pour la	III				
catégorie de sélectivité B	IV			X	
	V				
	VI (combinée)			X [c]	

[a] Tableau applicable à chacune des valeurs de U_e. Dans le cas de valeurs assignées multiples de U_e, le tableau s'applique à chaque valeur de U_e. La séquence d'essai applicable est indiquée par X dans la case correspondante.
[b] Essai applicable uniquement si $I_{cu} > I_{cw}$.
[c] A la discrétion du fabricant ou avec son accord, cette séquence d'essai peut être appliquée aux disjoncteurs de la catégorie de sélectivité B et, dans ce cas, elle remplace les séquences d'essai II et IV.
[d] La séquence d'essai IV s'applique seulement aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4).

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8.3.1.4 Programmes d'essais alternatifs pour disjoncteurs à courant alternatif comportant différents nombres de pôles

Ces programmes d'essai alternatifs peuvent uniquement être appliqués aux caractéristiques assignées en courant alternatif et lorsque toutes les caractéristiques assignées sont

identiques ou inférieures à celles de la variante soumise au programme complet du Tableau 9, et les différences de construction sont les mêmes pour toutes les variantes. Dans le cas de disjoncteurs unipolaires, les tensions assignées doivent être inférieures ou égales à la tension phase-neutre de la variante soumise au programme complet du Tableau 9. Il n'est pas nécessaire de soumettre à l'essai un disjoncteur bipolaire obtenu en supprimant la ligne de courant centrale d'un disjoncteur tripolaire soumis à essai selon le programme 1 ou le programme 2 du présent paragraphe, car il est considéré comme couvert par les essais de la variante tripolaire.

La conformité aux exigences d'essais est satisfaite en réalisant l'un des programmes alternatifs 1 ou 2 suivants:

– Programme 1: Les séquences d'essai applicables selon le Tableau 9 doivent être effectuées sur la variante tripolaire. De plus, le cas échéant, les essais ou les séquences d'essai énumérés dans le Tableau 9b doivent être effectués sur les autres variantes.

– Programme 2: Les séquences d'essai applicables selon le Tableau 9 doivent être effectuées sur la variante tétrapolaire. De plus, le cas échéant, les essais ou les séquences d'essai énumérés dans le Tableau 9c doivent être effectués sur les autres variantes.

Le principe d'application des programmes d'essais alternatifs est illustré ci-après:

	Programme 1				**Programme 2**			
	unipolaire	bipolaire	tripolaire	tétrapolaire	unipolaire	bipolaire	tripolaire	tétrapolaire
Construction 1[a]	□	□	■	□	○	○	○	■
Construction 2	–	–	■	□	–	–	–	■
Construction 3	–	–	■	□	–	–	–	■
…	–	–	■	□	–	–	–	■
Construction *n*	–	–	■	□	–	–	–	■
Légende	■ soumis à essai entièrement selon le Tableau 9 □ soumis à essai selon le Tableau 9b ○ soumis à essai selon le Tableau 9c – pas d'essai exigé							
[a] La construction 1 est celle qui couvre la caractéristique assignée maximale.								

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Tableau 9b – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tétrapolaires selon le programme alternatif 1 de 8.3.1.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tétrapolaire[f, h]	Applicabilité aux variantes unipolaires ou bipolaires[g]
I	8.3.3.2	Essai des limites et des caractéristiques de déclenchement		
	8.3.3.2.1	Généralités	X	X
	8.3.3.2.2	Déclencheurs de court-circuit	X[a]	X[e]
	8.3.3.2.3 a)[k] – instantanés/à retard indépendant – à temps inverse ou 8.3.3.2.3 b)[k] (suivant le cas)	Déclencheurs de surcharge:	X X	 X[e]
	8.3.3.2.4	Essai supplémentaire pour les déclencheurs à retard indépendant:		
	8.3.3.3	Propriétés diélectriques	X	X
	8.3.3.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	8.3.3.4.1	Généralités	X	X
	8.3.3.4.2	Dispositions de construction et fonctionnement mécanique	X[d]	X[d, e]
	8.3.3.4.3	Aptitude au fonctionnement en service sans courant	X	X
	8.3.3.4.4	Aptitude au fonctionnement en service avec courant	X	X
	8.3.3.4.5	Disjoncteur débrochables	X	
	8.3.3.5	Fonctionnement en surcharge	X	X
	8.3.3.6	Vérification de la tenue diélectrique	X	X
	8.3.3.7	Vérification de l'échauffement	X	X
	8.3.3.8	Vérification des déclencheurs de surcharge		
	8.3.3.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	8.3.3.10	Vérification de la position des contacts principaux	X	X
II	8.3.4	Pouvoir assigné de coupure de service en court-circuit		
III	8.3.5[b, c]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	8.3.6	Courant assigné de courte durée admissible	X 4ème pôle et pôle adjacent uniquement (voir 8.3.2.6.4)	
V	8.3.7	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	8.3.8	Séquence d'essai combinée		
Annexe C		Séquence d'essai en court-circuit sur un pôle séparément		
Annexe H		Séquence d'essai pour les disjoncteurs pour réseaux IT		
NOTE L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.				

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[a] Un essai sur une paire de pôles de phase choisis au hasard. Dans le cas d'une unité de déclenchement électronique, cet essai peut être réalisé sur un pôle choisi au hasard.

[b] Cette séquence d'essai s'applique aussi lorsque, pour les essais de disjoncteurs tripolaires, la séquence III sur la variante tripolaire est remplacée par la séquence II ou la séquence VI (voir le Tableau 9).

[c] ~~Un seul échantillon, de courant assigné maximal seulement, soumis à essai aux valeurs assignées~~ Essai à la valeur correspondant au maximum de kVA ($I_{cu} \times U_e$ correspondant).

[d] Sans les essais de vérification des déclencheurs à manque de tension (8.3.3.4.2.3) et des déclencheurs shunt (8.3.3.4.2.4).

[e] Applicable uniquement à la variante unipolaire; non exigé pour les variantes bipolaires.

[f] Dans le cas d'appareils tétrapolaires avec différents niveaux de protection du neutre (par exemple 60 % ou 100 %), seule la variante comportant le niveau le plus élevé est à soumettre à l'essai selon le Tableau 9b.

[g] Un seul échantillon, de courant assigné maximal seulement, pour chaque séquence d'essai.

[h] Un échantillon de courant assigné maximal pour chaque séquence d'essai; dans le cas d'une ou plusieurs différences de construction (voir 2.1.2 et 7.1.6) dans la taille, un échantillon supplémentaire est soumis à l'essai au courant assigné maximal correspondant à chaque construction.

[i] Disponible.

[j] Disponible.

[k] Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

Tableau 9c – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tripolaires selon le programme alternatif 2 de 8.3.1.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[g]	Applicabilité aux variantes unipolaires ou bipolaires[g]
I	8.3.3.2	Essai des limites et des caractéristiques de déclenchement		
	8.3.3.2.1	Généralités		X
	8.3.3.2.2	Déclencheurs de court-circuit		X [e]
	8.3.3.2.3 a)[k] ou 8.3.3.2.3 b)[k] (suivant le cas)	Déclencheurs de surcharge: – instantanés/à retard indépendant – à temps inverse		X[e]
	8.3.3.2.4	Essai supplémentaire des déclencheurs à retard indépendant		
	8.3.3.3	Propriétés diélectriques	X	X
	8.3.3.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	8.3.3.4.1	Généralités	X	X
	8.3.3.4.2	Dispositions de construction et fonctionnement mécanique		X[d, e]
	8.3.3.4.3	Aptitude au fonctionnement en service sans courant	X	X
	8.3.3.4.4	Aptitude au fonctionnement en service avec courant	X	X
	8.3.3.4.5	Disjoncteur débrochables		
	8.3.3.5	Fonctionnement en surcharge	X	X
	8.3.3.6	Vérification de la tenue diélectrique	X	X
	8.3.3.7	Vérification de l'échauffement	X	X
	8.3.3.8	Vérification des déclencheurs de surcharge		
	8.3.3.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	8.3.3.10	Vérification de la position des contacts principaux	X	X
II	8.3.4	Pouvoir assigné de coupure de service en court-circuit		

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Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[g]	Applicabilité aux variantes unipolaires ou bipolaires[g]
III	8.3.5[b, c]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	8.3.6	Courant assigné de courte durée admissible		
V	8.3.7	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	8.3.8	Séquence d'essai combinée		
Annexe C		Séquence d'essai en court-circuit sur un pôle séparément		
Annexe H		Séquence d'essai pour les disjoncteurs pour réseaux IT		

NOTE L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.

[a] Disponible.

[b] Cette séquence d'essai s'applique aussi lorsque, pour les essais de disjoncteurs tétrapolaires, la séquence III sur la variante tétrapolaire est remplacée par la séquence II ou la séquence VI (voir le Tableau 9).

[c] ~~Un seul échantillon, de courant assigné maximal seulement, soumis à essai aux valeurs assignées~~ Essai à la valeur correspondant au maximum de kVA ($I_{cu} \times U_e$ correspondant).

[d] Sans les essais de vérification des déclencheurs à manque de tension (8.3.3.4.2.3) et des déclencheurs shunt (8.3.3.4.2.4).

[e] Applicable uniquement à la variante unipolaire; non exigé pour les variantes bipolaires.

[f] Disponible.

[g] Un seul échantillon, de courant assigné maximal seulement, pour chaque séquence d'essai.

[h] Disponible.

[i] Disponible.

[j] Disponible.

[k] Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

8.3.2 Conditions générales d'essai

NOTE Les essais selon les exigences de cette norme n'excluent pas la nécessité d'effectuer des essais supplémentaires concernant les disjoncteurs incorporés dans des ensembles, par exemple des essais selon la série IEC 61439.

8.3.2.1 Exigences générales

Sauf accord contraire du fabricant, chaque séquence d'essai doit être effectuée sur un échantillon de disjoncteurs (ou un jeu d'échantillons) à l'état neuf et propre.

Le nombre d'échantillons à soumettre à essai pour chaque séquence d'essai et les conditions d'essai (par exemple: réglage des déclencheurs de surcharge, raccordement des bornes) suivant les paramètres du disjoncteur, sont indiqués au Tableau 10 ou, le cas échéant, pour les programmes d'essais alternatifs, dans le Tableau 9b et le Tableau 9c (voir 8.3.1.4).

Lorsque cela est nécessaire, des informations complémentaires sont données aux paragraphes correspondants.

Sauf spécification contraire, les essais sont à effectuer sur un disjoncteur ayant le courant maximal assigné pour une taille donnée et sont considérés comme couvrant tous les courants assignés de cette taille.

Dans le cas d'une ou de plusieurs différences de construction (voir 2.1.2 et 7.1.6) dans la taille considérée, des échantillons supplémentaires doivent être soumis à essai conformément au Tableau 9b et/ou au Tableau 10, suivant le cas.

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Sauf spécification contraire, les déclencheurs de court-circuit doivent être réglés au maximum (temps et courant) pour tous les essais.

Les disjoncteurs à soumettre à essai doivent être conformes dans tous leurs détails essentiels au plan du type qu'ils représentent.

Sauf indication contraire, les essais doivent être effectués avec un courant de même nature et, dans le cas du courant alternatif, de même fréquence assignée et avec le même nombre de phases que pour le service auquel le disjoncteur est destiné. Les essais réalisés à la fréquence de 50 Hz couvrent les applications à 60 Hz et vice-versa, à l'exception du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (voir 7.2.2 de l'IEC 60947-1:2007/AMD2:2010 et 7.2.2.6 de l'IEC 60947-1:2007).

Si le mécanisme est à commande électrique, il doit être alimenté à la tension minimale spécifiée en 7.2.1.1.4. En outre, les mécanismes à commande électrique doivent être alimentés par les circuits de commande appropriés du disjoncteur complet, avec leurs appareils de connexion. Il doit être vérifié que le disjoncteur fonctionne correctement à vide lorsqu'il est manœuvré dans les conditions ci-dessus.

Dans le cas de disjoncteurs à manœuvre dépendante manuelle (voir 2.4.12 de l'IEC 60947-1:2007), le disjoncteur doit être manœuvré à une vitesse de 0,1 m/s ± 25 %, cette vitesse étant mesurée à l'endroit où l'organe de manœuvre de l'appareil d'essai touche l'organe de manœuvre du disjoncteur en essai. Pour les poignées tournantes, la vitesse angulaire doit correspondre essentiellement aux conditions ci-dessus en référence à la vitesse de l'organe de manœuvre (à ses extrémités) du disjoncteur en essai.

Le disjoncteur à soumettre à essai doit être monté complet sur son propre support ou un support équivalent.

Les disjoncteurs doivent être soumis à essai à l'air libre.

Lorsqu'un disjoncteur peut être utilisé dans des enveloppes individuelles spécifiées et qu'il a été soumis à essai à l'air libre, il doit en plus être soumis à essai dans la plus petite des enveloppes déclarées par le fabricant, en utilisant un nouvel échantillon pour chacun des essais suivants:

a) Un essai de court-circuit selon 8.3.5, à U_e max et à la valeur correspondante de I_{cu}, avec les réglages du déclencheur au maximum (voir note de bas de tableau a du Tableau 10).

b) Un essai d'échauffement selon les conditions générales de 8.3.2.5 réalisé sur un disjoncteur ayant une valeur maximale de I_{th} au courant thermique assigné conventionnel sous enveloppe I_{the} (voir 4.3.3.2). Les échauffements doivent satisfaire aux exigences de 7.2.2 à l'exception du fait que l'échauffement des bornes ne doit pas dépasser 70 K.

Les détails concernant ces essais, y compris les dimensions de l'enveloppe, doivent être consignés dans le rapport d'essai.

NOTE Une enveloppe individuelle est une enveloppe conçue et dimensionnée pour ne contenir qu'un seul disjoncteur.

Cependant, si un disjoncteur peut être utilisé dans des enveloppes individuelles spécifiées et est soumis à essai dans la plus petite de ces enveloppes déclarées par le fabricant, il n'est pas nécessaire d'effectuer les essais à l'air libre pourvu qu'une telle enveloppe soit en métal nu, sans isolation. Les détails, y compris les dimensions de l'enveloppe doivent être consignés dans le rapport d'essai.

~~Pour les essais à l'air libre, pour les essais relatifs au fonctionnement en surcharge (8.3.3.5), au court-circuit (8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.6, 8.3.7.7 et 8.3.8.4), ainsi qu'à la tenue au courant de courte durée admissible (8.3.6.3 et 8.3.8.3), suivant le cas, un écran métallique doit être placé sur toutes les faces du disjoncteur conformément aux instructions~~

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~~du fabricant. Les détails, y compris les distances du disjoncteur par rapport à l'écran métallique doivent être consignés dans le rapport d'essai.~~

Pour les essais à l'air libre relatifs au fonctionnement en surcharge, au court-circuit, et le cas échéant à la tenue au courant de courte durée admissible, un écran métallique doit être placé sur toutes les faces du disjoncteur conformément aux instructions du fabricant. Les détails, y compris les distances du disjoncteur par rapport à l'écran métallique, doivent être consignés dans le rapport d'essai.

Les caractéristiques de l'écran métallique doivent être les suivantes:

- structure: écran à fils entrelacés, ou
  métal perforé, ou
  métal expansé,
- surface des trous par rapport à la surface totale: 0,45 à 0,65;
- surface de chaque trou: ne dépassant pas 30 mm^2;
- finition: sans revêtement (nu) ou revêtement conducteur;
- résistance: doit être comprise dans le calcul du courant présumé de défaut dans le circuit de l'élément fusible (voir 8.3.4.1.2, point d), de l'IEC 60947-1:2007) et mesurée à partir du point le plus éloigné de l'écran métallique susceptible d'être atteint par les émissions d'arc.

Les couples de serrage ~~appliqués~~ à appliquer aux vis des bornes doivent être conformes aux instructions du fabricant (voir ~~5.2 e)~~ Tableau 13, point 3.11).

L'entretien ou le remplacement de pièces n'est pas autorisé.

Si, pour faciliter un essai, il apparaît utile d'en augmenter la sévérité (par exemple adopter une fréquence de manœuvres plus élevée pour réduire la durée de l'essai), cela ne doit pas être effectué sans le consentement du fabricant.

Pour les essais en courant monophasé sur les pôles individuels des disjoncteurs multipolaires pour alimentation d'un circuit où une phase est reliée à la terre, voir l'Annexe C.

Pour les essais supplémentaires des disjoncteurs pour les réseaux (IT) non reliés à la terre ou reliés à la terre par une impédance, voir l'Annexe H.

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Tableau 10 – Nombre d'échantillons pour les essais *(1 de 2)*

Séquence d'essai	Nombre de caractéristiques assignées U_e marquées			Bornes repérées Alimentation/charge		Nombre d'échantillons	Echantillon N°	Courant de réglage [a]		Tension d'essai	Courant d'essai		Vérification de l'échauffement	Notes
	1	2	Plus	Oui	Non			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	Voir 8.3.3		X	g
II (I_{cs}) et VI (combinée)	X			X		2	1		X	U_e	X		X	h
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X		X	h
							2	X		U_e	X			b
							3		X	U_e	X		X	j
		X		X	X	3	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e max	X		X	k
			X	X	X	4	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e interméd.	X		X	e
							4		X	U_e max	X		X	k
III (I_{cu})	X			X		2	1		X	U_e	X			g
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X			g
							2	X		U_e	X			b
							3		X	U_e	X			c
		X		X	X	3	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e interméd.	X			e
							4		X	U_e max	X			d

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Tableau 10 *(2 de 2)*

Séquence d'essai	Nombre de caractéristiques assignées U_e marquées			Bornes repérées Alimentation/charge		Nombre d'échantillons	Echantillon N°	Courant de réglage [a]		Tension d'essai	Courant d'essai		Retard		Vérification de l'échauffement	Notes
	1	2	Plus	Oui	Non			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	g
							2		X	U_e max		X		X	X	m
			X	X	X	3	1		X	U_e max corr.		X	X		X	g
							2		X	U_e max corr.	X		X		X	i
							3		X	U_e max	X		X		X	n, d
V Fusibles incorporés (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	f, g
							2	X		U_e max	X					b
Pôle individuel (Annexe C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					g
							2	X		U_e max	I_{su}					–
Pôle individuel (Annexe H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					g

Légende

Plus = plusieurs (>2), Corr. = correspondant, Interméd. = intermédiaire

NOTE 1 Le Tableau 10 s'applique aux programmes d'essai du Tableau 9. Dans le cas des programmes d'essais alternatifs (voir 8.3.1.4), le Tableau 9b ou le Tableau 9c est applicable.

NOTE 2 L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case appropriée.

[a] Min signifie l'I_n minimum d'une taille donnée; dans le cas de déclencheurs de surcharge réglables, cela signifie le réglage minimal du I_n minimum. Max signifie le maximum de I_n pour une taille donnée.

[b] Cet échantillon est omis dans les cas suivants:

–un disjoncteur ayant un seul courant de réglage non ajustable pour une taille donnée,

–un disjoncteur équipé seulement d'un déclencheur shunt (c'est-à-dire sans déclencheur de surintensité intégré),

–un disjoncteur à protection électronique contre les surintensités, d'une taille donnée, ayant un courant assigné réglable seulement par des moyens électroniques (c'est-à-dire sans changer de capteurs de courant).

[c] Connexions inversées.

[d] Connexions inversées si les bornes ne sont pas repérées.

[e] Suivant accord à conclure entre le laboratoire d'essais et le fabricant.

[f] Si les bornes ne sont pas repérées, un échantillon supplémentaire doit être soumis à essai avec les connexions inversées.

[g] Dans le cas d'une ou plusieurs différences de construction (voir 2.1.2 et 7.1.6) pour une taille donnée, un autre échantillon est soumis à essai au courant maximal assigné correspondant à chaque construction dans les conditions applicables à l'échantillon 1.

[h] L'exigence de la note g est applicable à la séquence VI (combinée) et aussi à la séquence II lorsque $I_{cs} = I_{cu}$.

[i] Cet échantillon est sélectionné sur la base de la valeur la plus élevée de l'énergie thermique (I_{cw}^2t; où «*t*» est le retard de courte durée correspondant, voir 4.3.6.4). Cet échantillon est omis si la condition d'énergie thermique maximale est remplie par l'échantillon 1 ou 3.

[j] Cet échantillon, avec les connexions inversées, est uniquement exigé si la séquence III est remplacée par la séquence II ($I_{cu} = I_{cs}$, voir 8.3.5).

[k] Connexions inversées, si bornes non repérées, lorsque la séquence III est remplacée par la séquence II ($I_{cu} = I_{cs}$, voir 8.3.5) ou si la séquence VI remplace les séquences II, III et IV ($I_{cu} = I_{cs} = I_{cw}$, voir 8.3.8), autrement cet échantillon est soumis à essai avec une connexion dans le sens direct.

[l] S'applique uniquement aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4).

[m] Cet échantillon, avec les connexions inversées, est uniquement exigé avec les bornes non repérées si la séquence III est remplacée par la séquence IV ($I_{cu} = I_{cw}$, voir 8.3.5).

[n] Cet échantillon est uniquement exigé lorsque la séquence III est remplacée par la séquence IV ($I_{cu} = I_{cw}$, voir 8.3.5).

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8.3.2.2 Grandeurs d'essai

8.3.2.2.1 Valeurs des grandeurs d'essai

Le paragraphe 8.3.2.2.1 de l'IEC 60947-1:2007 est applicable.

8.3.2.2.2 Tolérances sur les grandeurs d'essai

Le paragraphe 8.3.2.2.2 de l'IEC 60947-1:2007 est applicable.

8.3.2.2.3 Fréquence du circuit d'essai en courant alternatif

Tous les essais doivent être effectués à la fréquence assignée du disjoncteur. Pour tous les essais de court-circuit, si le pouvoir de coupure assigné dépend essentiellement de la valeur de la fréquence, la tolérance ne doit pas dépasser ±5 %.

Si le fabricant indique que le pouvoir de coupure assigné est notablement indépendant de la valeur de la fréquence, la tolérance ne doit pas dépasser ±25 %.

8.3.2.2.4 Facteur de puissance du circuit d'essai

Le paragraphe 8.3.4.1.3 de l'IEC 60947-1:2007 est applicable avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2007 est remplacé par le Tableau 11 de la présente norme.

Tableau 11 – Valeurs des facteurs de puissance et des constantes de temps en fonction des courants d'essai

Courant d'essai *I* kA	Facteur de puissance			Constante de temps ms		
	Court-circuit	Aptitude au fonctionnement en service	Surcharge	Court-circuit	Aptitude au fonctionnement en service	Surcharge
$I \leq 3$	0,9			5		
$3 < I \leq 4{,}5$	0,8			5		
$4{,}5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5	0,8	0,5	5	2	2,5
$10 < I \leq 20$	0,3			10		
$20 < I \leq 50$	0,25			15		
$50 < I$	0,2			15		

8.3.2.2.5 Constante de temps du circuit d'essai

Le paragraphe 8.3.4.1.4 de l'IEC 60947-1:2007 est applicable avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2007 est remplacé par le Tableau 11 de la présente norme.

8.3.2.2.6 Tension de rétablissement à fréquence industrielle

Le point a) du 8.3.2.2.3 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

8.3.2.2.7 Ondulation du courant d'essai en courant continu

Le courant d'essai doit satisfaire aux exigences de 6.3.1 de l'IEC 62475:2010.

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8.3.2.3 Interprétation des résultats d'essai

L'état du disjoncteur après les essais doit être contrôlé par les vérifications spécifiées pour chaque séquence.

Un disjoncteur est réputé avoir satisfait aux exigences de la présente norme s'il répond aux exigences de chaque séquence à laquelle il est soumis.

Le boîtier ne doit pas présenter de cassure, mais les fissures fines sont acceptables.

NOTE Les fissures fines sont la conséquence de la pression élevée du gaz ou de contraintes thermiques dues aux arcs lors de l'interruption de courants de défaut très élevés, et sont de nature superficielle. En conséquence, elles ne se propagent pas dans toute l'épaisseur de l'enveloppe moulée de l'appareil.

8.3.2.4 Rapports d'essai

Le paragraphe 8.3.2.4 de l'IEC 60947-1:2007 est applicable.

8.3.2.5 Conditions d'essai pour les essais d'échauffement

Le disjoncteur doit répondre aux exigences de 7.2.2.

Le paragraphe 8.3.3.3 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, à l'exception de 8.3.3.3.6, avec le complément suivant:

Le disjoncteur doit être monté selon 8.3.2.1.

Pendant l'essai d'échauffement de la séquence I (voir 8.3.3.7), les bobines des déclencheurs à minimum de tension doivent (le cas échéant) être alimentées à une fréquence assignée et sa tension correspondante, choisies au hasard. Des essais supplémentaires pour vérifier les bobines à d'autres fréquences et tensions assignées doivent être réalisés en dehors de la séquence.

~~Pour les disjoncteurs tétrapolaires, un essai doit d'abord être effectué sur les trois pôles munis de déclencheurs à maximum de courant. Un essai complémentaire doit être effectué sur les disjoncteurs de courant assigné ne dépassant pas 63 A en faisant passer le courant d'essai par le quatrième pôle et le pôle adjacent. Pour les valeurs supérieures de courant assigné, la méthode d'essai doit faire l'objet d'un accord séparé entre le fabricant et l'utilisateur.~~

Pour les disjoncteurs tétrapolaires, un essai doit d'abord être réalisé sur les 3 pôles de phase; pour le pôle neutre, l'essai supplémentaire en courant monophasé du 8.3.3.3.4 de l'IEC 60947-1:2007 est applicable uniquement lorsqu'il y a une différence de construction entre le pôle neutre et les pôles de phase (voir 7.1.6), auquel cas le courant d'essai est le courant assigné du pôle neutre.

8.3.2.6 Conditions d'essai pour les essais de court-circuit

8.3.2.6.1 Exigences générales

Le paragraphe 8.3.4.1.1 de l'IEC 60947-1:2007 est complété comme suit:

a) Le disjoncteur doit être monté selon 8.3.2.1.

b) A moins qu'il ne puisse être montré que, les moyens de manœuvre manuelle étant dans n'importe quelle position, il n'y a pas d'ouverture autour des moyens de manœuvre manuelle par laquelle une corde à piano de 0,26 mm de diamètre peut être introduite jusqu'à la chambre d'arc, les dispositions d'essai suivantes doivent s'appliquer.

   Pour les manœuvres d'ouverture seulement, une feuille de polyéthylène à basse densité, transparente, d'une épaisseur égale à 0,05 mm ± 0,01 mm et de dimension

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100 mm × 100 mm positionnée comme indiqué sur la Figure 1, est fixée et tendue de façon raisonnable sur un cadre et placée à une distance de 10 mm:

– de la position la plus débordante de l'organe de fermeture manuelle d'un disjoncteur dont l'organe de fermeture ne se trouve pas dans un renfoncement;

– ou du bord du renfoncement pour un disjoncteur dont l'organe de fermeture manuelle se trouve dans un renfoncement.

La feuille de polyéthylène doit avoir les caractéristiques physiques suivantes:

– densité à 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3,

– point de fusion: 110 °C à 120 °C.

Sur le côté opposé au disjoncteur, il doit y avoir un renfort convenable afin d'éviter une déchirure de la feuille de polyéthylène due à l'onde de pression qui peut survenir pendant l'essai de court-circuit (voir Figure 1).

Pour les essais autres que ceux dans une enveloppe individuelle, un écran qui peut être en matériau isolant ou en métal, est placé entre l'écran métallique et la feuille de polyéthylène (voir Figure 1).

NOTE Le dispositif d'essai s'applique aux manœuvres O seulement étant donné qu'il est difficile d'effectuer les manœuvres CO et il est accepté que les manœuvres O ne sont pas moins graves que les manœuvres CO (voir 8.3.2.6.4).

c) Le disjoncteur doit être manœuvré au cours des essais de manière à reproduire aussi fidèlement que possible les conditions de service.

Un disjoncteur à manœuvre dépendante par source d'énergie extérieure doit se fermer au cours des essais avec une alimentation de commande (tension ou pression) égale à 85 % de sa valeur assignée.

Un disjoncteur à manœuvre indépendante par source d'énergie extérieure doit se fermer au cours des essais avec le mécanisme de manœuvre chargé à la valeur maximale fixée par le fabricant.

Un disjoncteur à manœuvre par accumulation d'énergie doit se fermer au cours des essais avec le dispositif de manœuvre alimenté à 85 % de la tension assignée de l'alimentation auxiliaire.

d) Si un disjoncteur est muni de déclencheurs réglables à maximum de courant, le réglage de ces déclencheurs doit être comme spécifié pour chaque séquence d'essai.

Dans le cas des disjoncteurs non équipés de déclencheurs à maximum de courant mais équipés d'un déclencheur shunt, celui-ci doit être alimenté sous une tension égale à 70 % de la tension assignée d'alimentation de commande de ce déclencheur (voir 7.2.1.2.3), appliquée au plus tôt au début du court-circuit et au plus tard 10 ms après le début de celui-ci.

e) Pour tous ces essais, le côté source du circuit d'essai doit être raccordé aux bornes correspondantes du disjoncteur telles qu'elles ont été repérées par le fabricant. En l'absence de tels repères, les connexions d'essai doivent être comme spécifiées au Tableau 10.

8.3.2.6.2 Circuit d'essai

Le paragraphe 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 est applicable.

8.3.2.6.3 Etalonnage du circuit d'essai

Le paragraphe 8.3.4.1.5 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.4 Mode opératoire d'essai

8.3.2.6.4.1 Généralités

Le paragraphe 8.3.4.1.6 de l'IEC 60947-1:2007 est applicable, avec le complément suivant.

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8.3.2.6.4.2 Essais ~~sur~~ communs aux disjoncteurs unipolaires, bipolaires, tripolaires et tétrapolaires

Après étalonnage du circuit d'essai, conformément à 8.3.2.6.3, les connexions provisoires sont remplacées par le disjoncteur en essai et ses câbles de raccordement, le cas échéant.

Les essais de vérification du fonctionnement en condition de court-circuit doivent être effectués conformément aux séquences du Tableau 9 (voir 8.3.1).

Pour les disjoncteurs dont le courant assigné ne dépasse pas 630 A, un câble d'au plus 75 cm de longueur, et de section correspondant au courant thermique conventionnel (voir 8.3.3.3.4, Tableaux 9 et 10 de l'IEC 60947-1:2007) doit être inséré, comme suit:

– environ 50 cm côté source,

– environ 25 cm côté charge.

Pour les caractéristiques assignées $\leq$ 20 A, le fabricant peut spécifier une section plus grande, auquel cas cette dernière doit être utilisée pour tous les essais de court-circuit applicables, et être indiquée dans le rapport d'essai. De plus, une vérification des déclencheurs à temps inverse selon 8.3.3.2.3 b) doit être réalisée avec ladite section.

La séquence de manœuvres doit être celle applicable à chaque séquence d'essai, comme spécifié en 8.3.4.2, 8.3.5.3, 8.3.6.5 et 8.3.7.7.

Des programmes d'essais alternatifs pour les disjoncteurs disposant de variantes à trois pôles et quatre pôles sont indiqués en 8.3.1.4.

8.3.2.6.4.3 Essais ~~de~~ supplémentaires sur les disjoncteurs tétrapolaires

~~Les exigences de 8.3.2.6.4.2 s'appliquent.~~

Des séquences de manœuvres supplémentaires doivent être ~~réalisées~~ effectuées sur un ou plusieurs échantillons ~~nouveaux~~ neufs, conformément au Tableau 10, sur le quatrième pôle et le pôle adjacent, conformément à la séquence d'essai III ou V, suivant le cas, et à la séquence d'essai IV le cas échéant. Cette exigence s'applique même lorsque la séquence d'essai III est remplacée par la séquence d'essai II (I_{cu} = I_{cs}) ou lorsque la séquence d'essai IV est remplacée par la séquence d'essai VI (I_{cw} = I_{cs}), c'est-à-dire que des essais supplémentaires conformément à la séquence d'essai III ou V, et à la séquence d'essai IV, suivant le cas, sont exigés.

En variante, à la demande du fabricant, ces essais peuvent être combinés avec les essais ~~en tripolaire~~ de 8.3.2.6.4.2 et réalisés sur les mêmes échantillons, auquel cas l'essai dans chaque séquence d'essai appropriée doit comprendre:

– l'essai des trois pôles adjacents de phase,

– l'essai du quatrième pôle et du pôle adjacent.

Les essais sur le quatrième pôle et le pôle adjacent sont réalisés sous une tension appliquée de $U_e/\sqrt{3}$, dans le circuit représenté à la Figure 12 de l'IEC 60947-1:2007/AMD1:2010 avec les connexions C1 et C2 retirées. Le courant d'essai doit faire l'objet d'un accord entre le fabricant et l'utilisateur, mais ne doit pas être inférieur à 60 % de I_{cu} ou de I_{cw} suivant le cas.

Des programmes d'essais alternatifs pour les disjoncteurs disposant de variantes à trois pôles et quatre pôles sont indiqués en 8.3.1.4.

8.3.2.6.4.4 Manœuvres d'essai

Les symboles suivants sont utilisés pour définir la séquence de manœuvres:

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O représente une manœuvre de coupure;

CO représente une manœuvre d'établissement suivie d'une manœuvre de coupure, après la durée d'ouverture appropriée;

t représente l'intervalle de temps entre deux manœuvres en court-circuit successives, qui doit être aussi court que possible, en tenant compte de la durée de réarmement du disjoncteur (voir 2.19), mais pas inférieure à 3 min. La valeur réelle de *t* doit être spécifiée dans le rapport d'essai.

La durée de réarmement maximale doit être de 15 min ou une durée plus longue pouvant être déclarée par le fabricant, mais sans dépasser 1 h, durant laquelle le disjoncteur ne doit pas être déplacé. Les tentatives de refermeture du disjoncteur pendant la durée de réarmement doivent être espacées d'au moins 1 min.

La valeur maximale de I^2t (voir 2.5.18 de l'IEC 60947-1:2007) notée durant ces essais peut être consignée dans le rapport d'essai (voir 7.2.1.2.4, point a)).

8.3.2.6.5 Comportement du disjoncteur pendant les essais de fermeture et de coupure en court-circuit

Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.6 Interprétation des enregistrements

Le paragraphe 8.3.4.1.8 de l'IEC 60947-1:2007 est applicable.

8.3.2.6.7 Vérification après les essais de court-circuit

Après les manœuvres d'ouverture des essais de pouvoir de coupure et de fermeture en court-circuit de 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, suivant le cas, les conditions suivantes doivent être remplies:

– l'isolant des câbles utilisés pour raccorder l'appareil ne doit présenter aucune dégradation;
– la feuille de polyéthylène, le cas échéant, ne doit pas présenter de trous visibles à l'œil nu ou avec vision corrigée sans grossissement supplémentaire. Les trous minuscules dont le diamètre est inférieur à 0,26 mm peuvent être ignorés;
– le boîtier ne doit pas présenter de cassure, mais les fissures fines sont acceptables.

NOTE Les fissures fines sont la conséquence de la pression élevée du gaz ou de contraintes thermiques dues aux arcs lors de l'interruption de courants de défaut très élevés, et sont de nature superficielle. En conséquence, elles ne se propagent pas dans toute l'épaisseur de l'enveloppe moulée de l'appareil.

Ensuite, après les essais de court-circuit, le disjoncteur doit satisfaire aux vérifications spécifiées pour chaque séquence d'essai s'il y a lieu.

8.3.3 Séquence d'essai I: Caractéristiques générales de fonctionnement

8.3.3.1 Généralités

Cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais suivants:

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Essai	Paragraphe
Limites et caractéristiques de déclenchement	8.3.3.2
Propriétés diélectriques	8.3.3.3
Fonctionnement mécanique et aptitude au fonctionnement en service	8.3.3.4
Fonctionnement en surcharge (le cas échéant)	8.3.3.5
Vérification de la tenue diélectrique	8.3.3.6
Vérification de l'échauffement	8.3.3.7
Vérification des déclencheurs de surcharge	8.3.3.8
Vérification des déclencheurs à minimum de tension et des déclencheurs shunt (le cas échéant)	8.3.3.9
Vérification de la position des contacts principaux (pour disjoncteurs aptes au sectionnement)	8.3.3.10

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

Voir 8.3.1 pour les essais qui peuvent être omis de la séquence et effectués sur des échantillons séparés.

8.3.3.2 Essai des limites et des caractéristiques de déclenchement

8.3.3.2.1 Généralités

Le paragraphe 8.3.3.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est développé comme suit:

La température de l'air ambiant doit être mesurée comme lors des essais d'échauffement (voir 8.3.2.5).

Quand le déclencheur d'ouverture à maximum de courant est normalement monté comme partie intégrante du disjoncteur, il doit être vérifié dans le disjoncteur correspondant.

Tout déclencheur séparé doit être monté approximativement comme dans les conditions normales de service. Le disjoncteur complet doit être monté selon 8.3.2.1. Le matériel à l'essai doit être protégé contre des échauffements ou des refroidissements anormaux dus à des causes extérieures.

Les connexions du déclencheur séparé, le cas échéant, ou du disjoncteur complet doivent être réalisées de la même façon que pour le service normal avec des conducteurs de section correspondant au courant assigné (I_n) (voir 8.3.3.3.4, Tableaux 9 et 10 de l'IEC 60947-1:2007), et de longueur conforme au 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Pour les disjoncteurs munis de déclencheurs à maximum de courant réglables, les essais doivent être effectués aux :

a) courant de réglage minimal et au réglage minimal de la temporisation, suivant le cas, et

b) courant de réglage maximal et au réglage maximal de la temporisation, suivant le cas,

dans chaque cas avec des conducteurs correspondant au courant assigné I_n (voir 4.7.2).

Pour les essais pour lesquels la caractéristique de déclenchement est indépendante de la température des bornes (par exemple les déclencheurs électroniques de surcharge, les déclencheurs magnétiques), les données relatives au raccordement (type, section, longueur) peuvent être différentes de celles exigées en 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014. Il convient que les raccordements soient compatibles avec le courant d'essai et les contraintes thermiques induites.

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Pour les disjoncteurs ayant un pôle neutre équipé d'un déclencheur de surcharge, la vérification de ce déclencheur de surcharge doit être effectuée sur le pôle neutre seul.

Les essais peuvent être effectués à toute tension convenable.

8.3.3.2.2 Déclencheurs de court-circuit

Le fonctionnement des déclencheurs de court-circuit (voir 4.7.1) doit être vérifié à 80 % et à 120 % du courant de réglage de court-circuit du déclencheur. Pour les essais en courant alternatif, le courant d'essai ne doit pas présenter d'asymétrie. Pour les essais en courant continu, le courant ne doit présenter aucun dépassement au démarrage et la constante de temps doit être inférieure à 10 ms.

Pour une valeur du courant d'essai égale à 80 % du courant de réglage de court-circuit, le déclencheur ne doit pas fonctionner, le courant étant maintenu:

– pendant 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour une valeur de courant d'essai égale à 120 % du courant de réglage de court-circuit, le déclencheur doit fonctionner:

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20);
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs munis d'un déclencheur de surintensité électronique, le fonctionnement des déclencheurs de court-circuit doit être vérifié par seulement un essai sur chaque pôle individuellement.

Pour les disjoncteurs munis de déclencheurs de surintensité électromagnétiques, le fonctionnement des déclencheurs multipolaires de court-circuit doit être vérifié par seulement un essai sur chaque combinaison de deux pôles de phase en série. Pour les disjoncteurs possédant un pôle neutre identifié muni d'un déclencheur de court-circuit, le pôle neutre doit être soumis à essai en série avec un pôle de phase choisi au hasard. De plus, le fonctionnement des déclencheurs de court-circuit doit être vérifié une fois sur chaque pôle individuellement, à 120 % de la valeur déclarée par le fabricant pour les pôles individuels ou de la valeur de réglage du courant de court-circuit (si aucune valeur n'est déclarée pour les pôles individuels), et le fonctionnement à cette valeur doit s'effectuer:

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Les déclencheurs à retard indépendant doivent, en outre, satisfaire aux exigences de 8.3.3.2.4.

8.3.3.2.3 Déclencheurs de surcharge

a) Déclencheurs instantanés ou à retard indépendant

Le fonctionnement des déclencheurs de surcharge instantanés ou à retard indépendant (voir Note 1 de 4.7.1) doit être vérifié à 90 % et à 110 % du courant de réglage de surcharge du déclencheur. Pour les essais en courant alternatif, le courant d'essai ne doit pas présenter d'asymétrie. Pour les essais en courant continu, le courant ne doit présenter aucun dépassement au démarrage et la constante de temps doit être inférieure à 10 ms. Le fonctionnement des déclencheurs de surcharge multipolaires doit être vérifié avec tous les pôles de phase alimentés simultanément par le courant d'essai.

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Les déclencheurs à retard indépendant doivent, en outre, satisfaire aux exigences de 8.3.3.2.4.

A un courant d'essai d'une valeur égale à 90 % du courant de réglage, le déclencheur ne doit pas fonctionner, le courant étant maintenu

– pendant 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),

– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

A un courant d'essai d'une valeur égale à 110 % du courant de réglage, le déclencheur doit fonctionner

– en 0,2 s dans le cas de déclencheurs instantanés (voir 2.20),

– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir ~~8.3.3.2.3~~ 8.3.3.2.1), le courant d'essai pour ce déclencheur doit avoir une valeur égale à 1,2 fois 110 % du courant de réglage.

b) Déclencheurs à temps inverse

Les caractéristiques de fonctionnement des déclencheurs de surcharge à temps inverse doivent être vérifiées selon les exigences de 7.2.1.2.4, point b) 2).

Pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir ~~8.3.3.2.4~~ 8.3.3.2.1), les courants d'essai pour ce déclencheur doivent être choisis dans le Tableau 6 excepté que le courant d'essai au courant conventionnel de déclenchement doit être multiplié par le facteur 1,2.

Pour les déclencheurs sensibles à la température de l'air ambiant, les caractéristiques de fonctionnement doivent être vérifiées à la température de référence (voir 4.7.3 et ~~point b) de 5.2~~ Tableau 13 point 2.14), le déclencheur étant alimenté sur tous les pôles de phase.

Si l'essai est effectué à une température différente de la température de l'air ambiant, une correction doit être effectuée conformément aux caractéristiques température/courant fournies par le fabricant.

Pour les déclencheurs magnétothermiques déclarés insensibles à la température de l'air ambiant par le fabricant, les caractéristiques de fonctionnement doivent être vérifiées par deux mesurages, l'un à 30 °C ± 2 °C, l'autre à 20 °C ± 2 °C ou à 40 °C ± 2 °C, le déclencheur étant alimenté sur tous les pôles de phase.

Pour les déclencheurs électroniques, les caractéristiques de fonctionnement doivent être vérifiées à la température ambiante du local d'essai (voir 6.1.1 de l'IEC 60947-1:2007/AMD2:2014), le déclencheur étant alimenté sur tous les pôles de phase.

Un essai supplémentaire, à une valeur de courant devant faire l'objet d'un accord entre le fabricant et l'utilisateur, doit être effectué en vue de vérifier que les caractéristiques temps/courant du déclencheur correspondent (dans les limites des tolérances indiquées) aux courbes fournies par le fabricant.

NOTE En plus des essais décrits dans ce paragraphe, les déclencheurs des disjoncteurs sont également vérifiés sur chaque pôle séparément au cours des séquences d'essai III, IV V et VI (voir 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 et 8.3.8.8).

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8.3.3.2.4 Essais supplémentaires des déclencheurs à retard indépendant

Les déclencheurs à retard indépendant doivent être soumis à essai pour vérifier les valeurs du retard et de la durée de non-déclenchement

a) Retard

Cet essai est effectué à un courant égal à 1,5 fois le courant de réglage:

– dans le cas de déclencheurs de surcharge, tous les pôles de phase étant chargés;

– pour les disjoncteurs ayant un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 8.3.3.2.1), le courant d'essai pour ce déclencheur doit être égal à 1,5 fois le courant de réglage;

– dans le cas de déclencheurs de court-circuit électromagnétiques, avec deux pôles en série parcourus par le courant d'essai, en utilisant successivement toutes les combinaisons possibles de pôles de phase munis d'un déclencheur de court-circuit.

– dans le cas de déclencheurs de court-circuit électroniques, sur un pôle choisi au hasard.

Le retard mesuré doit se trouver entre les limites fixées par le fabricant.

Si le courant d'essai chevauche une autre caractéristique de déclenchement (par exemple une caractéristique de déclenchement instantané), le réglage du déclenchement (par exemple I_{sd}, voir Figure K.1) et le courant d'essai doivent être réduits autant que nécessaire pour empêcher un déclenchement prématuré. Ces valeurs doivent être enregistrées dans le rapport d'essai.

b) Durée de non-déclenchement

Cet essai est effectué dans les mêmes conditions que pour l'essai du point a) ci-dessus pour les déclencheurs de surcharge et pour les déclencheurs de court-circuit.

Un courant d'essai égal à 1,5 fois le courant de réglage est d'abord maintenu pendant un intervalle de temps égal à la durée de non-déclenchement fixée par le fabricant; puis le courant est réduit à la valeur correspondant au courant de réglage de surcharge (I_r) et il est maintenu à cette valeur pendant un intervalle de temps égal au double du retard fixé par le fabricant. Le disjoncteur ne doit pas déclencher.

8.3.3.3 Essai des propriétés diélectriques

Le paragraphe 8.3.3.4.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, à l'exception du point 5), avec les compléments suivants:

(i) en référence à 8.3.3.4.1, point 2) c) i) et ii), de l'IEC 60947-1:2007: les positions normales de service comprennent la position de déclenchement, le cas échéant;

(ii) en référence à 8.3.3.4.1, point 3 c), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014: pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs reliés au circuit principal doivent être déconnectés pour l'essai;

(iii) les disjoncteurs non déclarés comme aptes au sectionnement doivent être soumis à essai avec la tension d'essai appliquée à travers les pôles du circuit principal, les bornes amont étant reliées entre elles et les bornes aval étant reliées entre elles. La tension d'essai doit être en conformité au Tableau 12 de l'IEC 60947-1:2007;

(iv) pour les disjoncteurs aptes au sectionnement (voir 3.5) et ayant une tension d'emploi supérieure à 50 V, le courant de fuite, mesuré à travers chaque pôle avec les contacts en position d'ouverture, à une tension d'essai égale à 1,1 U_e, ne doit pas dépasser 0,5 mA;

(v) les disjoncteurs ayant une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou 2 U_i selon la plus grande des deux valeurs;

(vi) les disjoncteurs débrochables (voir 7.1.2) doivent faire l'objet d'une vérification de la tension de tenue aux chocs, selon 8.3.3.4.1, point 2) b) de l'IEC 60947-1:2007. La tension d'essai doit être choisie dans le Tableau 14 de l'IEC 60947-1:2007, et elle doit être appliquée entre les contacts principaux des unités débrochables et leurs contacts fixes correspondantes, en position déconnectée. Les critères d'acceptation sont ceux de 8.3.3.4.1, point 2) d) de l'IEC 60947-1:2007.

8.3.3.4 Essais de fonctionnement mécanique et d'aptitude au fonctionnement en service

8.3.3.4.1 Conditions générales d'essai

Le disjoncteur doit être monté comme indiqué en 8.3.2.1, mis à part que, pour ces essais, il peut être monté sur un châssis métallique. Le disjoncteur doit être protégé contre tout échauffement ou refroidissement extérieur excessif.

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Les essais doivent être effectués à la température ambiante du local d'essai.

La tension d'alimentation de commande de chaque circuit de commande doit être mesurée à ses bornes sous le courant assigné.

Toutes les résistances ou impédances faisant partie de l'appareil de commande doivent être en circuit. Cependant, aucune impédance supplémentaire ne doit être insérée entre la source de courant et les bornes de l'appareil.

Les essais de 8.3.3.4.2, 8.3.3.4.3 et 8.3.3.4.4 doivent être effectués sur le même disjoncteur, mais l'ordre dans lequel ces essais sont effectués est facultatif. Cependant pour les essais des déclencheurs à minimum de tension et les déclencheurs shunt, les essais de 8.3.3.4.2 et 8.3.3.4.3 peuvent être effectués, à la place, sur un échantillon neuf.

S'il est souhaité, dans le cas des disjoncteurs pouvant être entretenus, qu'un nombre de manœuvres supérieur à celui spécifié au Tableau 8 soit effectué, ces manœuvres supplémentaires doivent être effectuées d'abord, suivies par des opérations d'entretien conformes aux instructions du fabricant et, ensuite, par le nombre de manœuvres prévu au Tableau 8, sans qu'aucune autre opération d'entretien soit permise au cours du restant de cette séquence d'essai.

Pour la commodité de l'essai, il est admis de diviser chacun de ces essais en deux périodes ou plus. Il convient cependant qu'aucune de ces périodes ne soit inférieure à 3 h.

8.3.3.4.2 Dispositions constructives et fonctionnement mécanique

8.3.3.4.2.1 Construction

Un disjoncteur débrochable doit être vérifié suivant les exigences de 7.1.2.

La conformité à 7.2.1.1.6 d'un disjoncteur à manœuvre par accumulation d'énergie doit être vérifiée en ce qui concerne l'indication de la charge et le sens de manœuvre du mécanisme manuel d'accumulation d'énergie.

8.3.3.4.2.2 Fonctionnement mécanique

Les essais doivent être effectués comme spécifié en 8.3.3.4.1 en vue de:

– vérifier le déclenchement satisfaisant du disjoncteur, ~~l'appareil~~ le déclencheur de fermeture étant alimenté;

– vérifier le comportement satisfaisant du disjoncteur lorsque la manœuvre de fermeture est provoquée, l'appareil de déclenchement étant en action;

– vérifier que la mise en action d'un appareil à commande par source d'énergie extérieure, lorsque le disjoncteur est déjà fermé, ne doit provoquer aucun dommage au disjoncteur ni mettre en danger l'opérateur.

Le fonctionnement mécanique d'un disjoncteur peut être vérifié à vide.

Un disjoncteur à manœuvre dépendante à source d'énergie extérieure doit satisfaire aux exigences de 7.2.1.1.4.

Un disjoncteur à manœuvre dépendante à source d'énergie extérieure doit fonctionner avec son mécanisme de manœuvre chargé aux limites minimale et maximale fixées par le fabricant.

Un disjoncteur à manœuvre par accumulation d'énergie doit être conforme aux exigences de 7.2.1.1.6 avec une tension d'alimentation auxiliaire égale à 85 % et à 110 % de la tension assignée d'alimentation de commande. Il doit être aussi vérifié que les contacts mobiles ne

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peuvent pas s'écarter de la position d'ouverture lorsque la charge du mécanisme de manœuvre est légèrement inférieure à la pleine charge mise en évidence par l'appareil indicateur.

Les contacts d'un disjoncteur à déclenchement libre ne doivent pas pouvoir être maintenus en contact ou en position de fermeture lorsque le déclencheur est en position de déclenchement.

Si les durées de fermeture et d'ouverture d'un disjoncteur sont indiquées par le fabricant, leurs valeurs doivent être conformes à ces indications.

8.3.3.4.2.3 Déclencheurs à minimum de tension

Les déclencheurs à minimum de tension doivent satisfaire aux exigences de 7.2.1.3 de l'IEC 60947-1:2007. Pour cela, le déclencheur doit être adapté à un disjoncteur ayant le courant maximal assigné pour lequel le déclencheur convient.

i) Tension de retombée

Il doit être aussi vérifié que le déclencheur fonctionne pour ouvrir le disjoncteur entre les limites de tension spécifiées.

La tension doit être réduite en partant de la tension assignée d'alimentation de commande pour atteindre 0 V en 30 s environ.

L'essai pour la limite inférieure est effectué sans courant dans le circuit principal et sans préchauffage préalable de la bobine du déclencheur.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation de commande, cet essai est effectué à la tension maximale de la plage.

L'essai pour la limite supérieure est effectué en partant d'une température constante correspondant à l'application de la tension assignée d'alimentation de commande au déclencheur et au courant assigné dans les pôles principaux du disjoncteur. Cet essai peut être combiné avec l'essai d'échauffement de 8.3.3.7.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation de commande, cet essai est effectué aux deux tensions assignées minimale et maximale d'alimentation de commande.

ii) Essai pour les limites de fonctionnement

En démarrant avec le disjoncteur ouvert, à la température du local d'essai et avec la tension d'alimentation égale à 30 % de la tension assignée maximale d'alimentation de commande, il doit être vérifié que le disjoncteur ne peut pas être fermé en manœuvrant l'organe de commande. Lorsque la tension d'alimentation est augmentée jusqu'à 85 % de la tension assignée minimale d'alimentation de commande, il doit être vérifié que le disjoncteur peut être fermé en manœuvrant l'organe de commande.

iii) Fonctionnement dans des conditions de maximum de tension

Le disjoncteur étant fermé sans courant dans le circuit principal, il doit être vérifié que le déclencheur à minimum de tension supporte l'application d'une tension égale à 110 % de la tension assignée d'alimentation de commande pendant 4 h sans altérer ses performances.

8.3.3.4.2.4 Déclencheurs shunt

Les déclencheurs à minimum de tension doivent satisfaire aux exigences de 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014. Pour cela, le déclencheur doit être adapté à un disjoncteur ayant le courant maximal assigné pour lequel le déclencheur convient.

Il doit être vérifié que le déclencheur fonctionne pour ouvrir le disjoncteur à 70 % de la tension assignée d'alimentation de commande, celui-ci étant soumis à essai à une température ambiante de + 55 °C ± 2 °C sans courant dans les pôles principaux du disjoncteur. Dans le cas d'un déclencheur ayant une plage de tensions assignées d'alimentation de commande, la tension d'essai doit correspondre à 70 % de la tension minimale assignée d'alimentation de commande.

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8.3.3.4.3 Aptitude au fonctionnement en service sans courant

Ces essais doivent être effectués dans les conditions spécifiées en 8.3.2.1. Le nombre de cycles de manœuvres à effectuer sur le disjoncteur est indiqué dans la colonne 3 du Tableau 8; le nombre de cycles de manœuvres par heure est indiqué dans la colonne 2 de ce tableau.

Les essais doivent être effectués sans courant dans le circuit principal du disjoncteur.

Pour les disjoncteurs qui peuvent être équipés de déclencheurs shunt, 10 % du nombre total de cycles de manœuvres doivent être des manœuvres de fermeture/déclenchement, c'est-à-dire avec le déclencheur shunt alimenté à la tension maximale assignée d'alimentation de commande.

Pour les disjoncteurs qui peuvent être équipés de déclencheurs à minimum de tension, 10 % du nombre total de cycles de manœuvres doivent être des manœuvres de fermeture/déclenchement à la tension minimale assignée d'alimentation de commande, cette tension étant retirée du déclencheur après chaque manœuvre de fermeture, afin de déclencher le disjoncteur.

Dans chaque cas, la moitié du nombre de cycles de manœuvres doit être effectuée au début des essais et l'autre moitié à la fin des essais.

Pour les disjoncteurs équipés de déclencheurs à minimum de tension, avant l'essai de fonctionnement en service, le déclencheur à minimum de tension non alimenté, il doit être vérifié que le disjoncteur ne peut pas être fermé en essayant 10 fois de le fermer.

Les essais doivent être réalisés sur un disjoncteur muni de son propre mécanisme de fermeture. Dans le cas de disjoncteurs munis d'un ~~appareil~~ déclencheur électrique ou pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation de commande ou à sa pression assignée. Des précautions doivent être prises pour éviter que les échauffements des organes électriques ne dépassent pas les limites indiquées au Tableau 7.

Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

8.3.3.4.4 Aptitude au fonctionnement en service avec courant

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, le circuit d'essai étant conforme au 8.3.3.5.2 de l'IEC 60947-1:2007.

Le nombre et la fréquence des cycles de manœuvres à effectuer sont donnés dans les colonnes 2 et 4 du Tableau 8.

Le fonctionnement du disjoncteur doit être tel qu'il établisse et qu'il coupe son courant assigné sous sa tension assignée d'emploi maximale, fixée par le fabricant, avec un facteur de puissance ou une constante de temps, suivant le cas, conforme au Tableau 11, les tolérances étant telles qu'indiquées en 8.3.2.2.2.

Les essais sur les disjoncteurs à courant assigné alternatif doivent être effectués à une fréquence comprise entre 45 Hz et 62 Hz.

Pour les disjoncteurs munis de déclencheurs réglables, les essais doivent être effectués avec les déclencheurs réglés à leur valeur de réglage maximale en surcharge et minimale en court-circuit.

Les essais doivent être réalisés sur un disjoncteur muni de son propre mécanisme de fermeture. Dans le cas de disjoncteurs munis d'un ~~appareil~~ déclencheur électrique ou

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pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation de commande ou à sa pression assignée. Des précautions doivent être prises pour s'assurer que les échauffements des organes électriques n'excèdent pas les valeurs indiquées au Tableau 7.

Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

8.3.3.4.5 Essai supplémentaire d'aptitude au fonctionnement en service sans courant pour les disjoncteurs débrochables

Un essai d'aptitude au fonctionnement en service sans courant doit être effectué sur le mécanisme de débrochage et les dispositifs de verrouillage associés des disjoncteurs débrochables.

Le nombre de cycles de manœuvres doit être 100.

Après cet essai, les contacts de sectionnement, le mécanisme de débrochage et les dispositifs de verrouillage doivent pouvoir assurer leur fonction. La vérification doit être effectuée par inspection.

8.3.3.5 Fonctionnement en surcharge

Cet essai s'applique aux disjoncteurs de courant assigné inférieur ou égal à 630 A.

NOTE 1 Sur demande du fabricant, cet essai peut aussi être effectué sur des disjoncteurs de courant assigné supérieur à 630 A.

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, et le circuit d'essai doit être conforme au 8.3.3.5.2 de l'IEC 60947-1:2007.

L'essai doit être effectué à une tension correspondant à la valeur maximale d'emploi $U_{e\ max}$ assignée par le fabricant au disjoncteur, en prenant en compte l'exigence relative à la tension de rétablissement du Tableau 12 (voir également 8.3.2.2.3 a) de l'IEC 60947-1:2007/AMD2:2014).

Pour les disjoncteurs munis de déclencheurs réglables, cet essai doit être effectué avec les déclencheurs réglés à leur valeur de réglage maximale.

Le disjoncteur doit être ouvert neuf fois à la main et trois fois de façon automatique par l'action d'un déclencheur de surcharge, sauf dans le cas de disjoncteurs ayant un déclencheur de court-circuit dont le réglage maximal est inférieur au courant d'essai, pour lesquels toutes les 12 manœuvres doivent être automatiques.

Si le moyen d'essai ne résiste pas au passage de l'énergie apparaissant pendant le fonctionnement automatique, l'essai peut être effectué de la façon suivante, avec l'accord du fabricant:

– 12 manœuvres manuelles;
– trois manœuvres supplémentaires avec une ouverture automatique, réalisées sous toute tension appropriée.

Au cours de chacun des cycles manuels, le disjoncteur doit rester fermé pendant une durée suffisante pour assurer l'établissement complet du courant, mais ne dépassant pas 2 s.

Le nombre de cycles de manœuvres par heure doit être comme spécifié dans la colonne 2 du Tableau 8. Si le disjoncteur ne se verrouille pas à la fréquence spécifiée, cette fréquence peut être réduite suffisamment pour permettre au disjoncteur de se fermer après l'établissement complet du courant.

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Si les conditions de l'installation d'essai ne permettent pas de réaliser les essais à la fréquence de manœuvre spécifiée au Tableau 8, une fréquence plus faible peut être adoptée, mais ce fait doit être mentionné dans le rapport d'essai.

Les valeurs du courant et de la tension de rétablissement d'essai doivent être conformes au Tableau 12, avec le facteur de puissance ou la constante de temps, le cas échéant, conforme au Tableau 11, les tolérances étant telles qu'indiquées en 8.3.2.2.2.

NOTE 2 Avec l'accord du fabricant, cet essai peut être effectué dans des conditions plus sévères que celles spécifiées.

Tableau 12 – Caractéristiques du circuit d'essai pour le fonctionnement en surcharge

	Courant alternatif	Courant continu
Courant	6 I_n	2,5 I_n
Tension de rétablissement	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = tension d'emploi maximale du disjoncteur.		

Les essais sur les disjoncteurs à courant assigné alternatif doivent être effectués à une fréquence comprise entre 45 Hz et 62 Hz.

Le courant présumé aux bornes d'alimentation du disjoncteur doit être au moins égal à la plus petite des deux valeurs suivantes: 10 fois la valeur du courant d'essai ou au moins 50 kA.

8.3.3.6 Vérification de la tenue diélectrique

8.3.3.6.1 Généralités

L'essai doit être effectué sur le disjoncteur restant monté tel qu'il l'était pour l'essai précédent. Si ce montage n'est pas possible, il peut être déconnecté et retiré du circuit d'essai, mais alors des mesures doivent être prises pour s'assurer que cela n'influence pas les résultats de l'essai.

8.3.3.6.2 Tension d'essai

Le paragraphe 8.3.3.4.1, point ~~3)~~ 4) b), de l'IEC 60947-1:2007/AMD1:2010 est applicable.

~~La valeur de la tension d'essai doit être égale à 2 U_e avec un minimum de 1 000 V en valeur efficace, ou 1 415 V en courant continu si une tension alternative ne peut pas être appliquée. La valeur de U_e à considérer est celle à laquelle les essais de manœuvre et/ou de court-circuit précédents ont été effectués.~~

8.3.3.6.3 Application de la tension d'essai

La tension d'essai doit être appliquée pendant 5 s conformément à 8.3.3.4.1, points 2) c) i), ii) et iii), de l'IEC 60947-1:2007 et, en complément, entre les bornes d'entrée et de sortie de chaque pôle, le disjoncteur étant ouvert. L'utilisation de la feuille métallique telle que spécifiée en 8.3.3.4.1, point 1), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 n'est pas exigée. Pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs reliés au circuit principal doivent être déconnectés pour les essais. Les positions normales de service comprennent la position de déclenchement, le cas échéant.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.3, point (iv), excepté que le courant de fuite ne doit pas dépasser 2 mA.

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8.3.3.6.4 Critères d'acceptation

Le paragraphe 8.3.3.4.1, point 3) d), de l'IEC 60947-1:2007 est applicable.

8.3.3.7 Vérification de l'échauffement

A la suite de l'essai de 8.3.3.6, un essai d'échauffement doit être effectué au courant thermique conventionnel, conformément à 8.3.2.5. A la fin de l'essai, les valeurs des échauffements ne doivent pas dépasser celles spécifiées au Tableau 7.

8.3.3.8 Vérification des déclencheurs de surcharge

Immédiatement après l'essai effectué conformément à 8.3.3.7, le fonctionnement des déclencheurs de surcharge doit être vérifié à 1,45 fois la valeur de leur courant de réglage, à la température de référence (voir 7.2.1.2.4, point b) 2)).

Tous les pôles doivent être reliés en série pour cet essai. En variante, cet essai peut être effectué avec une alimentation triphasée.

Cet essai peut être effectué sous toute tension convenable.

La durée de fonctionnement ne doit pas dépasser la durée conventionnelle de déclenchement.

Avec l'accord du fabricant, un délai entre les essais de 8.3.3.7 et 8.3.3.8 est admissible.

En variante, cet essai peut être effectué à la température de l'air ambiant, à un courant d'essai modifié conformément aux caractéristiques température/courant fournies par le fabricant, pour les déclencheurs sensibles à la température ambiante.

8.3.3.9 Vérification des déclencheurs à minimum de tension et des déclencheurs shunt

Les disjoncteurs équipés de déclencheurs à minimum de tension doivent être soumis à l'essai de 8.3.3.4.2.3 i), excepté que les essais pour les limites supérieures et inférieures doivent être effectués à la température du local d'essai sans courant dans le circuit principal. Le déclencheur ne doit pas fonctionner à 70 % de la tension minimale d'alimentation de commande et doit fonctionner à 35 % de la tension maximale assignée d'alimentation de commande.

Les disjoncteurs équipés de déclencheurs shunt doivent être soumis à l'essai de 8.3.3.4.2.4, excepté que l'essai peut être effectué à la température du local d'essai. Le déclencheur doit fonctionner à 70 % de la tension minimale assignée d'alimentation de commande.

8.3.3.10 Vérification de la position des contacts principaux

Pour les disjoncteurs aptes au sectionnement (voir 3.5), après la vérification de 8.3.3.8, un essai doit être effectué afin de vérifier l'efficacité de l'indication de la position des contacts principaux selon 8.2.5 de l'IEC 60947-1:2007/AMD1:2010.

8.3.4 Séquence d'essai II: Pouvoir assigné de coupure de service en court-circuit

8.3.4.1 Généralités

Sauf dans les cas où s'applique la séquence d'essai VI (combinée) (voir 8.3.8), cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais suivants:

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Essai	Paragraphe
Pouvoir assigné de coupure de service en court-circuit	8.3.4.2
Vérification de l'aptitude au fonctionnement	8.3.4.3
Vérification de la tenue diélectrique	8.3.4.4
Vérification de l'échauffement	8.3.4.5
Vérification des déclencheurs de surcharge	8.3.4.6

Pour le cas où $I_{cs} = I_{cu}$, voir 8.3.5.

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.4.2 Essai du pouvoir assigné de coupure de service en court-circuit

Un essai de court-circuit est effectué dans les conditions générales de 8.3.2, la valeur du courant présumé I_{cs} déclarée par le fabricant étant conforme à 4.3.6.2.3.

Le facteur de puissance pour cet essai doit être conforme au Tableau 11, pour le courant d'essai approprié.

La séquence de manœuvres doit être:

$$O - t - CO - t - CO$$

Dans le cas des disjoncteurs à fusibles incorporés, tout fusible fondu doit être remplacé après chaque manœuvre. Il peut être nécessaire d'augmenter pour cela l'intervalle de temps t.

8.3.4.3 Vérification de l'aptitude au fonctionnement

Après l'essai selon 8.3.4.2, l'aptitude au fonctionnement doit être vérifiée selon 8.3.3.4.4, excepté que cette vérification doit être effectuée à la même tension assignée d'emploi utilisée pour l'essai de 8.3.4.2 et que le nombre de manœuvres doit être égal à 5 % du nombre donné dans la colonne 4 du Tableau 8.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.4.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge tel que spécifié au Tableau 10.

8.3.4.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.4.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.6.

8.3.4.5 Vérification de l'échauffement

Après l'essai selon 8.3.4.4, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5. L'échauffement ne doit pas dépasser les valeurs données au Tableau 7.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.4.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

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8.3.4.6 Vérification des déclencheurs de surcharge

Immédiatement après l'essai de 8.3.4.5, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.3.8.

Avec l'accord du fabricant, un délai entre les essais de 8.3.4.5 et 8.3.4.6 est admissible.

8.3.5 Séquence d'essai III: Pouvoir assigné de coupure ultime en court-circuit

8.3.5.1 Généralités

Sauf dans les cas où s'applique la séquence d'essai VI (combinée) (voir 8.3.8), cette séquence d'essai s'applique aux disjoncteurs de catégorie de sélectivité A et à ceux de catégorie de sélectivité B dont le pouvoir assigné de coupure ultime en court-circuit est supérieur au courant assigné de courte durée admissible.

NOTE Pour ce type de disjoncteurs de catégorie de sélectivité B, le déclencheur instantané fonctionne à des valeurs de courant supérieures à celles indiquées dans la colonne 2 du Tableau 3 (4.3.6.4); ce type de déclencheur peut être appelé «commande instantanée».

Il n'est pas nécessaire d'effectuer cette séquence d'essai sur les disjoncteurs de catégorie de sélectivité B dont le courant assigné de courte durée admissible est égal au pouvoir assigné de coupure ultime en court-circuit car, dans ce cas, le pouvoir de coupure ultime en court-circuit est vérifié au cours de la séquence d'essai IV.

Pour les disjoncteurs à fusibles incorporés, la séquence d'essai V s'applique à la place de cette séquence.

Lorsque $I_{cs} = I_{cu}$, cette séquence d'essai peut ne pas être réalisée, et dans ce cas des essais de différences de construction sont exigés en séquence II (voir le Tableau 10) et les vérifications suivantes doivent être faites en plus dans la séquence d'essai II:

– la vérification de 8.3.5.2 au début de la séquence d'essai,
– la vérification de 8.3.5.5 à la fin de la séquence d'essai.

Cette séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.5.2
Pouvoir assigné de coupure ultime en court-circuit	8.3.5.3
Vérification de la tenue diélectrique	8.3.5.4
Vérification des déclencheurs de surcharge	8.3.5.5

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.5.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié à deux fois la valeur de leur courant de réglage sur chaque pôle séparément. Cet essai peut être effectué sous toute tension convenable.

Si la température ambiante est différente de la température de référence, la valeur du courant d'essai doit être corrigée conformément aux caractéristiques température/courant fournies par le fabricant, pour les déclencheurs sensibles à la température ambiante.

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Pour les essais pour lesquels la caractéristique de déclenchement est indépendante de la température des bornes (par exemple les déclencheurs électroniques de surcharge, les déclencheurs magnétiques), les données relatives au raccordement (type, section, longueur) peuvent être différentes de celles exigées en 8.3.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014. Il convient que les raccordements soient compatibles avec le courant d'essai et les contraintes thermiques induites.

La durée de fonctionnement ne doit pas dépasser la valeur maximale fixée par le fabricant pour le double du courant de réglage à la température de référence, sur un pôle séparément.

8.3.5.3 Essai de pouvoir assigné de coupure ultime en court-circuit

Après l'essai de 8.3.5.2, un essai de pouvoir de coupure en court-circuit est effectué avec un courant présumé de valeur égale au pouvoir assigné de coupure ultime en court-circuit déclaré par le fabricant, dans les conditions générales conformes à celles de 8.3.2.

La séquence de manœuvres doit être:

O – *t* – CO

8.3.5.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.5.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6. Pour les disjoncteurs aptes au sectionnement, le courant de fuite ne doit pas dépasser 6 mA.

8.3.5.5 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.5.4, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.6 Séquence d'essai IV: Courant assigné de courte durée admissible

8.3.6.1 Généralités

Sauf lorsque la séquence d'essai VI (combinée) s'applique (voir 8.3.8), cette séquence d'essai s'applique aux disjoncteurs à courant assigné de courte durée admissible (voir 4.4); elle comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.6.2
Courant assigné de courte durée admissible	8.3.6.3
Vérification de l'échauffement	8.3.6.4
Pouvoir de coupure en court-circuit au courant maximal de courte durée admissible	8.3.6.5
Vérification de la tenue diélectrique	8.3.6.6
Vérification des déclencheurs de surcharge	8.3.6.7

Les disjoncteurs à fusibles incorporés de catégorie de sélectivité B doivent satisfaire aux exigences de cette séquence.

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Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.6.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.6.3 Essai du courant assigné de courte durée admissible

Le paragraphe 8.3.4.3 de l'IEC 60947-1:2007 est applicable, avec le complément suivant:

Pour les besoins de cet essai seulement, tout déclencheur à maximum de courant, y compris la commande instantanée, s'il y a lieu, susceptible de fonctionner au cours de l'essai, doit être rendu inopérant.

8.3.6.4 Vérification de l'échauffement

Après l'essai de 8.3.6.3, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5. L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

Avec l'accord du fabricant, la vérification de l'échauffement peut être faite après la vérification de la tenue diélectrique (8.3.6.6). Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.7.3 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

8.3.6.5 Essai de pouvoir de coupure en court-circuit au courant maximal de courte durée admissible

Après l'essai de 8.3.6.4, un essai en court-circuit doit être effectué avec la séquence de manœuvres suivante:

O – *t* – CO

dans les conditions générales de 8.3.2, avec un courant présumé de valeur égale à celle de l'essai de tenue au courant de courte durée admissible (voir 8.3.6.3) et sous la tension la plus élevée applicable au courant assigné de courte durée admissible.

Le disjoncteur doit rester fermé pendant la courte durée associée à la durée maximale de réglage possible du déclencheur de court-circuit de courte durée, et la commande instantanée, le cas échéant, ne doit pas fonctionner. Si le disjoncteur a un déclencheur sous courant de fermeture (voir 2.10), cette exigence ne s'applique pas à la manœuvre CO si le courant présumé dépasse la valeur prédéterminée, puisqu'il va fonctionner; cette exception est également applicable à l'essai sur le quatrième pôle et le pôle adjacent, conformément à 8.3.2.6.4.3.

8.3.6.6 Vérification de la tenue diélectrique

Après l'essai selon 8.3.6.5, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

8.3.6.7 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.6.6, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

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8.3.7 Séquence d'essai V: Fonctionnement des disjoncteurs à fusibles incorporés

8.3.7.1 Généralités

Cette séquence d'essai s'applique aux disjoncteurs à fusibles incorporés. Elle remplace la séquence d'essai III et comprend les essais suivants:

	Essai	Paragraphe
Phase 1	Court-circuit au courant limite de sélectivité	8.3.7.2
	Vérification de l'échauffement	8.3.7.3
	Vérification de la tenue diélectrique	8.3.7.4
Phase 2	Vérification des déclencheurs de surcharge	8.3.7.5
	Court-circuit à 1,1 fois le courant d'intersection	8.3.7.6
	Court-circuit au pouvoir assigné de coupure ultime en court-circuit	8.3.7.7
	Vérification de la tenue diélectrique	8.3.7.8
	Vérification des déclencheurs de surcharge	8.3.7.9

Cette séquence d'essai est divisée en deux phases:

– La phase 1 comprend les essais de 8.3.7.2 à 8.3.7.4;
– La phase 2 comprend les essais de 8.3.7.5 à 8.3.7.9.

Ces deux phases peuvent être effectuées:

– sur deux disjoncteurs distincts, ou
– sur le même disjoncteur, avec des opérations d'entretien entre elles, ou
– sur le même disjoncteur, sans aucun entretien; auquel cas l'essai de 8.3.7.4 peut être omis.

L'essai selon 8.3.7.3 ne doit être effectué que si $I_{cs} > I_s$.

Les essais selon 8.3.7.2, 8.3.7.6 et 8.3.7.7 doivent être effectués à la tension maximale d'emploi du disjoncteur.

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.7.2 Court-circuit au courant limite de sélectivité

Un essai de court-circuit est effectué dans les conditions générales de 8.3.2, avec un courant présumé de valeur égale à celle du courant limite de sélectivité déclarée par le fabricant (voir 2.17.4).

Pour cet essai, les fusibles appropriés doivent être en place.

Cet essai doit consister en une manœuvre «O» à l'issue de laquelle les fusibles doivent demeurer intacts.

8.3.7.3 Vérification de l'échauffement

NOTE Cette vérification de l'échauffement est effectuée car les fusibles peuvent avoir fondu au cours de l'essai de court-circuit de la séquence d'essai II, 8.3.4.2, auquel cas l'essai de 8.3.7.2 est plus sévère.

Après l'essai selon 8.3.7.2, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.2.5.

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L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

8.3.7.4 Vérification de la tenue diélectrique

Après l'essai selon 8.3.7.3, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

8.3.7.5 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.7.6 Court-circuit à 1,1 fois le courant d'intersection

Après l'essai selon 8.3.7.5, un essai de court-circuit est effectué dans les mêmes conditions générales que celles de 8.3.7.2, avec un courant présumé de valeur égale à 1,1 fois celle du courant d'intersection déclarée par le fabricant (voir 2.17.5).

Pour cet essai, les fusibles appropriés doivent être en place.

Cet essai doit consister en une manœuvre «O», à l'issue de laquelle au moins deux des fusibles doivent avoir fondu.

8.3.7.7 Court-circuit au pouvoir assigné de coupure ultime en court-circuit

Après l'essai de 8.3.7.6, un essai de court-circuit est effectué dans les mêmes conditions générales que celles de 8.3.7.2, avec un courant présumé de valeur égale au pouvoir de coupure ultime en court-circuit I_{cu} déclaré par le fabricant.

Pour cet essai, un nouveau jeu de fusibles doit être mis en place.

La séquence de manœuvres doit être:

O – *t* – CO

un autre nouveau jeu de fusibles étant mis en place au cours de l'intervalle de temps *t*, qui peut être allongé pour cette raison.

8.3.7.8 Vérification de la tenue diélectrique

Après l'essai selon 8.3.7.7 et avec un nouveau jeu de fusibles adaptés, la tenue diélectrique doit être vérifiée selon 8.3.5.4.

8.3.7.9 Vérification des déclencheurs de surcharge

Après l'essai selon 8.3.7.8, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2, excepté que le courant d'essai doit être de valeur égale à 2,5 fois celle de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.8 Séquence d'essai VI: séquence d'essai combinée

8.3.8.1 Généralités

A la discrétion du fabricant ou en accord avec celui-ci, cette séquence d'essai peut s'appliquer aux disjoncteurs de catégorie de sélectivité B:

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a) lorsque le courant assigné de courte durée admissible et le pouvoir assigné de coupure de service en court-circuit ont la même valeur (I_{cw} = I_{cs}); dans ce cas, elle remplace les séquences d'essai II et IV;

b) lorsque le courant assigné de courte durée admissible, le pouvoir assigné de coupure de service en court-circuit et le pouvoir assigné de coupure ultime en court-circuit ont la même valeur (I_{cw} = I_{cs} = I_{cu}); dans ce cas, elle remplace les séquences d'essai II, III et IV.

Cette séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification des déclencheurs de surcharge	8.3.8.2
Courant assigné de courte durée admissible	8.3.8.3
Pouvoir assigné de coupure de service en court-circuit*	8.3.8.4
Vérification de l'aptitude au fonctionnement	8.3.8.5
Vérification de la tenue diélectrique	8.3.8.6
Vérification de l'échauffement	8.3.8.7
Vérification des déclencheurs de surcharge	8.3.8.8
* Pour les disjoncteurs répondant au cas de 8.3.8.1 b) ci-dessus, il s'agit également du pouvoir assigné de coupure ultime en court-circuit.	

Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10.

8.3.8.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.2.

8.3.8.3 Essai du courant assigné de courte durée admissible

Après l'essai selon 8.3.8.2, un essai doit être effectué au courant assigné de courte durée admissible conformément à 8.3.6.3.

Il n'est pas nécessaire d'effectuer cet essai sur l'échantillon de I_n minimum spécifié dans le Tableau 10.

8.3.8.4 Essai du pouvoir assigné de coupure de service en court-circuit

Après l'essai selon 8.3.8.3, un essai doit être effectué au pouvoir assigné de coupure de service en court-circuit, conformément à 8.3.4.2, à la tension la plus élevée applicable au courant assigné de court-circuit admissible. Le disjoncteur doit rester fermé pendant la courte durée correspondant à la durée maximale de réglage possible du déclencheur de court-circuit de courte durée.

Au cours de cet essai, la commande instantanée (le cas échéant) ne doit pas fonctionner et le déclencheur sous courant de fermeture (le cas échéant) doit fonctionner.

8.3.8.5 Vérification de l'aptitude au fonctionnement

Après l'essai selon 8.3.8.4, l'aptitude au fonctionnement doit être vérifiée selon 8.3.4.3.

8.3.8.6 Vérification de la tenue diélectrique

Après l'essai selon 8.3.8.5, la tenue diélectrique doit être vérifiée conformément à 8.3.3.6.

Pour les disjoncteurs aptes au sectionnement, le courant de fuite doit être mesuré selon 8.3.3.6.

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8.3.8.7 Vérification de l'échauffement

Après l'essai selon 8.3.8.6, l'échauffement aux bornes principales doit être vérifié conformément à 8.3.4.5.

L'échauffement ne doit pas dépasser la valeur indiquée au Tableau 7.

Cette vérification peut ne pas être faite lorsque, pour une taille donnée, l'essai de 8.3.8.4 a été effectué sur un disjoncteur avec un I_n minimal ou avec un réglage minimal du déclencheur de surcharge.

8.3.8.8 Vérification des déclencheurs de surcharge

Après refroidissement suivant l'essai de 8.3.8.7, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.3.8.

Le fonctionnement des déclencheurs de surcharge doit ensuite être vérifié sur chaque pôle individuellement selon 8.3.5.2, excepté que le courant d'essai doit être égal à 2,5 fois la valeur de leur courant de réglage.

Le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage à la température de référence pour un pôle seul.

8.3.9 Essai de courant continu critique de charge

Cet essai s'applique uniquement aux disjoncteurs ayant des valeurs assignées en courant continu.

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 8.3.2.1, et le circuit d'essai doit être conforme au 8.3.5.2 de l'IEC 60947-1:2007 excepté que l'écran métallique et l'élément fusible ne doivent pas être utilisés.

Les échantillons à soumettre à essai doivent être sélectionnés selon le Tableau 10 – séquence I, excepté que pour l'application de la note g, les différences de construction relatives aux appareils de déclenchement aux surintensités ne doivent pas être prises en compte.

L'essai doit être effectué à la tension continue maximale d'emploi (U_e max) assignée par le fabricant au disjoncteur.

Pour les disjoncteurs munis de déclencheurs réglables, l'essai doit être effectué avec les déclencheurs réglés à leur valeur maximale.

Le disjoncteur doit être fermé et ouvert 5 fois à chacun des courants d'essai énumérés ci-dessous. Si le sens de passage du courant est spécifié par le fabricant, l'essai doit être effectué en faisant passer le courant dans le sens spécifié, tel qu'indiqué par la polarité et le marquage amont/aval. Dans le cas contraire, cinq manœuvres doivent être effectuées dans le sens direct et cinq dans le sens inverse.

Au cours de chaque cycle de fermeture-ouverture, le disjoncteur doit rester fermé pendant une durée suffisante pour assurer l'établissement complet du courant, sans dépasser 2 s.

La constante de temps doit être conforme à la valeur indiquée dans le Tableau 11 comme pour le fonctionnement en service. A la discrétion du fabricant, une valeur plus élevée peut être utilisée, auquel cas cette valeur doit être indiquée dans le rapport d'essai.

Le nombre de cycles de manœuvres par heure doit être comme spécifié dans le Tableau 8.

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La durée d'arc pendant l'essai doit être consignée et ne doit pas dépasser 1 s.

Les valeurs du courant d'essai doivent être: 4 A, 8 A, 16 A, 32 A et 63 A en courant continu, avec une tolérance de ± 10 %, sans toutefois dépasser le courant assigné. La valeur critique est déterminée en considérant la durée d'arc moyenne maximale, pour chaque sens de passage du courant le cas échéant. Les valeurs les plus élevées et les plus basses du courant d'essai doivent présenter des durées d'arc moyennes plus courtes que pour la valeur critique. Si nécessaire, pour déterminer la valeur critique, la plage des courants d'essai doit être étendue à la hausse ou à la baisse en appliquant un rapport de 2 autant de fois que nécessaire, sans toutefois dépasser la valeur du courant assigné. Si aucune valeur critique du courant n'est trouvée dans les limites de ces critères, aucun autre essai conformément à ce paragraphe n'est nécessaire.

Les tolérances applicables aux grandeurs d'essai autres que celles du courant doivent être conformes à 8.3.2.2.2.

A l'issue de cet essai, le même échantillon doit faire l'objet d'une vérification de fonctionnement en service de 50 manœuvres, dans les mêmes conditions, au courant et dans le sens correspondant à la valeur critique. Après cet essai, la tenue diélectrique doit être vérifiée selon 8.3.3.6 avec une tension d'essai en courant continu.

8.4 Essais individuels de série

8.4.1 Généralités

Pour la définition des essais individuels de série, voir 2.6.2 et 8.1.3 de l'IEC 60947-1:2007.

Les essais suivants sont applicables:

– fonctionnement mécanique (8.4.2),
– vérification de l'étalonnage des déclencheurs de surintensité (8.4.3),
– vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (8.4.4),
– essais supplémentaires pour les DPR selon l'Annexe B (8.4.5),
– essais diélectriques (voir note) (8.4.6),
– vérification des distances d'isolement (8.4.7).

NOTE Si, par le contrôle des matériaux et des procédés de fabrication, l'intégrité des propriétés diélectriques a été prouvée, ces essais peuvent être remplacés par des essais sur prélèvement selon le plan d'échantillonnage reconnu (voir l'IEC 60410).[1]

Cependant, le fonctionnement du disjoncteur pendant la fabrication et/ou un autre essai individuel de série peut prendre la place des essais cités ci-dessus pourvu que les mêmes conditions soient applicables et que le nombre de manœuvres ne soit pas inférieur à celui spécifié.

Les essais de 8.4.3, 8.4.4 et 8.4.5 doivent être effectués avec les déclencheurs équipant le disjoncteur ou avec un matériel d'essai approprié simulant le comportement du disjoncteur.

Dans le contexte des essais de 8.4.2, 8.4.3, 8.4.4, 8.4.6 et 8.4.7, le terme «disjoncteurs» englobe les DPR, le cas échéant.

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[1] Cette publication a été supprimée.

8.4.2 Essais de fonctionnement mécanique

Les essais suivants doivent être effectués sans courant dans le circuit principal, sauf si cela est exigé pour le fonctionnement des déclencheurs. Pendant les essais, aucun réglage ne doit être effectué et le fonctionnement doit être satisfaisant.

Les essais suivants doivent être effectués sur les disjoncteurs manœuvrés manuellement:

– deux manœuvres de fermeture-ouverture,
– deux manœuvres à déclenchement libre.

NOTE Pour la définition d'un appareil mécanique de connexion à déclenchement libre, voir 2.4.23 de l'IEC 60947-1:2007.

Les essais suivants doivent être effectués sur les disjoncteurs alimentés à 110 % de la tension assignée maximale d'alimentation de commande et/ou de la pression d'alimentation assignée et à 85 % de la tension assignée minimale d'alimentation de commande et/ou de la pression d'alimentation assignée:

– deux manœuvres de fermeture-ouverture,
– deux manœuvres à déclenchement libre,
– pour les disjoncteurs à refermeture automatique, deux manœuvres de refermeture automatique.

8.4.3 Vérification de l'étalonnage des déclencheurs de surintensité

8.4.3.1 Déclencheurs à temps inverse

La vérification de l'étalonnage des déclencheurs à temps inverse doit être effectuée à un multiple du courant de réglage pour vérifier que le temps de déclenchement est conforme (avec des tolérances) à la courbe fournie par le fabricant.

Cette vérification peut être faite à toute température convenable, une correction devant être apportée pour toute différence de température par rapport à la température de référence (voir 4.7.3).

8.4.3.2 Déclencheurs instantanés et à retard indépendant

La vérification de l'étalonnage des déclencheurs instantanés et à retard indépendant doit permettre de s'assurer du non-fonctionnement et du fonctionnement des déclencheurs aux valeurs de courant données en 8.3.3.2.2 ou 8.3.3.2.3, point a), suivant le cas, aucun mesurage de la durée de coupure n'étant exigé.

Les essais peuvent être effectués en alimentant deux pôles en série avec le courant d'essai, en utilisant toutes les combinaisons possibles de pôles équipés de déclencheurs ou en alimentant avec le courant d'essai chaque pôle équipé individuellement d'un déclencheur.

Une méthode pour déterminer le niveau de déclenchement consiste à appliquer un courant d'essai augmentant lentement partant d'une valeur en dessous de la limite inférieure jusqu'à ce que le déclenchement du disjoncteur survienne. Le déclenchement doit se produire entre les limites inférieure et supérieure du courant d'essai.

8.4.4 Vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt

8.4.4.1 Déclencheurs à minimum de tension

Des essais doivent être effectués pour vérifier que le déclencheur fonctionne selon 7.2.1.3 de l'IEC 60947-1:2007 comme suit:

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a) Tension de maintien

Le déclencheur doit fermer à une tension correspondant à 85 % de la tension assignée minimale d'alimentation de commande.

b) Tension de retombée

Le déclencheur doit ouvrir lorsque la tension est réduite à une valeur comprise dans la plage correspondant à 70 % et 35 % de la tension assignée d'alimentation de commande, réglée afin de tenir compte de la nécessité de fonctionner dans les conditions spécifiées en 8.3.3.4.2.3 i). Dans le cas de déclencheurs ayant une plage de tensions assignées d'alimentation de commande, la limite supérieure doit correspondre au minimum de la plage et la limite inférieure au maximum de la plage.

8.4.4.2 Déclencheurs shunt (pour l'ouverture)

Un essai doit être effectué pour vérifier que le déclencheur fonctionne selon 7.2.1.4 de l'IEC 60947-1:2007/AMD2:2014. L'essai peut être effectué à toute température convenable pourvu que la tension d'essai soit réduite afin de tenir compte de la nécessité pour le déclencheur de fonctionner dans les conditions spécifiées en 8.3.3.4.2.4. Dans le cas d'un déclencheur ayant une plage de tensions assignées d'alimentation de commande, la tension d'essai doit correspondre à 70 % de la tension assignée minimale d'alimentation de commande.

8.4.5 Essais supplémentaires pour les DPR

Les essais supplémentaires suivants doivent être effectués sur les DPR ou les unités c.r.

a) Fonctionnement de l'appareil d'essai

Le DPR doit être soumis à deux manœuvres de fermeture-déclenchement ou, dans le cas d'unités c.r., à deux manœuvres de réarmement-déclenchement, avec un déclenchement par la manœuvre manuelle de l'appareil d'essai avec le DPR alimenté à la tension assignée la plus basse d'emploi.

b) Vérification de l'étalonnage de l'appareil de déclenchement par courant résiduel du DPR

En utilisant un courant résiduel sinusoïdal alternatif, il doit être vérifié que

– le DPR ne déclenche pas avec un courant résiduel égal à 0,5 fois $I_{\Delta n}$ dans chaque pôle séparément, au réglage minimal de $I_{\Delta n}$ s'il est réglable;

– le DPR déclenche avec un courant résiduel égal à $I_{\Delta n}$ dans chaque pôle séparément, au réglage minimal de $I_{\Delta n}$ s'il est réglable.

8.4.6 Essais diélectriques

Les conditions d'essai doivent être conformes à 8.3.3.4.1, point 1), de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, excepté que l'usage d'une feuille métallique n'est pas exigé. La tension d'essai doit être appliquée comme suit:

– le disjoncteur étant en position d'ouverture, entre chaque paire de bornes qui sont électriquement raccordées lorsque le disjoncteur est fermé;

– pour les disjoncteurs ne comprenant pas de circuits électroniques reliés aux pôles principaux, avec le disjoncteur en position de fermeture, entre chaque pôle et le ou les pôles adjacents et entre chaque pôle et le cadre, le cas échéant;

– pour les disjoncteurs comprenant des circuits électroniques reliés aux pôles principaux, avec le disjoncteur en position d'ouverture, entre chaque pôle et le ou les pôles adjacents et entre chaque pôle et le cadre, le cas échéant, soit sur le côté entrée, soit sur le côté sortie selon la position des composants électroniques.

En variante, la déconnexion des circuits électroniques reliés aux pôles principaux est permise, auquel cas la tension d'essai doit être appliquée avec le disjoncteur en position fermée, entre chaque pôle et le ou les pôles adjacents, et entre chaque pôle et le cadre, le cas échéant.

La méthode d'essai doit être celle de a), de b) ou de c) ci-dessous, au choix du fabricant:

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a) Deux essais doivent être effectués:

1) Tension de tenue aux chocs

La tension d'essai ne doit pas être inférieure à la plus grande des deux valeurs suivantes: 30 % de la tension assignée de tenue aux chocs (sans facteur de correction d'altitude) ou la valeur de crête correspondant à 2 U_i, et

2) Tension de tenue à fréquence industrielle

Le dispositif d'essai doit être le même que celui indiqué en 8.3.3.4.1, point 3) b), de l'IEC 60947-1:2007/AMD1:2010, excepté que la surintensité de déclenchement doit être réglée à 25 mA. Cependant, le fabricant peut, pour des raisons de sécurité, utiliser un dispositif d'essai de puissance inférieure ou de réglage de déclenchement plus bas mais le courant de court-circuit du dispositif d'essai doit être au moins égal à huit fois le réglage de déclenchement du relais de surintensité; par exemple, pour un transformateur avec un courant de court-circuit de 40 mA, le réglage de déclenchement maximal du relais de surintensité doit être 5 mA ± 1 mA.

La valeur efficace de la tension d'essai doit être 2 U_e max, avec un minimum de 1 000 V, appliquée pendant au moins 1 s. Le relais de surintensité ne doit pas déclencher.

b) Un seul essai à fréquence industrielle conformément au point a) 2) ci-dessus à une tension d'essai telle que la valeur de crête de l'onde sinusoïdale corresponde à la plus grande des valeurs de crête des valeurs suivantes: 30 % de U_{imp}, 2 U_i, 2 U_e max ou 1 000 V eff.

c) Un essai de résistance d'isolement à 500 V en courant continu. La résistance d'isolement ne doit pas être inférieure à 1 MΩ en tout point.

Si les propriétés diélectriques sont vérifiées conformément à un plan d'échantillonnage selon la note de 8.4.1, un essai de tenue à fréquence industrielle doit être effectué conformément à 8.4.6, point a) 2) de ce paragraphe, mais avec une tension d'essai selon le Tableau 12A de l'IEC 60947-1:2007/AMD2:2010. Les disjoncteurs ayant une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou 2 U_i selon la plus grande des deux valeurs.

8.4.7 Essai pour la vérification des distances d'isolement inférieures à celles correspondant au Tableau 13, cas A, de l'IEC 60947-1:2007

Le paragraphe 8.3.3.4.3 de l'IEC 60947-1:2007 est applicable excepté que, pour les besoins de la présente norme, cet essai doit être un essai individuel de série.

NOTE Le cas des distances d'isolement supérieures ou égales au cas A du Tableau 13 de l'IEC 60947-1:2007 est couvert par les essais de 8.4.6.

8.5 Essais spéciaux – Chaleur humide, brouillard salin, vibrations et chocs

Les essais spéciaux suivants doivent être réalisés soit à la discrétion du fabricant soit selon l'accord établi entre le fabricant et l'utilisateur (voir 2.6.4 de l'IEC 60947-1:2007). En tant qu'essais spéciaux, sauf indication spécifique, ces essais supplémentaires ne sont pas obligatoires et il n'est pas nécessaire pour un disjoncteur de satisfaire à l'un quelconque de ces essais pour être conforme à la présente norme.

L'Annexe Q de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 s'applique.

Au cours des séquences d'essai réalisées selon le Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, seule la vérification finale de l'aptitude au fonctionnement est exigée. Elle doit être effectuée en réalisant les essais individuels de série de 8.4 de la présente norme, à l'exception des essais diélectriques de 8.4.6, lesquels sont couverts par les essais du Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

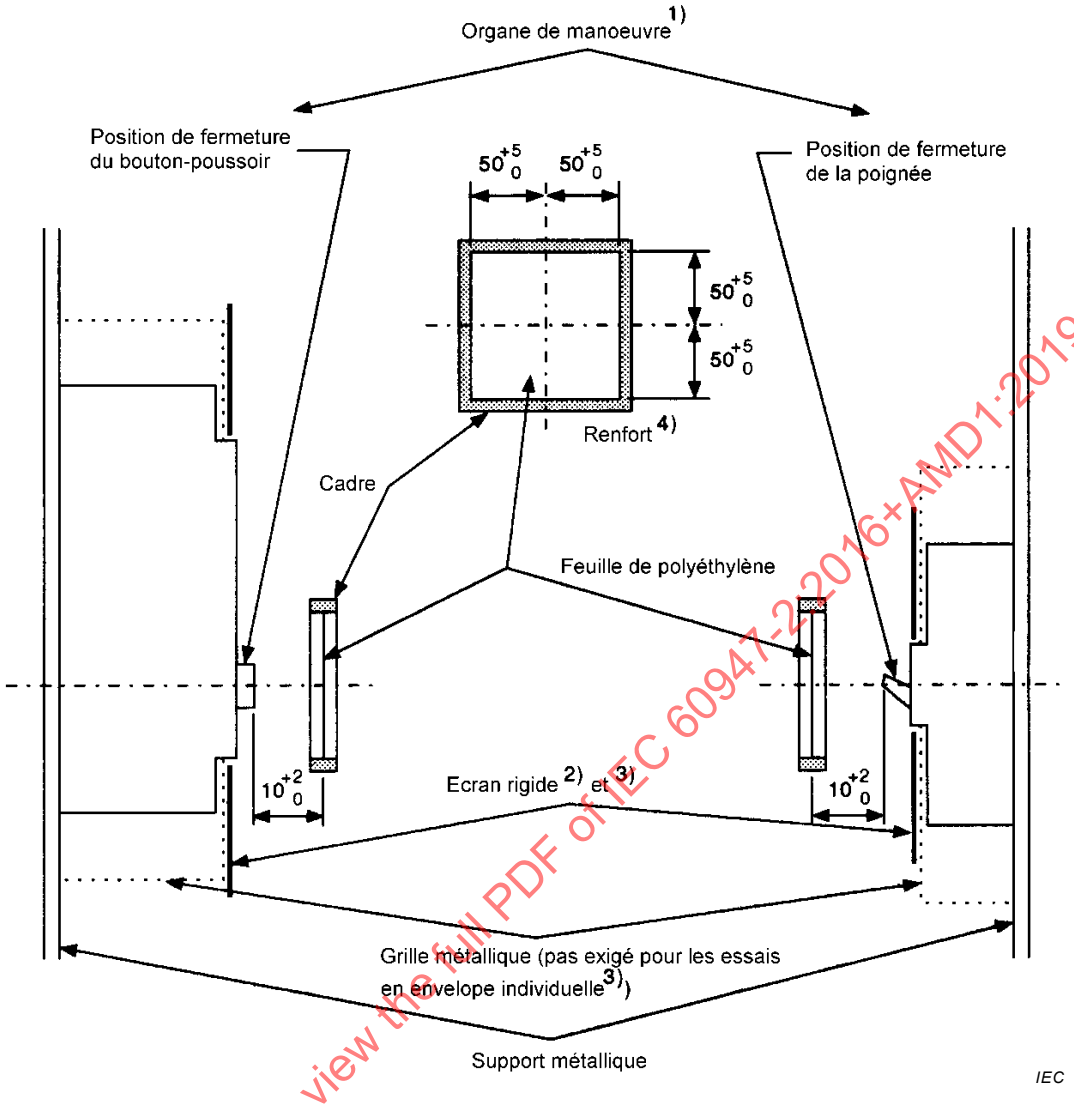
En référence à la note e) de bas de page du Tableau Q.1 de l'IEC 60947-1:2007 concernant l'essai de chaleur sèche, le disjoncteur ne doit pas être parcouru par le courant. Lorsqu'un

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déclencheur à minimum de tension est installé, il doit être alimenté sous sa tension assignée. Le disjoncteur doit être manœuvré selon le 8.4.2 pendant la dernière heure de l'essai.

En référence à la note g) de bas de page du Tableau Q.1 de l'IEC 60947-1:2007, pendant l'essai de chaleur humide, l'essai fonctionnel doit comprendre les manœuvres mécaniques du 8.4.2 de la présente norme. Lorsque seuls des organes de manœuvre manuels sont disponibles, cet essai peut être réalisé au cours du début de la période froide suivante.

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Cas d'un disjoncteur avec bouton-poussoir de fermeture — Cas d'un disjoncteur avec poignée de fermeture

Dimensions en millimètres

1) L'organe de manœuvre comprend toute extension normalement utilisée pour la manœuvre de fermeture.

2) L'écran rigide a pour but d'éviter que des projections issues de zones autres que celles de la poignée ou du bouton-poussoir n'atteignent la feuille de polyéthylène (cela n'est pas exigé pour les essais en enveloppe individuelle).

3) L'écran rigide et la façade de la grille (ou de l'écran) métallique peuvent être combinés en une seule plaque métallique conductrice.

4) Fait en matériau rigide convenable afin d'éviter le déchirement de la feuille de polyéthylène.

Figure 1 – Installation d'essai (câbles de raccordement non représentés) pour essais de court-circuit

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Annexe A
(normative)

Coordination entre un disjoncteur et un autre appareil de protection contre les courts-circuits associés dans le même circuit

A.1 Généralités

Pour assurer la coordination entre un disjoncteur (C_1) et un autre appareil de protection contre les courts-circuits (DPCC) associés dans le même circuit, il est nécessaire d'examiner les caractéristiques de chacun de ces deux appareils ainsi que leur comportement dynamique en tant qu'association.

NOTE Un DPCC peut comprendre des dispositifs de protection supplémentaires, par exemple des déclencheurs de surcharge.

Le DPCC peut être un fusible (ou un jeu de fusibles) – voir Figure A.1 – ou un autre disjoncteur (C_2) (voir Figure A.2 et Figure A.3).

La comparaison des caractéristiques individuelles de fonctionnement de chacun de ces deux appareils associés peut ne pas être suffisante lorsqu'il est nécessaire de faire référence au comportement de ces deux appareils fonctionnant en série, car leurs impédances ne sont pas toujours négligeables. Il convient de tenir compte de ce fait. Pour les courants de court-circuit, il est recommandé de faire référence à I^2t plutôt qu'au temps. Les modèles préférentiels pour la représentation des caractéristiques du courant coupé limité et de l'énergie limitée (I^2t) sont indiqués à l'Annexe K.

C_1 est fréquemment raccordé en série avec un autre DPCC, soit du fait de la méthode de distribution de puissance adoptée pour l'installation, soit parce que le pouvoir de coupure en court-circuit du disjoncteur C_1 seul peut être insuffisant pour l'emploi envisagé. Dans de tels cas, le DPCC peut être monté dans des emplacements éloignés de C_1. Le DPCC peut protéger une ligne d'alimentation comportant plusieurs disjoncteurs C_1 ou simplement un seul disjoncteur.

Dans de telles applications, l'utilisateur ou spécificateur peut avoir à décider, en se basant sur des études théoriques, comment le niveau optimal de coordination peut être réalisé. La présente annexe est destinée à donner des lignes directrices pour cette décision ainsi que pour le type d'information qu'il convient que le fabricant du disjoncteur mette à disposition.

Elle donne aussi des lignes directrices en ce qui concerne les exigences d'essai lorsque de tels essais sont jugés nécessaires à l'emploi envisagé.

Le terme «coordination» englobe à la fois l'examen de la sélectivité (voir 2.5.23 de l'IEC 60947-1:2007/AMD2:2014 ainsi que 2.17.2 et 2.17.3) et celui de la protection d'accompagnement (voir 2.5.24 de l'IEC 60947-1:2007).

L'examen de la sélectivité peut être effectué soit par des études théoriques, soit par un essai (voir A.5), alors que la vérification de la protection d'accompagnement nécessite normalement d'avoir recours à des essais (voir A.6).

Lors de l'étude du pouvoir de coupure en court-circuit, il peut être fait référence, soit au pouvoir assigné de coupure ultime en court-circuit (I_{cu}), soit au pouvoir assigné de coupure de service en court-circuit (I_{cs}), suivant le critère souhaité.

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A.2 Domaine d'application et objet

La présente annexe donne des lignes directrices et fournit les exigences pour la coordination des disjoncteurs avec d'autres DPCC associés dans le même circuit, aussi bien en ce qui concerne la sélectivité que la protection d'accompagnement.

La présente annexe a pour objet de spécifier:

– les exigences générales relatives à la coordination d'un disjoncteur avec un autre DPCC;
– les méthodes et les essais (s'ils sont jugés nécessaires) destinés à vérifier que les conditions de la coordination ont été remplies.

A.3 Exigences générales de coordination d'un disjoncteur avec un autre DPCC

A.3.1 Généralités

D'une manière idéale, il convient que la coordination soit telle qu'un disjoncteur (C_1) seul fonctionne pour toutes les valeurs de surintensité jusqu'à la limite de son pouvoir assigné de coupure en court-circuit I_{cu}.

NOTE 1 Si la valeur du courant présumé de défaut au point d'installation est inférieure au pouvoir assigné de coupure ultime en court-circuit de C_1, il peut être pris pour hypothèse que le DPCC n'est placé dans le circuit que pour des raisons autres que la protection d'accompagnement.

Dans la pratique, les considérations suivantes sont applicables:

a) si la valeur du courant limite de sélectivité I_s (voir 2.17.4) est trop basse, il y a risque de perte inutile de sélectivité.
b) si la valeur du courant présumé de défaut au point d'installation est supérieure au pouvoir assigné de coupure ultime en court-circuit de C_1, le DPCC doit être choisi de telle manière que le comportement de C_1 soit conforme à A.3.3 et que le courant d'intersection I_B (voir 2.17.5), le cas échéant, réponde aux exigences de A.3.2.

Chaque fois que possible, le DPCC doit être placé sur le côté source de C_1. Si le DPCC est placé sur le côté charge, il est essentiel que le raccordement entre C_1 et le DPCC soit réalisé de manière à réduire le plus possible tout risque de court-circuit.

NOTE 2 Dans le cas de déclencheurs interchangeables, ces conditions s'appliquent à chaque déclencheur concerné.

A.3.2 Courant d'intersection

Pour la protection d'accompagnement, le courant d'intersection I_B ne doit pas être supérieur au pouvoir assigné de coupure ultime en court-circuit I_{cu} de C_1 seul (voir Figure A.3a)).

A.3.3 Comportement de C_1 en association avec un autre DPCC

Pour toutes les valeurs de surintensité inférieures ou égales au pouvoir de coupure en court-circuit de l'association, C_1 doit répondre aux exigences de 7.2.5 de l'IEC 60947-1:2007 et l'association doit répondre aux exigences de 7.2.1.2.4, point a).

A.4 Type et caractéristiques du DPCC associé

Sur demande, le fabricant du disjoncteur doit donner des informations sur le type et les caractéristiques du DPCC à employer avec C_1 et sur le courant présumé de court-circuit maximal pour lequel l'association est valable sous la tension d'emploi déclarée.

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Les informations détaillées concernant le DPCC utilisé pour tout essai conforme à la présente annexe, c'est-à-dire nom du fabricant, désignation du type, tension assignée, courant assigné et pouvoir de coupure en court-circuit doivent figurer dans le rapport d'essai.

Le courant de court-circuit conditionnel maximal (voir 2.5.29 de l'IEC 60947-1:2007) ne doit pas être supérieur au pouvoir assigné de coupure ultime en court-circuit du DPCC.

Si le DPCC associé est un disjoncteur, il doit répondre aux exigences de la présente norme ou de toute autre norme applicable.

Si le DPCC associé est un fusible, il doit être conforme à la norme de fusibles appropriée.

A.5 Vérification de la sélectivité

A.5.1 Généralités

La sélectivité peut normalement être étudiée par le fabricant sur le seul plan théorique, c'est-à-dire en comparant les caractéristiques de fonctionnement de C_1 et du DPCC associé (voir A.5.2). La sélectivité peut également être déterminée par essais (voir A.5.3).

Dans certains cas, des essais sur l'association montrent qu'un niveau de I_s plus élevé que dans l'étude théorique est obtenu, par exemple:

– lorsque C_1 est du type limiteur et que C_2 n'a pas de retard intentionnel;
– lorsque le temps d'ouverture du DPCC est inférieur au temps correspondant à une demi-période.

Pour obtenir une sélectivité améliorée lorsque le DPCC associé est un disjoncteur, C_2 est parfois muni d'un retard de courte durée intentionnel.

La sélectivité peut être partielle (voir Figure A.3a)) ou totale jusqu'au pouvoir assigné de coupure ultime en court-circuit I_{cu} de C_1.

Deux exemples de sélectivité totale sont représentés à la Figure A.2a) et la Figure A.2b).

A.5.2 Examen de la sélectivité par étude théorique

A.5.2.1 Sélectivité dans la zone de surcharge

Deux cas sont considérés ci-après, selon que le DPCC est un disjoncteur ou un fusible

a) Disjoncteurs en série (C_1 et C_2) – détermination de la sélectivité par comparaison des caractéristiques

   La sélectivité dans la zone de surintensité retardée est vérifiée par comparaison des caractéristiques temps/courant. La séparation des caractéristiques selon l'axe du temps et l'axe du courant permet un fonctionnement sélectif de C_1 par rapport à C_2 dans cette zone. Une tolérance s'applique aux caractéristiques, et il convient d'en tenir compte. Il convient que les données du fabricant présentent une bande de tolérance ou indiquent autrement la tolérance applicable, comme l'exige la présente norme.

b) Disjoncteurs (C_1) avec fusible comme DPCC – détermination de la sélectivité par comparaison des caractéristiques

   La sélectivité dans la zone de surcharge est déterminée par comparaison des caractéristiques temps/courant. La séparation des caractéristiques selon l'axe du temps et l'axe du courant permet un fonctionnement sélectif de C_1 par rapport au fusible, dans cette zone. Une tolérance s'applique aux caractéristiques, et il convient d'en tenir compte. Il convient que les données du fabricant présentent une bande de tolérance, ou indiquent autrement la tolérance applicable, comme l'exigent les normes du produit.

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A.5.2.2 Détermination de la sélectivité dans la zone de courant de défaut (court-circuit)

La détermination de la sélectivité entre deux disjoncteurs dans la zone de courant de défaut (court-circuit) (voir Figure A.2a)) à partir des caractéristiques temps/courant est limitée au cas où C_2 est muni d'un déclencheur électronique avec fonction de déclenchement de court-circuit temporisée.

a) Disjoncteurs en série (C_1 et C_2) – détermination de la sélectivité par examen du courant coupé limité

Lorsque le déclenchement instantané de C_2 dépend d'un effet électromagnétique (c'est-à-dire disjoncteur magnétothermique ou disjoncteur magnétique seulement) ou dans le cas d'une unité de déclenchement électronique à déclencheur instantané, le niveau minimal de sélectivité entre deux disjoncteurs dans la zone de courant de défaut peut être déterminé comme suit:

La sélectivité est assurée jusqu'au niveau de courant de défaut pour lequel le courant coupé limité de C_1 est inférieur à la valeur de crête correspondant au réglage de courant de court-circuit instantané (I_i) de C_2, en tenant compte de la tolérance.

NOTE 1 Exemple de calcul de sélectivité

C_2 = disjoncteur 800 A; I_i = 8 kA eff – 12 kA eff (réglage 10 kA ± 20 %); C_1 = disjoncteur 125 A.

Le niveau de déclenchement minimal de C_2 est 8 × 1,414 = 11,3 kA de crête.

Le courant coupé limité de C_1 au courant présumé 15 kA eff, dû à la limitation de courant de C_1, est 11 kA de crête, sur la base des données d'essai.

Par conséquent, le système est sélectif jusqu'à au moins un courant présumé de 15 kA eff.

NOTE 2 La limite de sélectivité obtenue avec cette méthode est basse, et la limite réelle déterminée par essai est sensiblement plus élevée dans la plupart des cas.

b) Disjoncteurs (C_1) avec fusible comme DPCC

La sélectivité dans la zone de courant de défaut (court-circuit) (voir Figure A.1) est déterminée à partir des caractéristiques I^2t. Le courant limite de sélectivité I_s est la valeur maximale à laquelle la caractéristique limitée I^2t du disjoncteur est inférieure à la caractéristique de préarc I^2t du fusible. En l'absence de courbe réelle, la valeur de la caractéristique de préarc I^2t indiquée par le fabricant pour le fusible est prise en compte.

c) Fusible (C_1) avec disjoncteur comme DPCC

La sélectivité dans la zone de court-circuit de déclenchement instantané est déterminée à partir du courant coupé limité du fusible.

Le courant limite de sélectivité I_s est la valeur maximale à laquelle le courant coupé limité du fusible est inférieur à la valeur de crête correspondant au niveau de déclenchement instantané (I_i) du disjoncteur, en tenant compte de la tolérance.

A.5.2.3 Détermination du courant limite de sélectivité pour des conditions d'installation spécifiques

Les données relatives aux limites de sélectivité peuvent être fournies sous forme de tableaux, de graphiques ou sur support logiciel. Les données obtenues par étude théorique ou par des essais, conformément à la présente norme, sont basées sur le niveau de courant de défaut présumé au niveau de l'appareil amont (C_2) et prennent pour hypothèse que les appareils coordonnés sont proches l'un de l'autre. Dans la pratique, la limite de sélectivité est influencée par l'impédance entre les deux appareils. Par conséquent, en pratique, tenir compte du courant de défaut présumé au niveau du disjoncteur aval donne une valeur plus précise pour la limite de sélectivité.

A.5.3 Sélectivité déterminée par essai

Un exemple de schéma du circuit d'essai est donné à la Figure A.5, où:

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– C_1 peut être un disjoncteur conforme à la présente norme ou une autre norme IEC ou un fusible conforme à la norme IEC appropriée;

– les réglages de C_1 et C_2 sont fixés au réglage instantané maximal, le cas échéant.

Les essais avec d'autres réglages des déclencheurs peuvent être réalisés à la discrétion du fabricant, auquel cas les réglages des déclencheurs doivent être consignés dans le rapport d'essai.

Les câbles de raccordement doivent être inclus, comme spécifié en 8.3.2.6.4, hormis le fait que la longueur totale des câbles peut être répartie entre le côté source et le côté charge de C_1 et C_2 selon ce qui convient.

Chaque essai doit consister en une manœuvre O – *t* – CO, la manœuvre CO étant réalisée en fermant l'appareil aval C_1. Si l'appareil aval est un fusible, la manœuvre doit être réalisée en fermant C_2.

L'essai est effectué au niveau de courant présumé pour lequel l'association de C_1 et C_2 est déclarée sélective par le fabricant.

Résultats à obtenir:

– Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 s'applique;

– Pendant chaque manœuvre, C_1 doit fonctionner et C_2 ne doit pas déclencher. Si les contacts de C_2 se séparent momentanément durant les manœuvres, le temps entre le début du court-circuit et la fin de la séparation des contacts de C_2 doit être inférieur ou égal à 30 ms. La valeur réelle doit être indiquée dans le rapport d'essai.

– De plus, il doit être vérifié que les contacts de C_2 peuvent être ouverts au moyen des organes de manœuvre normaux.

A.6 Vérification de la protection d'accompagnement

A.6.1 Détermination du courant d'intersection

La conformité aux exigences de A.3.2 peut être vérifiée en comparant les caractéristiques de fonctionnement de C_1 et celles du DPCC associé pour tous les réglages de C_1 et, le cas échéant, pour tous les réglages de C_2.

A.6.2 Vérification de la protection d'accompagnement

La protection d'accompagnement peut être vérifiée par des essais ou par la comparaison des caractéristiques.

a) Vérification par des essais

La conformité aux exigences de A.3.3 se vérifie normalement par des essais conformément à A.6.3. Dans ce cas, toutes les conditions d'essai doivent être comme spécifié en 8.3.2.6, les résistances et bobines d'inductance réglables pour les essais de court-circuit étant placées du côté source de l'association.

b) Vérification par comparaison des caractéristiques

Dans quelques cas pratiques et lorsque le DPCC est un disjoncteur (voir Figure A.3a) et Figure A.3b)), il peut être suffisant que le fabricant compare les caractéristiques de fonctionnement de C_1 et du DPCC associé, en portant une attention particulière aux points suivants:

– valeurs de l'intégrale de Joule de C_1 à son I_{cu} et du DPCC au courant présumé de l'association,

– influence sur C_1 (par exemple de l'énergie d'arc, du courant de crête maximal, du courant coupé limité) à la valeur de crête du courant de fonctionnement du DPCC.

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La validité de l'association peut être évaluée en examinant la caractéristique I^2t de fonctionnement totale maximale du DPCC sur la plage allant du pouvoir assigné de coupure en court-circuit I_{cu} de C_1 au courant de court-circuit présumé de l'emploi envisagé, mais ne dépassant pas la valeur maximale de la caractéristique limitée I^2t de C_1 à son pouvoir assigné de coupure en court-circuit ou une autre valeur limite plus basse précisée par le fabricant.

NOTE Lorsque le DPCC associé est un fusible, l'étude théorique n'est valable que jusqu'à I_{cu} de C_1.

A.6.3 Essais de vérification de la protection d'accompagnement

Si C_1 est équipé de déclencheurs d'ouverture réglables à maximum de courant, les caractéristiques de fonctionnement doivent être celles correspondant à la durée et au courant de réglage minimaux.

Si C_1 peut être équipé de déclencheurs instantanés d'ouverture à maximum de courant, les caractéristiques de fonctionnement à utiliser doivent être celles correspondant à C_1 équipé de tels déclencheurs.

Si le DPCC associé est un disjoncteur (C_2) équipé de déclencheurs d'ouverture réglables à maximum de courant, les caractéristiques de fonctionnement à utiliser doivent être celles correspondant à la durée et au courant de réglage maximaux.

Lorsque le DPCC associé est un jeu de fusibles, chaque essai doit être effectué en utilisant un nouveau jeu de fusibles, même si certains fusibles utilisés pendant un essai précédent n'ont pas fondu.

S'il y a lieu, les câbles de raccordement doivent être inclus comme spécifié en 8.3.2.6.4, excepté que si le DPCC associé est un disjoncteur (C_2), la longueur totale (75 cm) du câble associé à ce disjoncteur peut être située côté source (voir Figure A.4).

Chaque essai doit consister en une séquence de manœuvres O – t – CO effectuée conformément à 8.3.5, la manœuvre CO étant effectuée sur C1.

Un essai est effectué au courant présumé maximal pour l'emploi proposé. Ce courant ne doit pas être supérieur au courant assigné de court-circuit conditionnel (voir 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014).

Un essai supplémentaire doit être effectué à une valeur de courant présumé égale au pouvoir assigné de coupure en court-circuit I_{cu} (ou I_{cs}) de C_1; pour cet essai, un nouvel échantillon de C_1 peut être utilisé et, si le DPCC associé est un disjoncteur, un nouvel échantillon de C_2 peut aussi être utilisé.

Au cours de chaque manœuvre:

a) si le DPCC associé est un disjoncteur (C_2):

- soit C_1 et C_2 doivent déclencher aux deux courants d'essai, aucun autre essai n'étant alors exigé.

  C'est le cas général qui n'assure que la protection d'accompagnement.

- soit C_1 doit déclencher et C_2 doit être en position fermée à la fin de chaque manœuvre aux deux courants d'essai, aucun essai complémentaire n'étant alors exigé.

  Les contacts de C_2 sont autorisés à se séparer momentanément au cours de chaque manœuvre. Dans ce cas, le rétablissement de l'alimentation est assuré en plus de la protection d'accompagnement (voir Note 1 de la Figure A.3a)). La durée de séparation des contacts de C_2, le cas échéant, doit être enregistrée au cours de ces essais.

- soit C_1 doit déclencher au courant d'essai le plus faible, et C_1 et C_2 doivent déclencher tous deux au courant d'essai le plus élevé.

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Les contacts de C_2 sont autorisés à se séparer momentanément au courant d'essai le plus faible. Des essais supplémentaires doivent être effectués à des valeurs de courants intermédiaires pour déterminer la valeur la plus faible du courant à laquelle C_1 et C_2 déclenchent tous les deux et jusqu'à laquelle le rétablissement de l'alimentation est assuré. La durée de séparation des contacts de C_2, le cas échéant, doit être enregistrée au cours de ces essais.

b) lorsque le DPCC associé est un fusible (ou un jeu de fusibles):

- dans le cas d'un circuit monophasé, un fusible au moins doit fondre;
- dans le cas d'un circuit à plusieurs phases, au moins deux fusibles doivent fondre ou bien un fusible doit fondre et C_1 doit déclencher.

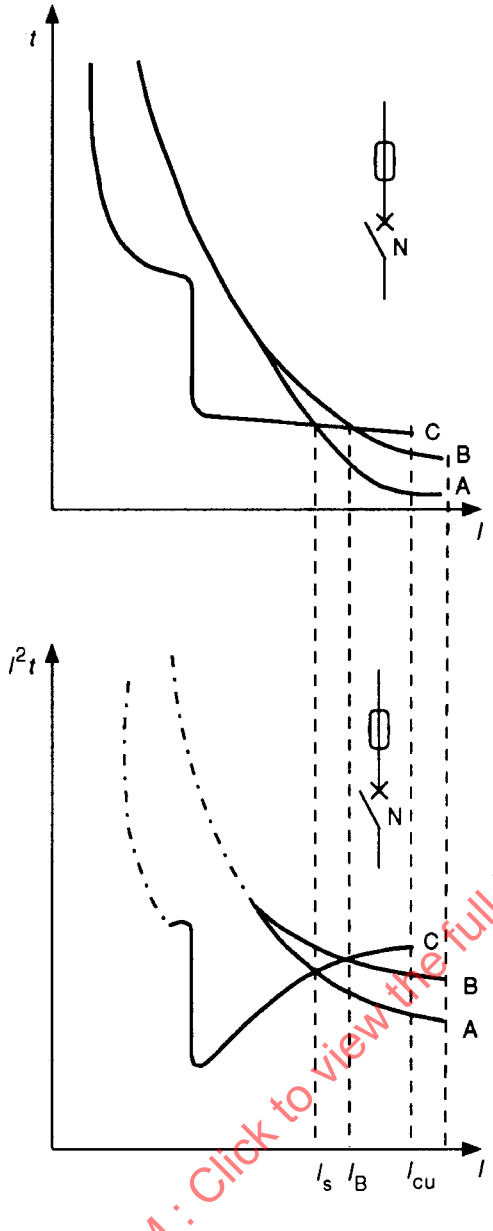
A.6.4 Résultats à obtenir

Le paragraphe 8.3.4.1.7 de l'IEC 60947-1:2007 et le paragraphe 8.3.2.6.7 premier alinéa de la présente norme sont applicables, avec le complément suivant:

Après les essais, si C_1 est un disjoncteur, il doit se conformer aux 8.3.5.4 et 8.3.5.5; si C_1 est un fusible, il doit se conformer aux exigences applicables de l'IEC 60269-1.

De plus, si le DPCC associé est un disjoncteur (C_2), il doit être vérifié par une manœuvre manuelle ou tout autre moyen approprié que les contacts de C_2 ne sont pas soudés.

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I = Courant de court-circuit présumé

I_{cu} = Pouvoir assigné de coupure ultime en court-circuit

(4.3.6.2.2)

I_s = Courant limite de sélectivité (2.17.4)

I_B = Courant d'intersection (2.17.5)

A = Caractéristique de préarc du fusible

B = Caractéristique de fonctionnement du fusible

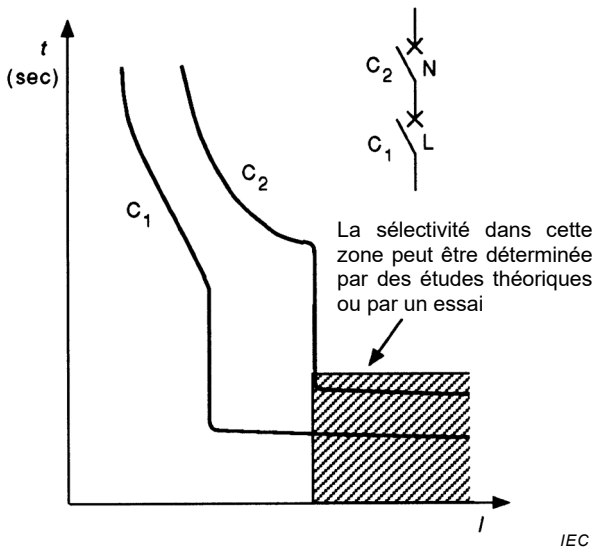
C = Caractéristique de fonctionnement du disjoncteur, non-limiteur de courant (N) (durée de coupure/courant et I^2t /courant)

NOTE 1 A est estimé être la limite inférieure; B et C sont estimés être les limites supérieures.

NOTE 2 Zone non adiabatique pour I^2t repérée en ligne discontinue.

Figure A.1 – Coordination pour la surintensité entre un disjoncteur et un fusible ou protection d'accompagnement par un fusible: caractéristiques de fonctionnement

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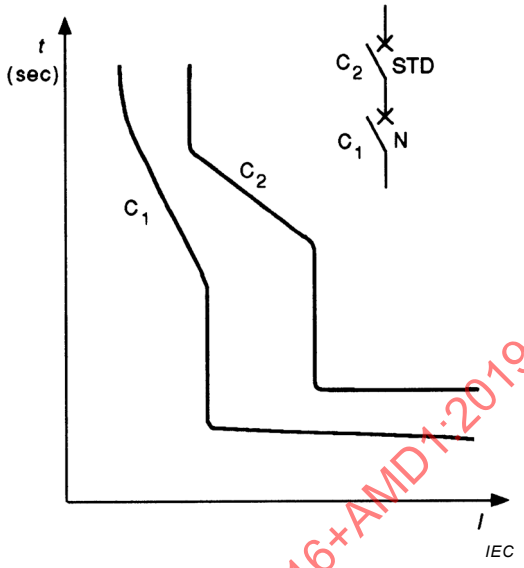


C_1 = Disjoncteur à limitation de courant (L) (caractéristique de durée de coupure)

C_2 = Disjoncteur limiteur de courant ou non-limiteur de courant (N) (caractéristique de déclenchement)

Les valeurs de I_{cu} ne sont pas indiquées.

Figure A.2a) – Disjoncteur aval limiteur de courant



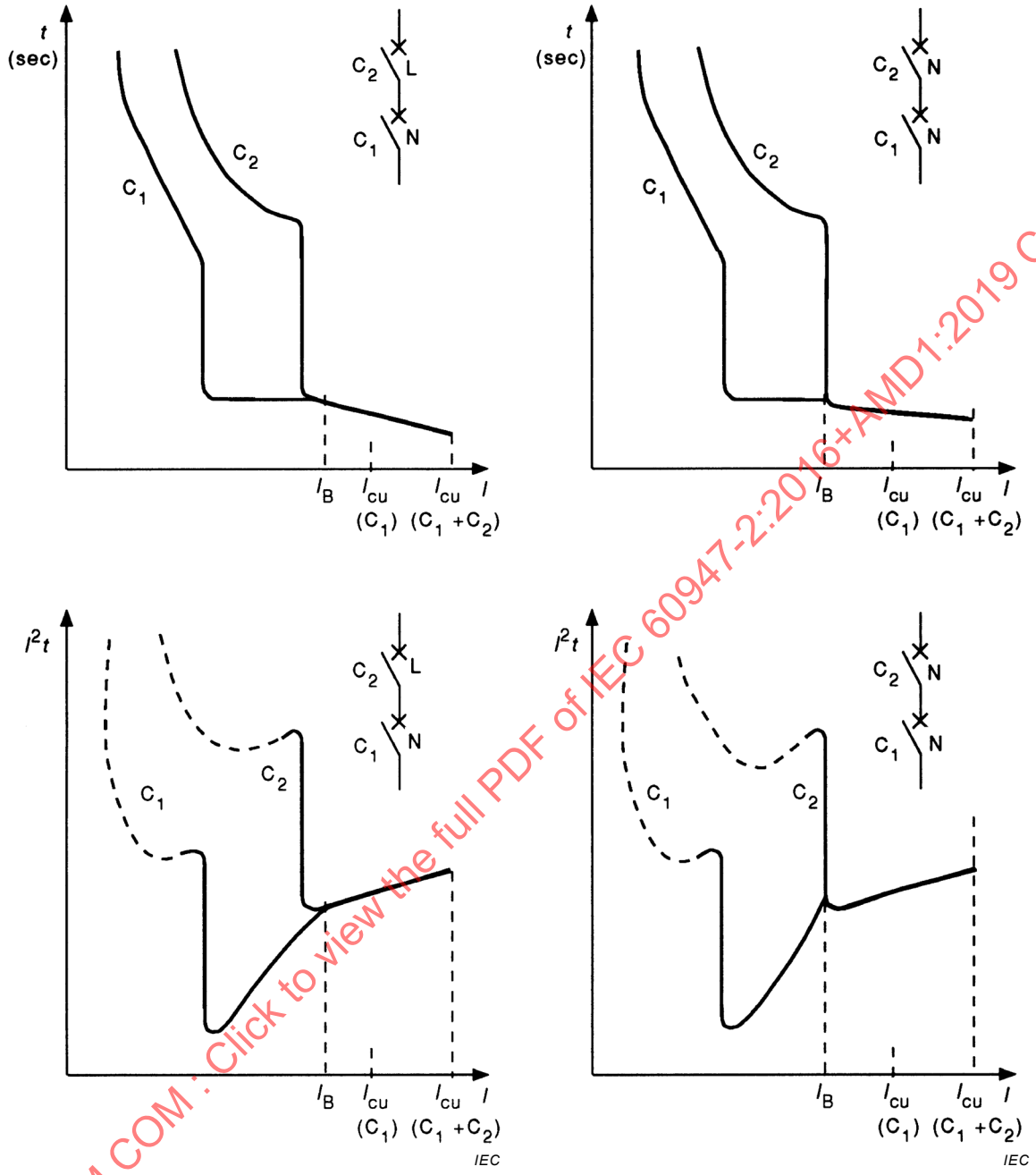
C_1 = Disjoncteur non-limiteur de courant (N) (caractéristique de durée de coupure)

C_2 = Disjoncteur avec retard intentionnel de courte durée (STD) (caractéristique de déclenchement)

Figure A.2b) – Disjoncteur aval non-limiteur de courant

Figure A.2 – Sélectivité totale entre deux disjoncteurs

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C_1 = Disjoncteur non-limiteur de courant (N)

C_2 = Disjoncteur limiteur de courant (L)

Figure A.3a) – Disjoncteur amont limiteur de courant

C_1, C_2 = Disjoncteur non-limiteur de courant (N)

Figure A.3b) – Disjoncteur amont non-limiteur de courant

I_B = Courant d'intersection

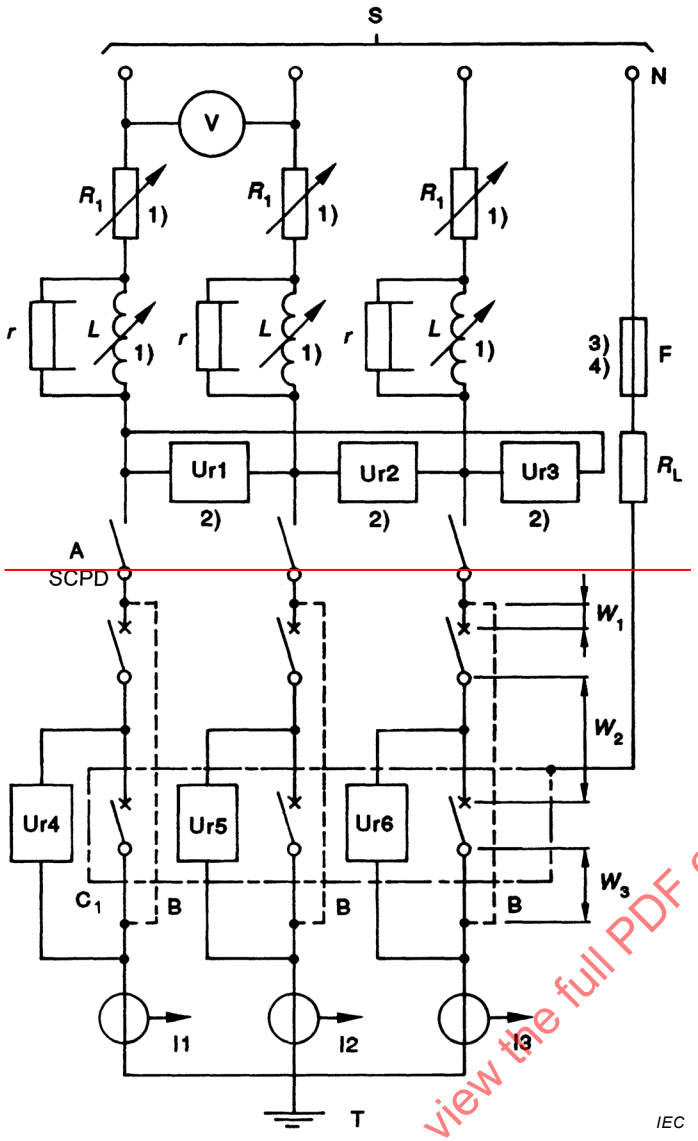
NOTE 1 Le cas échéant, le rétablissement de l'alimentation a lieu par C_2.

NOTE 2 I_{cu} $(C_1 + C_2) \leq I_{cu}$ (C_2)

NOTE 3 Pour les valeurs de $I > I_B$, la courbe est celle de l'association (montrée en gras), pour laquelle les données sont obtenues par des essais.

Figure A.3 – Protection d'accompagnement par un disjoncteur – Caractéristiques de fonctionnement

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S = Alimentation

Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 = Capteurs de tension

V = Appareil de mesure de tension

A = Appareil de fermeture

R_1 = Résistance réglable

N = Neutre de la source (ou neutre artificiel)

F = Elément fusible (8.3.4.1.2, point d) de l'IEC 60947-1:2007)

L = Bobines d'inductance réglables

R_L = Résistance de limitation du courant de défaut

B = Connexions provisoires d'étalonnage

I1, I2, I3 = Appareils d'enregistrement des courants

T = Terre; un seul point de terre (côté charge ou côté source)

r = Résistance shunt (8.3.4.1.2, point b) de l'IEC 60947-1:2007)

W_1 = 75 cm de câble de courant assigné pour le DPCC

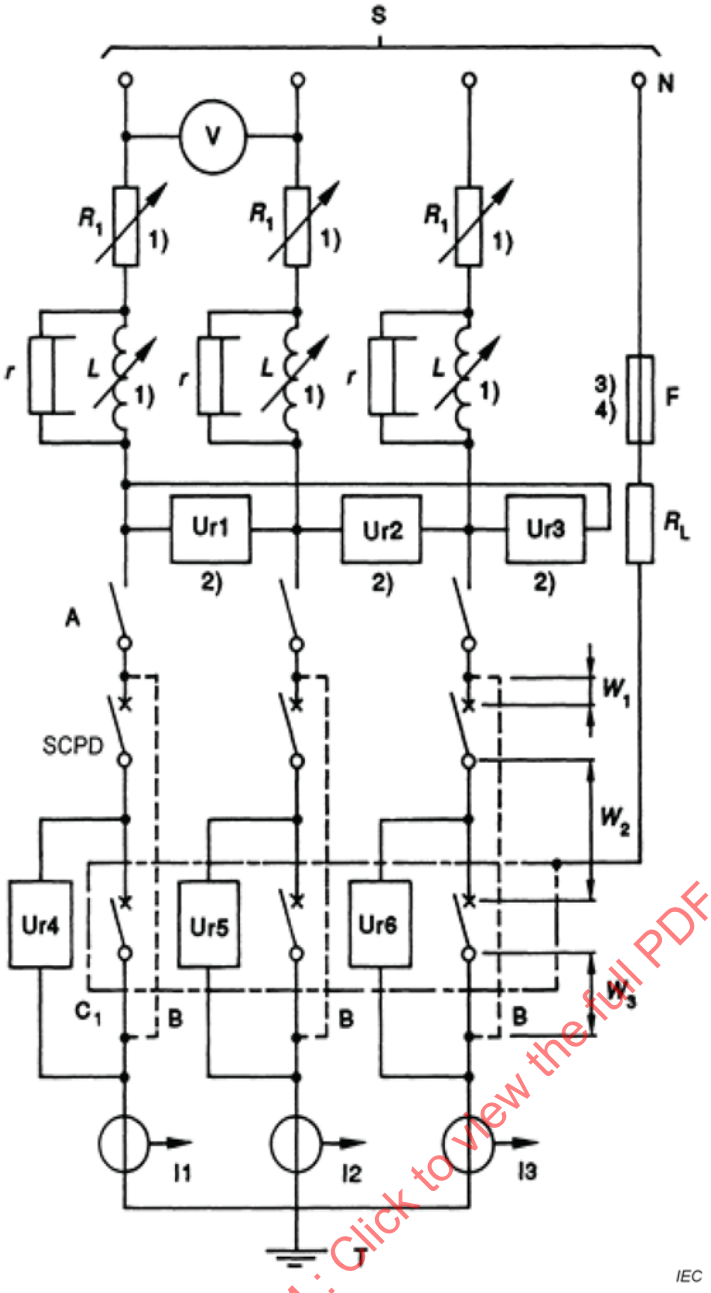
W_2 = 50 cm de câble de courant assigné pour C_1

W_3 = 25 cm de câble de courant assigné pour C_1

SCPD = Disjoncteur C_2 ou jeu de 3 fusibles

C_1 = Disjoncteur en essai

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S = Alimentation
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 = Capteurs de tension
V = Appareil de mesure de tension
A = Appareil de fermeture
R_1 = Résistance réglable
N = Neutre de la source (ou neutre artificiel)
F = Elément fusible (8.3.4.1.2, point d) de l'IEC 60947-1:2007)
L = Bobines d'inductance réglables
R_L = Résistance de limitation du courant de défaut
B = Connexions provisoires d'étalonnage
I1, I2, I3 = Appareils d'enregistrement des courants
T = Terre; un seul point de terre (côté charge ou côté source)
r = Résistance shunt (8.3.4.1.2, point b) de l'IEC 60947-1:2007)
W_1 = 75 cm de câble de courant assigné pour le DPCC
W_2 = 50 cm de câble de courant assigné pour C_1
W_3 = 25 cm de câble de courant assigné pour C_1
SCPD = Disjoncteur C_2 ou jeu de 3 fusibles
C_1 = Disjoncteur en essai

~~Les charges réglables L et R_1 peuvent être disposées, soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation, l'appareil d'enclenchement A étant disposé dans la partie basse tension.~~

Les charges réglables L et R_1 peuvent être disposées soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation.

Ur1, Ur2, Ur3 peuvent, en variante, être raccordés entre phase et neutre.

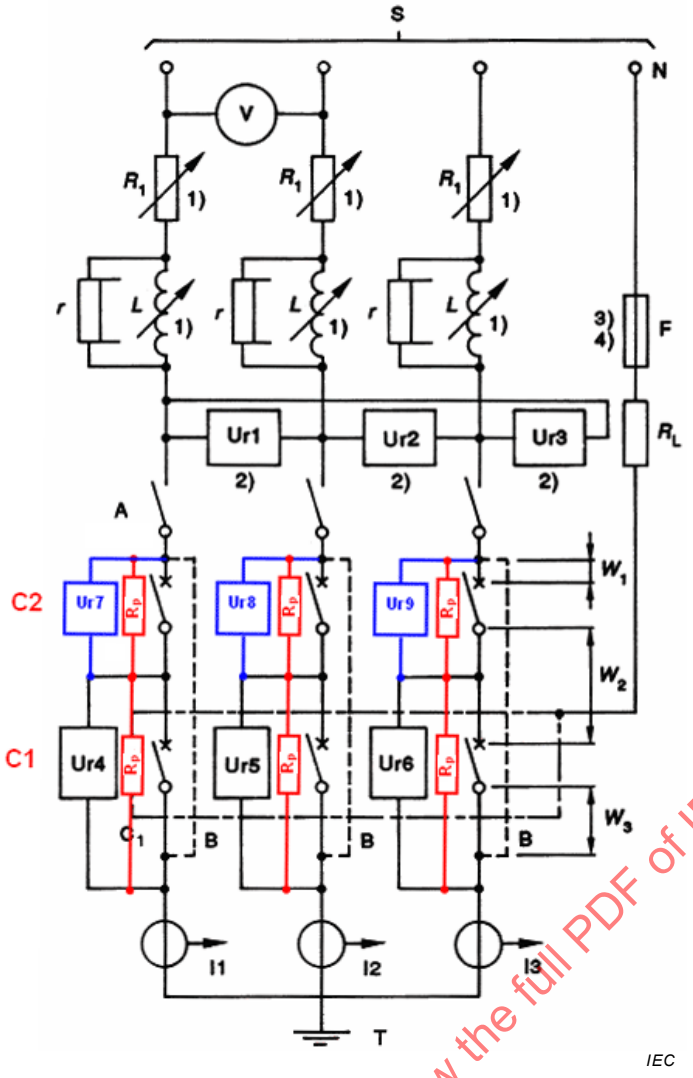
Dans le cas d'appareils destinés à être employés dans un réseau dont une phase est reliée à la terre, F doit être raccordé à une phase de l'alimentation.

Aux Etats-Unis et au Canada (voir notes du 4.3.2.1), F doit être relié:

– à une phase de l'alimentation pour les matériels marqués d'une seule valeur de U_e,
– au neutre pour les matériels marqués d'une double valeur de U_e.

Figure A.4 – Exemple de circuit d'essai pour les essais de pouvoir de coupure en court-circuit conditionnel montrant les connexions d'un disjoncteur triphasé (C_1)

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S	=	Alimentation
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 Ur7, Ur8, Ur9	=	Capteurs de tension
V	=	Appareil de mesure de tension
A	=	Appareil de fermeture
R_1	=	Résistance réglable
N	=	Neutre de la source (ou neutre artificiel)
F	=	Elément fusible (8.3.4.1.2, point d) de l'IEC 60947-1:2007)
L	=	Bobines d'inductance réglables
R_L	=	Résistance de limitation du courant de défaut
R_p	=	Résistance de polarisation facultative
B	=	Connexions provisoires d'étalonnage
I1, I2, I3	=	Appareils d'enregistrement des courants
T	=	Terre:– un seul point de terre (côté charge ou côté source)
r	=	Résistance shunt (8.3.4.1.2, point b) de l'IEC 60947-1:2007)
W_1	=	75 cm de câble de courant assigné pour C_2
$W_2 + W_3$	=	75 cm de câble de courant assigné pour C_1 (voir A.5.2)
C_1, C_2	=	Disjoncteurs en essai

~~Les charges réglables L et R_1 peuvent être disposées, soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation, l'appareil d'enclenchement A étant disposé dans la partie basse tension.~~

Les charges réglables L et R_1 peuvent être disposées soit dans la partie haute tension, soit dans la partie basse tension du circuit d'alimentation.

Ur1, Ur2, Ur3 peuvent, en variante, être raccordés entre phase et neutre.

Dans le cas d'appareils destinés à être employés dans un réseau dont une phase est reliée à la terre, F doit être raccordé à une phase de l'alimentation.

NOTE 1 Aux Etats-Unis et au Canada (voir notes du 4.3.2.1), F doit être relié:

– à une phase de l'alimentation pour les matériels marqués d'une seule valeur de U_e,

– au neutre pour les matériels marqués d'une double valeur de U_e.

NOTE 2 Les résistances de polarisation permettent de déterminer la durée d'ouverture des contacts pour les deux appareils en série, la valeur étant suffisamment élevée pour ne pas influencer les appareils en essai.

Figure A.5 – Exemple de circuit d'essai pour la vérification de la sélectivité

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Annexe B
(normative)

Disjoncteurs à protection incorporée par courant différentiel résiduel

B.1 Généralités

B.1.1 Préambule

Pour assurer la protection contre les dangers occasionnés par les chocs électriques, des appareils agissant sous l'effet des courants différentiels résiduels sont utilisés comme mesure de protection. Ces appareils sont fréquemment utilisés en conjonction avec un disjoncteur ou comme partie intégrante de celui-ci pour répondre à un double objectif, c'est-à-dire:

– assurer la protection des installations contre les surcharges et contre les courants de court-circuit,

– assurer la protection des personnes contre les contacts indirects, c'est-à-dire les augmentations dangereuses du potentiel à la terre dues à une isolation défectueuse.

Les appareils à courant différentiel résiduel peuvent assurer également une protection supplémentaire contre les dangers d'incendie ou autres dangers qui peuvent se développer à la suite d'un défaut à la terre de nature persistante ne pouvant pas être détecté par l'appareil de protection contre les surintensités.

Les appareils à courant différentiel résiduel dont le courant différentiel résiduel assigné ne dépasse pas 30 mA sont également utilisés comme moyens de protection supplémentaires contre les contacts directs en cas de défaillance des dispositifs de protection prévus.

Les exigences pour l'installation de tels appareils sont spécifiées dans les différentes sections de la série IEC 60364.

La présente annexe est fondée principalement sur les exigences correspondantes des IEC 60755, IEC 61008-1 et IEC 61009-1.

B.1.2 Domaine d'application et objet

La présente annexe est applicable aux disjoncteurs assurant la protection par courant différentiel résiduel (DPR). Elle contient les exigences pour les appareils qui assurent à la fois la détection des courants différentiels résiduels, comparent ces mesurages à une valeur réglée au préalable et provoquent la coupure du circuit protégé lorsque cette valeur est dépassée.

La présente annexe est applicable:

– aux disjoncteurs conformes à la présente norme et dont la fonction de courant différentiel résiduel constitue une partie intégrée (désignés ci-après DPR intégrés);

– aux DPR combinant un appareil à courant différentiel résiduel (désignés ci-après unités c.r.) et un disjoncteur conforme à la présente norme; ils peuvent être combinés, mécaniquement et électriquement, soit en usine, soit sur le site par l'utilisateur, suivant les instructions du fabricant.

Cette annexe couvre également les exigences pour les DPR concernant la compatibilité électromagnétique (CEM).

NOTE Les moyens de détection du courant du neutre peuvent, le cas échéant, être extérieurs au disjoncteur ou à la combinaison suivant le cas.

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La présente annexe n'est applicable qu'aux DPR destinés à être utilisés dans des circuits à courant alternatif.

La fonction «courant différentiel résiduel» des DPR visés par la présente annexe peut ou non dépendre fonctionnellement de la tension d'alimentation. Les DPR dépendant d'une autre source d'alimentation ne sont pas visés par cette annexe.

Cette annexe n'est pas applicable aux matériels dont les dispositifs de détection du courant (à l'exception des dispositifs de détection du courant du neutre) ou l'appareil de traitement sont montés séparément du disjoncteur.

Les exigences pour de tels appareils sont données à l'Annexe M.

La présente annexe a pour objet de spécifier:

a) les caractéristiques spécifiques de la fonction de courant différentiel résiduel;

b) les exigences spécifiques auxquelles doivent répondre les DPR

- dans les conditions normales du circuit;
- dans les conditions anormales du circuit, qu'elles se rapportent ou non au courant différentiel résiduel;

c) les essais qui doivent être effectués pour vérifier la conformité aux exigences du point b) ci-dessus, ainsi que les modes opératoires d'essai appropriés;

d) les informations correspondantes sur le matériel.

B.2 Termes et définitions

En complément de l'Article 2 de la présente norme, les définitions suivantes s'appliquent:

B.2.1 Termes et définitions relatifs aux courants circulant entre les parties actives et la terre

B.2.1.1
courant de défaut à la terre
courant qui s'écoule à la terre lors d'un défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
courant de fuite à la terre
courant qui s'écoule des parties actives de l'installation à la terre, en l'absence de tout défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Termes et définitions relatives à l'alimentation d'un DPR

B.2.2.1
grandeur d'alimentation
grandeur électrique qui, seule ou en combinaison avec d'autres grandeurs électriques, doit être appliquée à un DPR pour qu'il puisse fonctionner dans des conditions spécifiées

B.2.2.2
grandeur d'alimentation d'entrée
grandeur d'alimentation par laquelle le DPR est mis en action, lorsqu'elle est appliquée dans des conditions spécifiées

Note 1 à l'article: Ces conditions peuvent prévoir, par exemple, l'alimentation de certains organes auxiliaires.

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[SOURCE: IEC 60050-442:1998, 442-05-58, modifiée – adapté aux DPR]

B.2.2.3
courant différentiel résiduel
I_A
somme vectorielle des courants qui circulent dans le circuit principal du DPR, exprimée en valeur efficace

[SOURCE: IEC 60050-442:1998, 442-05-19, modifiée – adapté aux DPR]

B.2.2.4
courant différentiel résiduel de fonctionnement
I_{An}
valeur du courant différentiel résiduel qui fait fonctionner le DPR dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-20, modifiée – adapté aux DPR]

B.2.2.5
courant différentiel résiduel de non-fonctionnement
I_{Ano}
valeur du courant différentiel résiduel pour laquelle (et au-dessous de laquelle) le DPR ne fonctionne pas dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-21, modifiée – symbole introduit et adapté aux DPR]

B.2.3 Termes et définitions relatifs au fonctionnement et aux fonctions des DPR

B.2.3.1
disjoncteur à protection par courant différentiel résiduel incorporée
DPR
disjoncteur (voir 2.1) conçu pour provoquer l'ouverture des contacts lorsque le courant différentiel résiduel atteint une valeur donnée dans des conditions spécifiées

B.2.3.2
DPR fonctionnellement indépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et d'évaluation et le moyen de déclenchement (voir B.2.3.6) ne dépendent pas de la tension d'alimentation

B.2.3.3
DPR fonctionnellement dépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et/ou d'évaluation et/ou le moyen de déclenchement (voir B.2.3.6) dépendent de la tension d'alimentation

Note 1 à l'article: Il est entendu que la tension d'alimentation pour la détection, l'évaluation ou l'interruption est celle appliquée au DPR.

B.2.3.4
détection (d'un courant différentiel résiduel)
fonction consistant à détecter la présence d'un courant différentiel résiduel

Note 1 à l'article: Cette fonction peut être remplie, par exemple, par un transformateur intégrant la somme vectorielle des courants.

[SOURCE: IEC 60050-442:1998, 442-05-24]

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B.2.3.5
évaluation
fonction consistant à donner au DPR la possibilité de fonctionner quand le courant différentiel résiduel détecté dépasse une valeur de référence spécifiée

[SOURCE: IEC 60050-442:1998, 442-05-25, modifiée – sans «(d'un courant différentiel résiduel)» et adapté aux DPR]

B.2.3.6
coupure
fonction consistant à amener automatiquement les contacts principaux du DPR de la position de fermeture à la position d'ouverture, interrompant ainsi le ou les courants qui les traversent

[SOURCE: IEC 60050-442:1998, 442-05-26, modifiée – sans «(pour un dispositif de coupure différentiel)» et adapté aux DPR]

B.2.3.7
temps limite de non-réponse
temps maximal pendant lequel une valeur de courant différentiel résiduel supérieure à la valeur assignée du courant différentiel résiduel de non-fonctionnement peut être appliquée au DPR, sans provoquer son fonctionnement

[SOURCE: IEC 60050-442:1998, 442-05-23, modifiée – ajout de «assigné» et adapté aux DPR]

B.2.3.8
DPR à retard
DPR spécialement conçu pour atteindre une valeur prédéterminée du temps limite de non-réponse correspondant à une valeur donnée du courant différentiel résiduel

Note 1 à l'article: La caractéristique courant différentiel résiduel/temporisation peut ou non être à temps/courant inverse.

[SOURCE: IEC 60050-442:1998, 442-05-05, modifiée – adapté aux DPR et ajout d'une Note 1 à l'article]

B.2.3.9
DPR de réinitialisation
DPR muni d'une unité c.r. qu'il est nécessaire de réarmer intentionnellement par des moyens différents des moyens de manœuvre du DPR, à la suite d'un courant différentiel résiduel, avant que celui-ci puisse se refermer

[SOURCE: IEC 60050-442:1998, 442-05-10, modifiée – adapté aux DPR]

B.2.3.10
appareil d'essai
appareil destiné à vérifier, en simulant un courant différentiel résiduel, que le DPR fonctionne

B.2.4 Termes et définitions relatifs aux valeurs et aux plages des grandeurs d'alimentation

B.2.4.1
valeur limite de surintensité de non-fonctionnement dans le cas d'une charge monophasée
valeur maximale de surintensité dans un circuit monophasé qui, en l'absence de courant différentiel résiduel, peut circuler dans un DPR (quel que soit le nombre de pôles) sans provoquer la manœuvre de celui-ci

Note 1 à l'article: Voir B.7.2.7.

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B.2.4.2
valeur limite de courant de non-fonctionnement dans le cas d'une charge équilibrée
valeur maximale du courant qui, en l'absence de défaut au bâti ou à la terre ou de courant de fuite à la terre, peut circuler dans le circuit surveillé par le DPR avec une charge équilibrée (quel que soit le nombre de pôles) sans provoquer la manœuvre de celui-ci

B.2.4.3
pouvoir de fermeture et de coupure différentiel résiduel en court-circuit
valeur de la composante alternative d'un courant différentiel résiduel de court-circuit présumé qu'un DPR est capable d'établir, de supporter pendant son temps de déclenchement et d'interrompre dans des conditions spécifiées d'utilisation et de comportement

B.3 Classification

B.3.1 Classification selon le mode de fonctionnement de la fonction de courant différentiel résiduel

B.3.1.1 DPR fonctionnellement indépendant de la tension d'alimentation (voir B.2.3.2)

B.3.1.2 DPR fonctionnellement dépendant de la tension d'alimentation (voir B.2.3.3 et B.7.2.11)

B.3.1.2.1 S'ouvrant automatiquement en cas de défaillance de la tension d'alimentation avec ou sans retard.

B.3.1.2.2 Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation.

Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation, mais capable de déclencher dans des conditions spécifiées en cas de défaut à la terre apparaissant lors d'une défaillance de la tension d'alimentation.

NOTE Les cas indiqués dans ce paragraphe comprennent les DPR incapables de s'ouvrir automatiquement lorsqu'il n'existe pas de situation dangereuse.

B.3.2 Classification selon la possibilité de réglage du courant différentiel résiduel de fonctionnement

B.3.2.1 DPR à courant différentiel résiduel de fonctionnement unique

B.3.2.2 DPR à réglages multiples de courant différentiel résiduel de fonctionnement (voir note de B.4.1.1)

Un DPR peut avoir plusieurs réglages de courant différentiel résiduel de fonctionnement, soit par échelons soit par variation continue.

B.3.3 Classification selon la temporisation de la fonction de courant différentiel résiduel

B.3.3.1 DPR sans temporisation: type non temporisé

B.3.3.2 DPR avec temporisation: type temporisé (voir B.2.3.8)

B.3.3.2.1 DPR à temporisation non réglable

B.3.3.2.2 DPR à temporisation réglable

Un DPR peut avoir une temporisation réglable, soit par échelons soit par variation continue.

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~~B.3.4 Classification selon le comportement en présence d'une composante continue~~

~~B.3.4.1 DPR de type AC (voir B.4.4.1)~~

~~B.3.4.2 DPR de type A (voir B.4.4.2)~~

~~B.4 Caractéristiques des DPR pour leur fonction de courant différentiel résiduel~~

~~B.4.1 Valeurs assignées~~

~~B.4.1.1 Courant différentiel de fonctionnement assigné ($I_{\Delta n}$)~~

~~Valeur efficace d'un courant sinusoïdal différentiel résiduel de fonctionnement (voir B.2.2.4) assignée par le fabricant au DPR, à laquelle celui-ci doit fonctionner dans des conditions spécifiées.~~

~~NOTE Pour un DPR à réglages multiples de courant différentiel résiduel de fonctionnement, le réglage le plus élevé pour désigner ses caractéristiques assignées est utilisé. Voir cependant l'Article B.5 concernant le marquage.~~

~~B.4.1.2 Courant différentiel de non-fonctionnement assigné ($I_{\Delta no}$)~~

~~Valeur efficace du courant sinusoïdal différentiel résiduel de non-fonctionnement (voir B.2.2.5) assignée par le fabricant, à laquelle le DPR ne fonctionne pas dans des conditions spécifiées.~~

~~B.4.1.3 Pouvoir de fermeture et de coupure différentiel résiduel de court-circuit assigné ($I_{\Delta m}$)~~

~~Valeur efficace de la composante alternative du courant différentiel résiduel de court-circuit présumé (voir B.2.4.3), assignée au DPR par le fabricant, que le DPR peut fermer, véhiculer et couper dans des conditions spécifiées.~~

~~B.4.2 Valeurs préférentielles et valeurs limites~~

~~B.4.2.1 Valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)~~

~~Les valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné sont~~

~~0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A~~

~~Des valeurs plus élevées peuvent être spécifiées.~~

~~$I_{\Delta n}$ peut s'exprimer en pourcentage du courant assigné.~~

~~B.4.2.2 Valeur minimale du courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)~~

~~La valeur minimale du courant différentiel résiduel de non-fonctionnement assigné est 0,5 $I_{\Delta n}$.~~

~~B.4.2.3 Valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée~~

~~La valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée doit être conforme à B.7.2.7.~~

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~~**B.4.2.4 Caractéristiques de fonctionnement**~~

~~**B.4.2.4.1 Type non temporisé**~~

~~La caractéristique de fonctionnement pour un type non temporisé est donnée au Tableau B.1.~~

~~**Tableau B.1 – Caractéristique de fonctionnement pour le type non temporisé**~~

~~Courant différentiel résiduel~~	~~$I_{\Delta n}$~~	~~$2\ I_{\Delta n}$~~	~~$5\ I_{\Delta n}$ [a]~~	~~$10\ I_{\Delta n}$ [b]~~
~~Durée maximale de coupures en s~~	~~0,3~~	~~0,15~~	~~0,04~~	~~0,04~~
~~[a] Pour les DPR avec $I_{\Delta n} \leq 30$ mA, 0,25 A peut être utilisé à la place de $5\ I_{\Delta n}$.~~ ~~[b] 0,5 A si 0,25 A est utilisé conformément à la note de bas de page a.~~				

~~Les DPR avec $I_{\Delta n} \leq 30$ mA doivent être du type non temporisé.~~

~~**B.4.2.4.2 Type temporisé**~~

~~**B.4.2.4.2.1 Temps limite de non-réponse** (voir B.2.3.7)~~

~~Pour un type temporisé, le temps limite de non-réponse est défini à $2\ I_{\Delta n}$ et doit être déclaré par le fabricant.~~

~~Le temps limite de non-réponse minimal à $2\ I_{\Delta n}$ est 0,06 s.~~

~~Les valeurs préférentielles de temps limite de non-réponse à $2\ I_{\Delta}$ sont~~

~~0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s.~~

~~**B.4.2.4.2.2 Caractéristique de fonctionnement**~~

~~Pour les DPR avec un temps limite de non-réponse supérieur à 0,06 s, le fabricant doit déclarer les durées de coupure maximales pour $I_{\Delta n}$, $2\ I_{\Delta n}$, $5\ I_{\Delta n}$ et $10\ I_{\Delta n}$.~~

~~Pour les DPR avec un temps limite de non-réponse de 0,06 s, les caractéristiques de fonctionnement sont données au Tableau B.2.~~

~~**Tableau B.2 – Caractéristique de fonctionnement pour le type temporisé ayant un temps limite de non-réponse de 0,06 s**~~

~~Courant différentiel résiduel~~	~~$I_{\Delta n}$~~	~~$2\ I_{\Delta n}$~~	~~$5\ I_{\Delta n}$~~	~~$10\ I_{\Delta n}$~~
~~Durée maximale de coupure en s~~	~~0,5~~	~~0,2~~	~~0,15~~	~~0,15~~

~~Dans le cas d'un DPR à caractéristique temps/courant inverse, le fabricant doit déclarer la caractéristique courant différentiel résiduel/durée de coupure.~~

~~**B.4.3 Valeur du pouvoir de coupure et de fermeture différentiel résiduel assigné ($I_{\Delta m}$) en court-circuit**~~

~~La valeur minimale de $I_{\Delta m}$ est 25 % de I_{cu}.~~

~~Des valeurs supérieures peuvent être soumises à essai et déclarées par le fabricant.~~

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B.4.4 Caractéristiques de fonctionnement dans le cas d'un courant de défaut à la terre avec ou sans composante continue

B.4.4.1 DPR du type AC

DPR pour lequel le déclenchement est assuré pour des courants alternatifs sinusoïdaux différentiels résiduels, sans composante continue, appliqués soudainement ou de façon progressive.

B.4.4.2 DPR du type A

DPR pour lequel le déclenchement est assuré pour des courants alternatifs sinusoïdaux différentiels résiduels en présence de courants continus pulsés différentiels résiduels spécifiés, avec ou sans un niveau spécifié de courant continu superposé, appliqués soudainement ou de façon progressive.

B.5 Marquage

Chaque DPR doit être marqué de façon indélébile:

a) Les indications suivantes doivent être marquées sur les DPR intégrés (voir B.1.1) en plus des marquages spécifiés en 5.2 et être distinctement visibles après l'installation:

- courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$;
- réglages du courant différentiel résiduel de fonctionnement, le cas échéant;
- temps limite de non-réponse à 2 $I_{\Delta n}$, pour le type temporisé, par le symbole Δt suivi du temps limite de non-réponse en ms; en variante, dans le cas où le temps limite de non-réponse est 0,06 s, ce symbole peut être S (S dans un carré);
- l'organe de manœuvre de l'appareil d'essai, par la lettre T (voir aussi B.7.2.6);
- caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composantes continues:

pour les DPR de type AC avec le symbole 

pour les DPR de type A avec le symbole 

b) Les indications suivantes doivent être marquées sur les unités c.r. et être distinctement visibles après l'installation:

- tension(s) assignée(s) si elle(s) diffère(nt) de celle(s) du disjoncteur;
- valeur (ou plage de valeurs) de la fréquence assignée si elle diffère de celle du disjoncteur;
- l'indication $I_n \leq ...$A (I_n étant le courant assigné maximal du disjoncteur auquel l'unité c.r. peut être associée);
- courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$;
- réglages du courant différentiel résiduel de fonctionnement, le cas échéant;
- temps limite de non-réponse, comme spécifié au point a);
- organe de manœuvre de l'appareil d'essai, comme spécifié au point a);
- caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composantes continues:

pour les DPR de type A avec le symbole 

pour les DPR de type AC avec le symbole 

c) Les indications suivantes doivent être marquées sur les unités c.r. et être distinctement visibles après l'assemblage avec le disjoncteur:

- nom du fabricant ou marque de fabrique;
- désignation du type ou numéro de série;

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– identification du (des) disjoncteur(s) avec le(s)quel(s) l'unité c.r. peut être assemblée, sauf si un assemblage incorrect (rendant la protection inopérante) est impossible du fait de sa conception;

– IEC 60947-2;

– aptitude à une utilisation avec une alimentation triphasée seulement, avec le symbole



d) Les indications suivantes doivent être marquées sur les DPR intégrés ou les unités c.r., suivant le cas, ou figurer dans la documentation du fabricant:

– pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit $I_{\Delta m}$ s'il est supérieur à 25 % de I_{cu} (voir B.4.3);

– schéma des connexions, y compris celles du circuit d'essai et, le cas échéant, celles de la ligne pour les DPR dépendant de la tension d'alimentation;

– valeur du courant différentiel résiduel de non-fonctionnement assigné $I_{\Delta no}$ s'il est supérieur à 0,5 $I_{\Delta n}$.

e) Les indications suivantes doivent être disponibles dans la documentation du fabricant:

– aptitude à une utilisation dans des:

• circuits triphasés seulement, ou

• circuits triphasés et monophasés.

B.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

B.7 Exigences relatives à la conception et au fonctionnement

B.7.1 Exigences relatives à la conception

Il ne doit pas être possible de modifier la caractéristique de fonctionnement d'un DPR par des moyens autres que ceux spécifiquement destinés au réglage du courant différentiel résiduel de fonctionnement assigné ou de la temporisation définie.

Les DPR combinant une unité c.r. appropriée et un disjoncteur associé doivent être conçus et réalisés de manière telle que:

– l'assemblage de l'unité c.r. adaptable et du disjoncteur associé n'exige aucune liaison mécanique et/ou électrique pouvant être nuisible à l'installation ou présentant des risques pour l'utilisateur;

– l'adjonction de l'unité c.r. adaptable ne compromet en aucune manière le fonctionnement normal ou les performances du disjoncteur;

– l'unité c.r. n'est pas endommagée de façon permanente à la suite des courants de court-circuit au cours des séquences d'essai.

B.7.2 Exigences relatives au fonctionnement

B.7.2.1 Fonctionnement en cas de courant différentiel résiduel

Le DPR doit s'ouvrir automatiquement lors de l'apparition de tout courant de fuite ou de courant de défaut à la terre égal ou supérieur au courant différentiel résiduel de fonctionnement assigné pendant une durée supérieure au temps limite de non-réponse.

La manœuvre du DPR doit être conforme aux exigences de durée spécifiées en B.4.2.4. La conformité doit être vérifiée par les essais de B.8.1.1.

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~~**B.7.2.2 Pouvoir de fermeture et de coupure différentiel résiduel de court-circuit assigné $I_{\Delta m}$**~~

~~Les DPR doivent satisfaire aux exigences d'essai de B.8.10.~~

~~**B.7.2.3 Aptitude au fonctionnement en service**~~

~~Les DPR doivent satisfaire aux essais de B.8.1.1.1.~~

~~**B.7.2.4 Effets des conditions d'environnement**~~

~~Les DPR doivent fonctionner de manière satisfaisante, compte tenu des effets des conditions d'environnement.~~

~~La conformité est vérifiée par l'essai de B.8.11.~~

~~**B.7.2.5 Propriétés diélectriques**~~

~~Les DPR doivent satisfaire aux essais de B.8.3.~~

~~**B.7.2.6 Appareil d'essai**~~

~~Les DPR doivent être munis d'un appareil d'essai permettant à l'appareil de détection d'être traversé par un courant simulant un courant différentiel résiduel, afin de permettre de vérifier périodiquement par essai l'aptitude au fonctionnement des DPR.~~

~~L'appareil d'essai doit satisfaire aux essais de B.8.4.~~

~~Aucune tension ne doit apparaître sur le conducteur de protection, lorsqu'il existe, lors du fonctionnement du dispositif de contrôle.~~

~~Il ne doit pas être possible d'alimenter le circuit protégé par la manœuvre de l'appareil d'essai lorsque le DPR est en position d'ouverture.~~

~~L'appareil d'essai ne doit pas être le seul moyen d'effectuer la manœuvre d'ouverture et n'est pas prévu pour cette fonction.~~

~~L'organe de manœuvre de l'appareil d'essai doit être désigné par la lettre T et sa couleur ne doit être ni rouge ni verte; il convient d'employer, de préférence, une couleur claire.~~

~~NOTE L'appareil d'essai est seulement destiné à vérifier la fonction de déclenchement, et non la valeur à laquelle cette fonction s'accomplit, par rapport au courant assigné différentiel résiduel de fonctionnement et à la durée de la coupure.~~

~~**B.7.2.7 Valeur du courant de surcharge de non-fonctionnement pour un circuit de charge monophasé**~~

~~Les DPR doivent supporter sans déclencher la plus faible des deux valeurs suivantes de surintensité:~~

~~– $6\ I_n$;~~

~~– 80 % du courant maximal de réglage du déclencheur de court-circuit.~~

~~La conformité est vérifiée par l'essai de B.8.5.~~

~~Cet essai n'est toutefois pas nécessaire dans le cas de DPR de catégorie de sélectivité B puisque les exigences de ce paragraphe sont vérifiées pendant la séquence d'essai IV (ou la séquence d'essai VI (combinée)).~~

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NOTE Les essais pour les circuits de charge polyphasés en régime équilibré ne sont pas nécessaires car ils sont estimés être satisfaits par les exigences de ce paragraphe.

B.7.2.8 Résistance des DPR aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc

B.7.2.8.1 Résistance aux déclenchements intempestifs dans le cas de charge de capacité de réseau

Les DPR doivent satisfaire à l'essai de B.8.6.2.

B.7.2.8.2 Résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Les DPR doivent satisfaire à l'essai de B.8.6.3.

B.7.2.9 Comportement des DPR du type A en cas de courant de défaut à la terre comprenant une composante continue

Le comportement des DPR en cas de courant de défaut à la terre comprenant une composante continue doit être tel que les durées maximales de coupure définies dans le Tableau B.1 et le Tableau B.2, suivant le cas, doivent également être respectées, les valeurs du courant d'essai spécifiées étant cependant multipliées :

- par le facteur 1,4 pour les DPR ayant $I_{\Delta n} > 0{,}015$ A,
- par le facteur 2 pour les DPR ayant $I_{\Delta n} \leq 0{,}015$ A (ou 0,03 A, selon celle qui est la plus élevée).

La conformité est vérifiée par les essais de B.8.7.

B.7.2.10 Conditions de fonctionnement des DPR à réarmement

Il ne doit pas être possible de remettre en position de fermeture, après déclenchement dû à un courant différentiel résiduel, les DPR à réarmement (voir B.2.3.9) s'ils n'ont pas été réarmés.

La conformité est vérifiée pendant l'essai de 8.3.3.4.4 selon B.8.1.1.1.

B.7.2.11 Exigences supplémentaires relatives aux DPR fonctionnellement dépendants de la tension d'alimentation

Les DPR fonctionnellement dépendants de la tension d'alimentation doivent fonctionner correctement à toute valeur de la tension d'alimentation comprise entre 0,85 et 1,1 fois sa valeur assignée.

La conformité est vérifiée par les essais de B.8.2.3.

Lorsqu'un DPR a plus d'une fréquence assignée ou une plage de fréquences assignées, le DPR doit être capable de fonctionner selon ce paragraphe à toutes les fréquences.

La conformité est vérifiée en effectuant les essais de B.8.2 et B.8.4.

Suivant leur classification, les DPR fonctionnellement dépendants de la tension d'alimentation doivent satisfaire aux exigences figurant au Tableau B.3.

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Tableau B.3 – Exigences pour les DPR fonctionnellement dépendants de la tension d'alimentation

Classification de l'appareil selon B.3.1		Comportement en cas de défaillance de la tension d'alimentation
DPR s'ouvrant automatiquement en cas de défaillance de la tension d'alimentation (B.3.1.2.1)	Sans retard	Ouverture sans retard selon B.8.8.3, point a)
	Avec retard	Ouverture avec retard selon B.8.8.3, point b)
DPR ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation mais capables de s'ouvrir en cas de situation dangereuse (B.3.1.2.2)		Fonctionnement selon B.8.9

B.7.3 Compatibilité électromagnétique

Les exigences de l'Annexe J s'appliquent.

Des spécifications d'essai supplémentaires sont données en B.8.12.

L'immunité aux variations de tension est couverte par les exigences de B.7.2.11.

B.8 Essais

B.8.1 Généralités

Ce paragraphe spécifie les essais pour les DPR de courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$ inférieur ou égal à 30 A.

La validité des essais spécifiés dans ce paragraphe lorsque $I_{\Delta n}$ > 30 A fait l'objet d'un accord entre le fabricant et l'utilisateur.

Les instruments de mesure du courant différentiel résiduel doivent être au moins de la classe 0,5 (voir l'IEC 60051) et doivent indiquer (ou permettre de déterminer) la valeur efficace vraie.

Les instruments de mesure du temps doivent avoir une erreur relative ne dépassant pas 10 % de la valeur mesurée.

Les essais spécifiés dans la présente annexe s'ajoutent aux essais de l'Article 8.

a) Essais de type

Les DPR doivent être soumis à toutes les séquences d'essai de l'Article 8 qui leur sont applicables. Pour les vérifications de la tenue diélectrique au cours de ces séquences d'essai (voir 8.3.3.6), le circuit de commande des appareils différentiels résiduels fonctionnellement dépendants de la tension d'alimentation doit être déconnecté du circuit principal.

Les essais doivent être effectués avec des courants essentiellement sinusoïdaux.

Pour les DPR comprenant une unité c.r. distincte et un disjoncteur, l'ensemble doit être réalisé conformément aux instructions du fabricant.

Dans le cas des DPR avec plusieurs réglages du courant différentiel résiduel de fonctionnement, les essais doivent, sauf indication contraire, être effectués au réglage le plus bas.

Dans le cas des DPR à temporisation réglable (voir B.3.3.2.2), la temporisation doit, sauf indication contraire, être réglée à son maximum.

Dans le cas des DPR à déclenchement instantané réglable, le déclencheur instantané doit être réglé au maximum, sauf indication contraire.

b) Essais individuels de série

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Le 8.4.5 est applicable.

B.8.1.1 Essais à effectuer au cours des séquences d'essai de l'Article 8

B.8.1.1.1 Aptitude au fonctionnement en service

Au cours des cycles de manœuvres avec courant (voir 8.3.3.4.4) spécifiés au Tableau 8 (voir 7.2.4.2), un tiers des manœuvres de coupure doit être réalisé par la manœuvre de l'appareil d'essai et un autre tiers en appliquant à l'un des pôles un courant différentiel résiduel de valeur $I_{\Delta n}$ (ou, le cas échéant, de valeur égale au réglage le plus bas du courant différentiel résiduel de fonctionnement).

Dans le cas d'un DPR à réarmement, il doit être vérifié qu'il n'est pas possible de refermer le DPR après déclenchement sans manœuvre intentionnelle de réarmement. Cette vérification doit être faite au début et à la fin de l'essai d'aptitude au fonctionnement en service avec courant (8.3.3.4.4).

Aucun défaut de déclenchement ne doit être admis.

B.8.1.1.2 Vérification de l'aptitude à supporter les courants de court-circuit

B.8.1.1.2.1 Pouvoir assigné de coupure de service en court-circuit (séquence d'essai II)

Après les essais de 8.3.4, la vérification du fonctionnement correct du DPR en cas de courant différentiel résiduel doit être effectuée conformément à B.8.2.4.2.

B.8.1.1.2.2 Pouvoir assigné de coupure ultime en court-circuit (séquence d'essai III)

Pour vérifier le fonctionnement correct des déclencheurs de surcharge, les essais sur un seul pôle spécifiés en 8.3.5.2 et 8.3.5.5 doivent être remplacés par des essais sur deux pôles sur toutes les combinaisons possibles des pôles de phase, à tour de rôle, les conditions d'essai étant celles spécifiées en 8.3.5.2 et 8.3.5.5, mais applicables à deux pôles.

Après les essais de 8.3.5, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.1.2.3 Courant assigné de courte durée admissible (séquence d'essai IV ou séquence d'essai VI (combinée))

Les exigences suivantes sont applicables:

a) Comportement pendant l'essai au courant assigné de courte durée admissible

Aucun déclenchement ne doit se produire pendant l'essai de 8.3.6.3 ou 8.3.8.3, suivant le cas.

b) Vérification des déclencheurs de surcharge

– Pour la séquence d'essai IV

Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.6.2 et 8.3.6.7, les essais sur un seul pôle spécifiés en 8.3.5.2 doivent être remplacés par des essais sur deux pôles effectués selon toutes les combinaisons possibles de pôles de phase à tour de rôle.

– Pour la séquence d'essai combinée

Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.8.2, l'essai sur un seul pôle spécifié en 8.3.5.2 doit être remplacé par des essais sur deux pôles effectués selon toutes les combinaisons possibles de pôles de phase à tour de rôle.

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Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.8.7, l'essai spécifié en 8.3.3.8 doit être effectué en utilisant une alimentation triphasée.

c) Vérification de l'appareil de déclenchement au courant différentiel résiduel

Après les essais de 8.3.6 ou 8.3.8, suivant le cas, la vérification de l'appareil de déclenchement au courant différentiel résiduel doit être effectuée selon B.8.2.4.4.

B.8.1.1.2.4 Disjoncteurs à fusibles incorporés (séquence d'essai V)

Pour vérifier le fonctionnement correct des déclencheurs de surcharge, les essais sur un seul pôle spécifiés en 8.3.7.5 et 8.3.7.9 doivent être remplacés par des essais sur deux pôles sur toutes les combinaisons possibles des pôles de phase, à tour de rôle, les conditions d'essai étant celles spécifiées en 8.3.7.5 et 8.3.7.9, mais applicables à deux pôles.

Après les essais de 8.3.7, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.1.2.5 Séquence d'essai VI (combinée)

Après les essais de 8.3.8, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.2 Séquences d'essai supplémentaires

Des séquences d'essai supplémentaires doivent être effectuées sur les DPR, conformément au Tableau B.4.

Tableau B.4 – Séquences d'essai supplémentaires

Séquences	Essai	Paragraphe
B I	Caractéristique de fonctionnement	B.8.2
	Propriétés diélectriques	B.8.3
	Fonctionnement de l'appareil d'essai aux limites de la tension assignée	B.8.4
	Valeur limite du courant de non-fonctionnement en conditions de surintensités	B.8.5
	Résistance aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc	B.8.6
	Comportement en cas de courant de défaut à la terre comprenant une composante continue	B.8.7
	Comportement en cas de défaut de la tension d'alimentation pour les DPR classés selon B.3.1.2.1	B.8.8
	Comportement en cas de défaut de la tension d'alimentation pour les DPR classés selon B.3.1.2.2	B.8.9
B II	Pouvoir de fermeture et de coupure différentiel résiduel en court-circuit ($I_{\Delta m}$)	B.8.10
B III	Effets des conditions d'environnement	B.8.11
B IV	Essais d'immunité	B.8.12.1
	Essais d'émission	B.8.12.2

Pour les DPR comportant des variantes avec différents nombres de pôles, les essais doivent être effectués sur la variante avec le plus grand nombre de pôles. Pour une variante pour laquelle il n'existe pas de différences de construction par rapport à la variante soumise à essai, aucun essai supplémentaire n'est exigé. Si la construction des variantes n'est pas identique à celle de la variante soumise à essai, ces variantes doivent alors être aussi soumises aux essais.

Un échantillon doit être soumis à essai pour chacune des séquences d'essai B I, B II et B III.

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Pour la séquence d'essai B IV, un nouvel échantillon peut être utilisé pour chaque essai ou un seul échantillon peut être utilisé pour plusieurs essais, à la discrétion du fabricant.

Séquence d'essai B I

B.8.2 Vérification de la caractéristique de fonctionnement

B.8.2.1 Circuit d'essai

Le DPR est installé comme en service normal.

Le circuit d'essai doit être conforme à la Figure B.1.

B.8.2.2 Tension d'essai pour les DPR fonctionnellement indépendants de la tension d'alimentation

Les essais peuvent être effectués sous toute tension convenable.

B.8.2.3 Tension d'essai pour les DPR fonctionnellement dépendants de la tension d'alimentation

Les essais doivent être effectués aux valeurs suivantes de la tension appliquée aux bornes correspondantes:

– 0,85 fois la tension assignée minimale pour les essais spécifiés en B.8.2.4 et B.8.2.5.2,

– 1,1 fois la tension assignée maximale pour les essais spécifiés en B.8.2.5.3.

Les DPR ayant plus d'une fréquence assignée ou une plage de fréquences assignées doivent être soumis à essai à la fréquence assignée la plus élevée et à la fréquence assignée la plus basse dans chaque cas. Cependant, pour les DPR ayant des fréquences assignées égales à 50 Hz et 60 Hz, les essais à 50 Hz ou à 60 Hz sont considérés comme couvrant les exigences.

B.8.2.4 Essai à vide à 20 °C ± 5 °C

B.8.2.4.1 Généralités

Les connexions étant comme représentées à la Figure B.1, le DPR doit subir les essais de B.8.2.4.2, B.8.2.4.3 et B.8.2.4.4 ainsi que celui de B.8.2.4.5, le cas échéant, tous ces essais étant effectués sur un seul pôle choisi au hasard. Chaque essai doit comprendre trois mesurages ou vérifications, suivant le cas.

Sauf spécification contraire, pour les DPR avec réglage, par variation continue ou par valeurs discrètes, du courant différentiel résiduel de fonctionnement, les essais doivent être effectués au réglage minimal et au réglage maximal, et à un réglage intermédiaire.

B.8.2.4.2 Vérification du fonctionnement correct en cas d'augmentation régulière du courant différentiel résiduel

Pour les DPR avec une temporisation réglable, les essais doivent être effectués au réglage minimal. Les interrupteurs S_1 et S_2 et le DPR étant en position de fermeture, le courant différentiel résiduel est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$ afin d'atteindre la valeur $I_{\Delta n}$ en approximativement 30 s, le courant de déclenchement étant mesuré chaque fois. Les trois valeurs mesurées doivent être supérieures à $I_{\Delta no}$ et inférieures ou égales à $I_{\Delta n}$.

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B.8.2.4.3 Vérification du fonctionnement correct en cas de fermeture sur le courant différentiel résiduel

Le circuit d'essai étant étalonné à la valeur assignée du courant différentiel résiduel de fonctionnement $I_{\Delta n}$ (ou aux réglages spécifiques du courant de fonctionnement différentiel résiduel, le cas échéant, voir B.8.2.4), les interrupteurs S_1 et S_2 étant en position de fermeture, le DPR est fermé sur le circuit de manière à simuler aussi fidèlement que possible les conditions de service. La durée de coupure est mesurée trois fois.

Aucun mesurage ne doit dépasser la valeur limite spécifiée pour $I_{\Delta n}$ en B.4.2.4.1 ou B.4.2.4.2.2, suivant le cas.

B.8.2.4.4 Vérification du fonctionnement correct en cas d'apparition brusque du courant différentiel résiduel

Le circuit d'essai étant étalonné à chacune des valeurs du courant différentiel résiduel de fonctionnement I_{Δ} spécifiées en B.4.2.4.1 ou B.4.2.4.2.2, suivant le cas, et l'interrupteur S_1 et le DPR étant en position de fermeture, le courant différentiel résiduel est établi brusquement par la fermeture de l'interrupteur S_2.

Le DPR doit déclencher au cours de chaque essai.

Trois mesurages de la durée de coupure sont effectués à chaque valeur de I_{Δ}. Aucune des valeurs ainsi obtenues ne doit dépasser la valeur limite correspondante.

B.8.2.4.5 Vérification du temps limite de non-fonctionnement des DPR du type temporisé

Le circuit d'essai étant étalonné à la valeur $2\ I_{\Delta n}$, l'interrupteur d'essai S_1 et le DPR étant en position de fermeture, le courant différentiel résiduel est établi par la fermeture de l'interrupteur S_2 pendant un temps égal à la durée limite de non-fonctionnement déclarée par le fabricant conformément à B.4.2.4.2.1.

Au cours de chacune des trois vérifications, le DPR ne doit pas déclencher. Si le DPR a un courant différentiel résiduel de réglage ajustable et/ou une temporisation réglable, l'essai est effectué, suivant le cas, au réglage minimal du courant différentiel résiduel de fonctionnement et au réglage maximal de la temporisation.

B.8.2.5 Essais aux limites de température

B.8.2.5.1 Généralités

NOTE La limite supérieure de température peut être la température de référence.

Les limites de température de ce paragraphe peuvent être étendues par accord entre le fabricant et l'utilisateur; dans ce cas, les essais doivent être effectués aux limites de température convenues.

B.8.2.5.2 Essai à vide à –5 °C

Le DPR est placé dans une enceinte dont la température ambiante est stabilisée dans les limites de –7 °C à –5 °C. Après avoir atteint l'équilibre thermique, le DPR est soumis aux essais de B.8.2.4.4 et, le cas échéant, de B.8.2.4.5.

B.8.2.5.3 Essai en charge à la température de référence ou à + 40 °C

Le DPR, raccordé conformément à la Figure B.1, est placé dans une enceinte dont la température ambiante est stabilisée à une valeur égale à la température de référence (voir 4.7.3) ou, en l'absence de température de référence, égale à 40 °C ± 2 °C. Un courant de charge égal à I_n (non indiqué en Figure B.1) est appliqué à tous les pôles de phase.

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Après avoir atteint l'équilibre thermique, le DPR est soumis aux essais de B.8.2.4.4 et, s'il y a lieu, de B.8.2.4.5.

B.8.3 Vérification des propriétés diélectriques

Les DPR doivent satisfaire à 8.3.3.3.

B.8.4 Vérification de la manœuvre de l'appareil d'essai aux limites de la tension assignée

La vérification comporte les essais suivants:

a) Le DPR étant alimenté à une tension égale à 1,1 fois la tension assignée maximale, l'appareil d'essai est manœuvré 25 fois à des intervalles de 5 s, le DPR étant refermé avant chaque manœuvre.

b) L'essai a) est ensuite renouvelé à 0,85 fois la tension assignée minimale, l'appareil d'essai étant manœuvré 3 fois.

c) L'essai a) est ensuite renouvelé, mais seulement une fois, les organes de manœuvre de l'appareil d'essai étant maintenus en position de fermeture pendant 5 s.

Pour ces essais:

– dans le cas des DPR dont les bornes d'alimentation et de charge sont identifiées, les connexions d'alimentation doivent être conformes au repérage;

– dans le cas des DPR dont les bornes d'alimentation et de charge ne sont pas identifiées, l'alimentation doit être raccordée successivement à chaque jeu de bornes ou, en variante, simultanément aux deux jeux de bornes.

Le DPR doit fonctionner à chaque essai.

Pour les DPR à courant différentiel résiduel de fonctionnement réglable:

– le réglage le plus bas doit être utilisé pour les essais a) et c);

– le réglage le plus élevé doit être utilisé pour l'essai b).

Pour les DPR à temporisation réglable, l'essai est effectué à la temporisation maximale.

NOTE La vérification de l'endurance de l'appareil d'essai est considérée comme étant effectuée par les essais de B.8.1.1.1.

B.8.5 Vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité

L'essai doit être effectué avec une charge monophasée, les raccordements étant réalisés selon la Figure B.2.

L'impédance *Z* est ajustée de manière à permettre le passage dans le circuit d'un courant égal à la plus faible des deux valeurs suivantes:

– $6\ I_n$;

– 80 % du courant maximal de réglage du déclencheur de court-circuit.

NOTE 1 Pour ce réglage du courant, le DPR D (voir Figure B.2) peut être remplacé par des connexions d'impédance négligeable.

Pour les DPR à courant différentiel résiduel réglable, l'essai est effectué au réglage le plus bas.

Les DPR fonctionnellement indépendants de la tension d'alimentation sont soumis à essai sous toute tension convenable.

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~~Les DPR fonctionnellement dépendants de la tension d'alimentation sont alimentés côté source à leur tension assignée (ou, le cas échéant, à une tension dans la plage des tensions assignées).~~

~~L'essai est effectué à un facteur de puissance de 0,5.~~

~~L'interrupteur S_1 étant ouvert, est fermé et rouvert après 2 s. L'essai est répété trois fois pour chaque combinaison possible des voies de passage du courant, avec un intervalle d'au moins 1 min entre deux manœuvres de fermeture successives.~~

~~Le DPR ne doit pas déclencher.~~

~~NOTE 2 La durée de 2 s peut être réduite (mais pas à une valeur inférieure à celle de la durée de coupure minimale) pour éviter le risque de déclenchement sous l'action du ou des déclencheurs de surcharge du DPR.~~

~~B.8.6 Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc~~

~~B.8.6.1 Généralités~~

~~Pour les DPR à temporisation réglable (voir B.3.3.2.2), la temporisation doit être réglée au minimum.~~

~~B.8.6.2 Vérification de la résistance aux déclenchements intempestifs dans le cas de charge de capacité du réseau~~

~~Le DPR est soumis à essai en utilisant un générateur de courant de choc capable de délivrer un courant oscillatoire amorti comme montré à la Figure B.4.~~

~~Un exemple de circuit pour la connexion du DPR est montré à la Figure B.5.~~

~~Un pôle du DPR choisi au hasard doit être soumis à 10 applications du courant de choc. La polarité de l'onde du courant de choc doit être inversée toutes les deux applications. L'intervalle entre deux applications successives doit être approximativement égal à 30 s. Le courant de choc doit être mesuré avec des moyens appropriés et réglé en utilisant un échantillon supplémentaire de DPR du même type (voir B.3.4) afin de satisfaire aux exigences suivantes:~~

- ~~valeur de crête: 200 A $^{+10}_{0}$ %,~~
- ~~durée de front conventionnelle: 0,5 µs ± 30 %,~~
- ~~période de l'onde oscillatoire suivante: 10 µs ± 20 %,~~
- ~~chacune des crêtes successives: environ 60 % de la crête précédente.~~

~~Pendant les essais, le DPR ne doit pas déclencher.~~

~~B.8.6.3 Vérification de la résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite~~

~~Le DPR est soumis à essai en utilisant un générateur de courant de choc capable de délivrer une onde de courant de choc de 8/20 µs, sans polarité inverse, comme montré à la Figure B.6.~~

~~Un exemple de circuit pour la connexion du DPR est montré à la Figure B.7.~~

~~Un pôle du DPR, choisi au hasard, doit être soumis à 10 applications du courant de choc. La polarité de l'onde du courant de choc doit être inversée toutes les deux applications. L'intervalle entre deux applications successives doit être égal à 30 s environ.~~

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Le courant de choc doit être mesuré avec des moyens appropriés et réglé, en utilisant un échantillon supplémentaire de DPR du même type (voir B.3.4), afin de satisfaire aux exigences suivantes:

– valeur de crête: 250 A $^{+10}_{0}$ %,

– durée de front conventionnelle (T_1): 8 µs ± 10 %,

– durée jusqu'à mi-valeur (T_2): 20 µs ± 10 %.

Pendant les essais, le DPR ne doit pas déclencher.

B.8.7 Vérification du comportement des DPR de type A en cas de courant de défaut à la terre comprenant une composante continue

B.8.7.1 Conditions d'essai

Les conditions d'essai de B.8 et de B.8.2.1, B.8.2.2 et B.8.2.3 sont applicables, excepté que les circuits d'essai doivent être ceux définis à la Figure B.8 et la Figure B.9, suivant le cas.

B.8.7.2 Vérifications

B.8.7.2.1 Vérification du fonctionnement correct dans le cas d'une augmentation régulière du courant différentiel résiduel continu pulsé

Le circuit d'essai doit être conforme à la Figure B.8. Dans le cas d'un DPR avec une temporisation réglable (voir B.3.3.2.2), la temporisation doit être réglée au minimum.

Les interrupteurs auxiliaires S_1 et S_2 et le DPR-D doivent être fermés. Le thyristor approprié doit être commandé de façon à obtenir des angles de retard du courant α de 0°, 90° et 135°. Chaque pôle du DPR doit être soumis à essai pour chaque angle de retard du courant, deux fois dans la position I et deux fois dans la position II de l'interrupteur auxiliaire S_3.

A chaque essai, le courant démarrant de zéro doit être augmenté progressivement avec un taux de variation approximatif de:

$\frac{1{,}4\ I_{\Delta n}}{30}$ A/s pour les DPR de $I_{\Delta n} > 0{,}015$ A,

$\frac{2\ I_{\Delta n}}{30}$ A/s pour les DPR de $I_{\Delta n} \leq 0{,}015$ A.

Le courant de déclenchement doit être conforme aux valeurs indiquées dans le Tableau B.5.

Tableau B.5 – Plage de courant de déclenchement pour les DPR dans le cas d'un défaut à la terre comprenant des composantes continues

Angle α	Courant de déclenchement A	
	Limite inférieure	Limite supérieure
0°	0,35 I_{Δ}n	0,03 A pour I_{Δ}n ≤ 0,015 A ou 1,4I_{Δ}n pour I_{Δ}n > 0,015 A
90°	0,25 I_{Δ}n	
135°	0,11 I_{Δ}n	

B.8.7.2.2 Vérification du fonctionnement correct dans le cas d'une apparition soudaine de courants différentiels résiduels continus pulsés

L'essai doit être effectué selon la Figure B.8.

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Le circuit étant étalonné pour les valeurs spécifiées ci-après et l'interrupteur auxiliaire S_1 et le DPR étant en position fermée, le courant différentiel résiduel est appliqué brutalement en fermant l'interrupteur S_2.

NOTE Dans le cas de DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.2, le circuit de commande étant alimenté du côté source du circuit principal, cette vérification ne prend pas en compte le temps nécessaire pour alimenter le DPR. En conséquence, dans ce cas, la vérification est considérée comme étant faite en établissant le courant différentiel résiduel par la fermeture de S_1, le DPR en essai et S_2 étant fermés au préalable.

Quatre mesurages sont effectués pour chaque valeur de courant d'essai avec un angle de retard de courant α = 0°, deux avec l'interrupteur auxiliaire dans la position I et deux avec l'interrupteur auxiliaire dans la position II.

Pour les DPR de $I_{\Delta n}$ > 0,015 A, l'essai doit être effectué à chacune des valeurs de $I_{\Delta n}$ spécifiée au Tableau B.1, multipliée par le facteur 1,4.

Pour les DPR de $I_{\Delta n}$ ≤ 0,015 A, l'essai doit être effectué à chacune des valeurs de $I_{\Delta n}$ spécifiée au Tableau B.1, multipliée par le facteur 2 (ou à 0,03 A, selon la valeur la plus élevée).

Aucune valeur ne doit dépasser les valeurs limites spécifiées (voir B.7.2.9).

B.8.7.2.3 Vérification du fonctionnement correct avec charge à la température de référence

Les essais de B.8.7.2.1 et B.8.7.2.2 sont répétés, le pôle en essai et un autre pôle du DPR étant parcourus par le courant assigné, le courant étant établi juste avant l'essai.

NOTE La charge avec le courant assigné n'est pas montrée à la Figure B.8.

B.8.7.2.4 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pulsés auxquels un courant continu lissé de 0,006 A est superposé

Le DPR doit être soumis à essai selon la Figure B.9, avec un courant différentiel résiduel redressé demi-alternance (angle de retard de courant α = 0°) auquel est superposé un courant continu lissé de 0,006 A.

Chaque pôle du DPR doit être soumis à essai à tour de rôle, deux fois pour chacune des positions I et II.

Pour les DPR avec $I_{\Delta n}$ > 0,015 A, le courant redressé demi-alternance, démarrant de 0, étant augmenté progressivement avec un niveau d'accroissement d'environ 1,4 $I_{\Delta n}$ / 30 A/s, le déclenchement doit se produire avant que le courant n'atteigne une valeur ne dépassant pas 1,4 $I_{\Delta n}$ + 0,006 A.

Pour les DPR avec $I_{\Delta n}$ ≤ 0,015 A, le courant redressé demi-alternance, démarrant de 0, étant augmenté progressivement avec un niveau d'accroissement d'environ 2 $I_{\Delta n}$ / 30 A/s, le déclenchement doit se produire avant que le courant n'atteigne une valeur ne dépassant pas 0,03 A + 0,006 A.

B.8.8 Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.1

B.8.8.1 Généralités

Pour les DPR à courant différentiel résiduel de fonctionnement réglable, l'essai est effectué au réglage le plus bas.

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Pour les DPR à temporisation réglable, l'essai est effectué à l'un quelconque des réglages de la temporisation.

B.8.8.2 Détermination de la valeur limite de la tension d'alimentation

Une tension égale à la tension assignée est appliquée aux bornes d'alimentation du DPR et est ensuite diminuée progressivement jusqu'à zéro, en un délai ayant la plus longue des deux valeurs suivantes jusqu'à ce que se produise l'ouverture automatique:

- environ 30 s;
- un temps suffisamment long pour tenir compte du retard à l'ouverture du DPR, s'il y a lieu (voir B.7.2.11).

La tension correspondante est mesurée.

Trois mesurages sont effectués. Toutes les valeurs doivent être inférieures à 0,85 fois la tension assignée minimale du DPR.

Après ces mesurages, il doit être vérifié que le DPR déclenche lorsqu'un courant différentiel résiduel égal à $I_{\Delta n}$ est appliqué, la tension appliquée étant juste supérieure à la plus forte valeur mesurée.

Il doit alors être vérifié que, pour toute valeur de tension inférieure à la valeur la plus faible, il n'est pas possible de fermer le DPR à l'aide de ses organes de manœuvre manuels.

B.8.8.3 Vérification de l'ouverture automatique en cas de défaillance de la tension d'alimentation

Le DPR étant en position de fermeture, une tension égale à sa tension assignée ou, dans le cas d'une plage de tensions assignées, à n'importe laquelle des tensions assignées, est appliquée à ses bornes d'alimentation. La tension est ensuite interrompue. Le DPR doit déclencher. L'intervalle de temps entre l'interruption de la tension et l'ouverture des contacts principaux est mesuré.

Trois mesurages sont effectués:

a) pour les DPR à ouverture sans retard (voir B.7.2.11), aucune valeur ne doit dépasser 0,2 s;

b) pour les DPR à ouverture avec retard, les valeurs minimale et maximale doivent se situer à l'intérieur de la plage indiquée par le fabricant.

B.8.9 Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.2 en cas de défaillance de la tension d'alimentation

B.8.9.1 Généralités

Pour les DPR à courant différentiel résiduel de fonctionnement réglable, l'essai est effectué au réglage le plus bas.

Pour les DPR à temporisation réglable, l'essai est effectué à l'un quelconque des réglages de temporisation.

B.8.9.2 Cas d'une perte d'une phase dans un réseau triphasé (pour les DPR tripolaires et tétrapolaires)

Le DPR est raccordé comme indiqué à la Figure B.3 et alimenté du côté source à 0,85 fois la tension assignée ou, dans le cas d'une plage de tensions assignées, à 0,85 fois la valeur la plus basse de la tension assignée.

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Une phase est alors interrompue en ouvrant l'interrupteur S_4; le DPR est alors soumis à l'essai de B.8.2.4.4. L'interrupteur S_4 étant refermé, un autre essai est effectué en ouvrant l'interrupteur S_5; le DPR est alors soumis à l'essai de B.8.2.4.4.

Ce mode opératoire d'essai est répété en raccordant la résistance variable *R* à chacune des deux autres phases successivement.

B.8.9.3 Cas de chute de tension causée par une surintensité résultant d'un défaut, à basse impédance, à la terre

Le DPR est raccordé selon la Figure B.3 et alimenté du côté source avec la tension assignée ou, dans le cas d'une plage de tensions assignées, avec la tension assignée la plus basse.

L'alimentation est ensuite interrompue en ouvrant S_1. Le DPR ne doit pas déclencher.

S_1 est ensuite refermé et la tension est réduite de la manière suivante:

a) pour les DPR destinés à être utilisés avec une alimentation triphasée: à 70 % de la tension assignée la plus basse;

b) pour les DPR destinés à être utilisés avec une alimentation monophasée: à une tension de 85 V appliquée comme suit:

   – pour les DPR à un pôle ou deux pôles: entre les pôles;

   – pour les DPR tripolaires ou tétrapolaires, déclarés aptes à une utilisation avec une alimentation monophasée (voir B.5 e)): entre chaque combinaison de deux pôles, raccordés selon les spécifications du fabricant.

NOTE Pour les besoins de la présente annexe, un DPR à un pôle est un appareil avec un pôle protégé contre les surintensités et un neutre non coupé (deux voies de passage de courant).

Un courant de valeur égale à $I_{\Delta n}$ est ensuite appliqué à a) et/ou à b), suivant le cas. Le DPR doit déclencher.

Séquence d'essai B II

B.8.10 Vérification du pouvoir de fermeture et de coupure différentiel résiduel en court-circuit

B.8.10.1 Généralités

Cet essai est destiné à vérifier l'aptitude du DPR à établir, supporter pendant une durée spécifiée, et interrompre les courants différentiels résiduels de court-circuit.

B.8.10.2 Conditions d'essai

Le DPR doit être soumis à essai conformément aux conditions générales d'essai en 8.3.2.6, suivant la Figure 9 de l'IEC 60947-1:2007/AMD1:2010, mais en étant raccordé d'une manière telle que le courant de court-circuit soit un courant différentiel résiduel.

L'essai est effectué sous une tension entre phase et neutre sur un seul pôle qui ne doit pas être le pôle neutre. Les parties conductrices par lesquelles le courant différentiel résiduel de court-circuit n'a pas à passer sont raccordées à la tension d'alimentation par leurs bornes d'alimentation.

Le cas échéant, le DPR est réglé à la valeur minimale du courant différentiel résiduel de fonctionnement et à la valeur maximale de la temporisation.

Si le DPR a plus d'une valeur de I_{cu}, chacune d'elles ayant une valeur correspondante de $I_{\Delta m}$, l'essai est effectué à la valeur maximale de $I_{\Delta m}$, sous la tension correspondante entre phase et neutre.

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B.8.10.3 Mode opératoire d'essai

La séquence de manœuvres à effectuer est:

O – *t* – CO

B.8.10.4 Conditions du DPR après essai

B.8.10.4.1 Après l'essai de B.8.10.3, le DPR ne doit présenter aucune détérioration susceptible de compromettre son emploi ultérieur et doit pouvoir, sans entretien :

- supporter une tension égale à deux fois sa tension assignée d'emploi maximale, dans les conditions de 8.3.3.4.1, point 4) de l'IEC 60947-1:2007. Pour les besoins de la présente norme, les circuits comprenant des appareils à semi-conducteurs doivent être déconnectés pour les essais;
- établir et couper son courant assigné sous sa tension assignée d'emploi maximale.

B.8.10.4.2 Le DPR doit pouvoir satisfaire aux essais spécifiés en B.8.2.4.4, mais à une valeur égale à 1,25 $I_{\Delta n}$ et sans mesurage de la durée de coupure. Cet essai est effectué sur un pôle pris au hasard.

Si le DPR a un courant différentiel résiduel de fonctionnement réglable, l'essai est effectué au réglage le plus bas, à un courant correspondant à 1,25 fois celui du réglage.

B.8.10.4.3 Le cas échéant, le DPR doit aussi être soumis à l'essai de B.8.2.4.5.

B.8.10.4.4 Les DPR fonctionnellement dépendants de la tension d'alimentation doivent aussi satisfaire aux essais de B.8.8 ou B.8.9, suivant le cas.

Séquence d'essai B III

B.8.11 Vérification des effets des conditions d'environnement

Cet essai est effectué conformément à l'IEC 60068-2-30.

La température supérieure doit être de 55 °C ± 2 °C (variante 1) et le nombre de cycles doit être

- 6 pour $I_{\Delta n} > 1$ A,
- 28 pour $I_{\Delta n} \leq 1$ A.

L'essai de 28 cycles doit être appliqué aux DPR ayant plusieurs réglages de courant différentiel résiduel de fonctionnement si l'un des réglages possibles est ≤ 1 A.

A la fin des cycles, le DPR doit pouvoir satisfaire aux essais de B.8.2.4.4, mais avec un courant différentiel résiduel de fonctionnement de 1,25 $I_{\Delta n}$ et sans mesurage de la durée de coupure. Il est nécessaire de n'effectuer qu'une seule vérification.

Le cas échéant, le DPR doit aussi être soumis à l'essai de B.8.2.4.5. Il est nécessaire de n'effectuer qu'une seule vérification.

B.8.12 Vérification de la compatibilité électromagnétique

B.8.12.1 Essais d'immunité

B.8.12.1.1 Généralités

L'Annexe J est applicable avec les exigences complémentaires suivantes:

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Pour les DPR avec réglage du courant différentiel résiduel de fonctionnement et/ou de la temporisation, les essais doivent être effectués au réglage minimum.

Le DPR doit être alimenté à la tension assignée d'emploi ou, dans le cas d'une plage de tensions assignées d'emploi, à toute tension appropriée comprise dans cette plage.

Les essais sont réalisés sans courant de charge mais avec le courant différentiel résiduel, lorsque celui-ci est spécifié.

Les résultats des essais d'immunité doivent être évalués sur la base des critères de comportement indiqués en J.2.1, avec les spécifications suivantes:

Critère de comportement A:

Pour l'étape 1, le DPR ne doit pas déclencher lorsqu'il est chargé à 0,3 $I_{\Delta n}$ sur un pôle choisi au hasard; les fonctions de surveillance, le cas échéant, doivent indiquer correctement l'état.

Pour l'étape 2, le DPR doit déclencher à chaque fréquence d'essai lorsqu'il est chargé à 1,25 $I_{\Delta n}$; le temps de maintien à chaque fréquence ne doit pas être inférieur à la durée maximale de coupure spécifiée pour $I_{\Delta n}$ en B.4.2.4.1 ou en B.4.2.4.2, suivant le cas.

Après ces essais, le fonctionnement correct du DPR doit être vérifié dans le cas d'une apparition soudaine d'un courant différentiel résiduel selon B.8.2.4.4, mais à $I_{\Delta n}$ seulement.

Critère de comportement B:

Pendant l'essai, le DPR ne doit pas déclencher lorsqu'il est chargé à 0,3 $I_{\Delta n}$ sur un pôle choisi au hasard; les fonctions de surveillance, le cas échéant, peuvent être temporairement affectées. Après l'essai, le fonctionnement correct du DPR doit être vérifié dans le cas d'une apparition soudaine d'un courant différentiel résiduel, selon B.8.2.4.4, mais à $I_{\Delta n}$ seulement.

B.8.12.1.2 Décharges électrostatiques

L'Annexe J est applicable, en particulier J.2.2.

L'installation d'essai doit être conforme à la Figure J.1 et la Figure J.3.

Le critère de comportement B de B.8.12.1.1 est applicable, mis à part que le DPR peut déclencher pendant l'essai. Si c'est le cas, un nouvel essai doit être effectué au niveau immédiatement inférieur, et le DPR ne doit pas déclencher.

B.8.12.1.3 Champs électromagnétiques RF rayonnés

L'Annexe J est applicable, en particulier J.2.3.

L'installation d'essai doit être conforme à la Figure J.4.

Les raccordements d'essai doivent être conformes à la Figure 5 ou la Figure 6 de l'IEC 61000-4-3:2006, suivant le cas, en prenant en considération les instructions du fabricant pour l'installation. Le type de câble utilisé doit être indiqué dans le rapport d'essai.

Le critère de comportement A de B.8.12.1.1 est applicable.

B.8.12.1.4 Transitoires électriques rapides en salves (TER/S)

L'Annexe J est applicable, en particulier J.2.4.

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Les raccordements d'essai doivent être conformes à la Figure 4 de l'IEC 61000-4-4:2012.

L'installation d'essai doit être conforme à la Figure J.5 pour l'essai des lignes d'alimentation et à la Figure J.6 pour l'essai des lignes de signaux, en prenant en considération les instructions du fabricant pour l'installation.

Le critère de comportement B de B.8.12.1.1 est applicable.

B.8.12.1.5 Ondes de choc

L'Annexe J est applicable, en particulier J.2.5.

Les conditions d'essai de 7.2 de l'IEC 61000-4-5:2014 sont applicables.

Par commodité, le montage spécifié en B.8.12.1.4 peut être utilisé mais l'emploi du plan de référence de terre est facultatif.

Les raccordements d'essai doivent être conformes aux Figures 6, 7, 8 ou 9 de l'IEC 61000-4-5:2014, en prenant en considération les instructions du fabricant pour l'installation.

Le critère de comportement B de B.8.12.1.1 est applicable.

B.8.12.1.6 Perturbations conduites, induites par les champs RF (mode commun)

L'Annexe J est applicable, en particulier J.2.6.

Le critère de comportement A de B.8.12.1.1 est applicable.

B.8.12.2 Essais d'émission

B.8.12.2.1 Généralités

L'Annexe J est applicable avec les exigences complémentaires suivantes:

Le DPR doit être alimenté à la tension assignée d'emploi ou, dans le cas d'une plage de tensions assignées d'emploi, à toute tension appropriée comprise dans cette plage.

Les essais doivent être effectués sans courant de charge et sans courant différentiel résiduel.

B.8.12.2.2 Perturbations conduites aux fréquences radioélectriques (150 kHz à 30 MHz)

L'Annexe J est applicable, en particulier J.3.2.

B.8.12.2.3 Perturbations rayonnées aux fréquences radioélectriques (30 MHz à 1 000 MHz)

L'Annexe J est applicable, en particulier J.3.3.

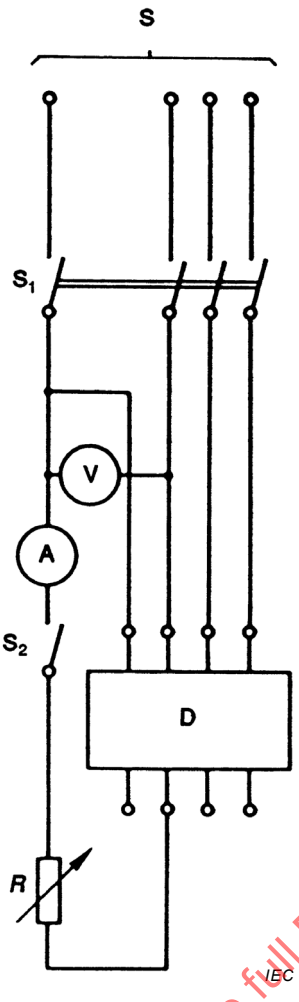
B.8.13 Essais pour des variations ou des interruptions de tension et pour des creux de tension

NOTE Pour une définition des creux de tension, voir l'IEC 61000-4-11.

Les essais correspondants de B.8.8 et B.8.9 sont considérés comme adaptés pour couvrir les exigences CEM.

Aucun essai supplémentaire n'est donc exigé.

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S = Alimentation

V = Voltmètre

A = Ampèremètre

S_1 = Interrupteur pour tous les pôles

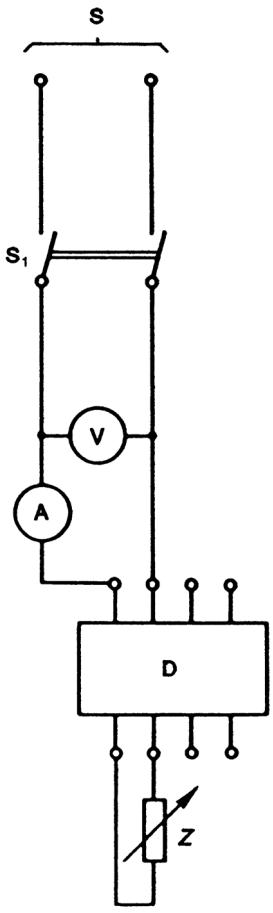
S_2 = Interrupteur unipolaire

D = DPR soumis à essai

R = Résistance réglable

Figure B.1 – Circuit d'essai pour la vérification de la caractéristique de fonctionnement (voir B.8.2)

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S = Alimentation

S_1 = Interrupteur bipolaire

V = Voltmètre

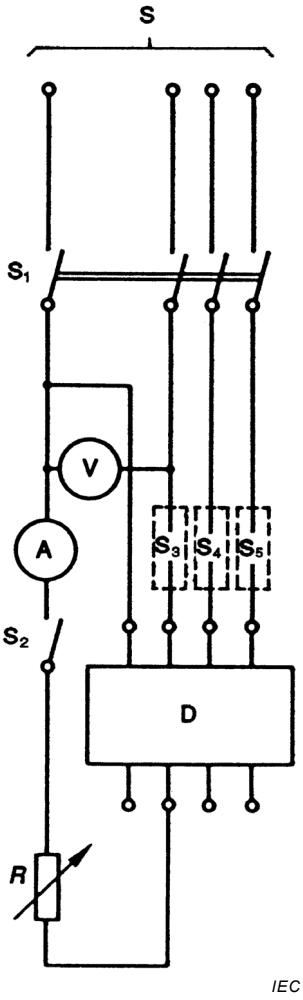
A = Ampèremètre

D = DPR soumis à essai

Z = Impédance réglable

Figure B.2 – Circuit d'essai pour la vérification de la valeur limite du courant de non-fonctionnement en cas de surintensités (voir B.8.5)

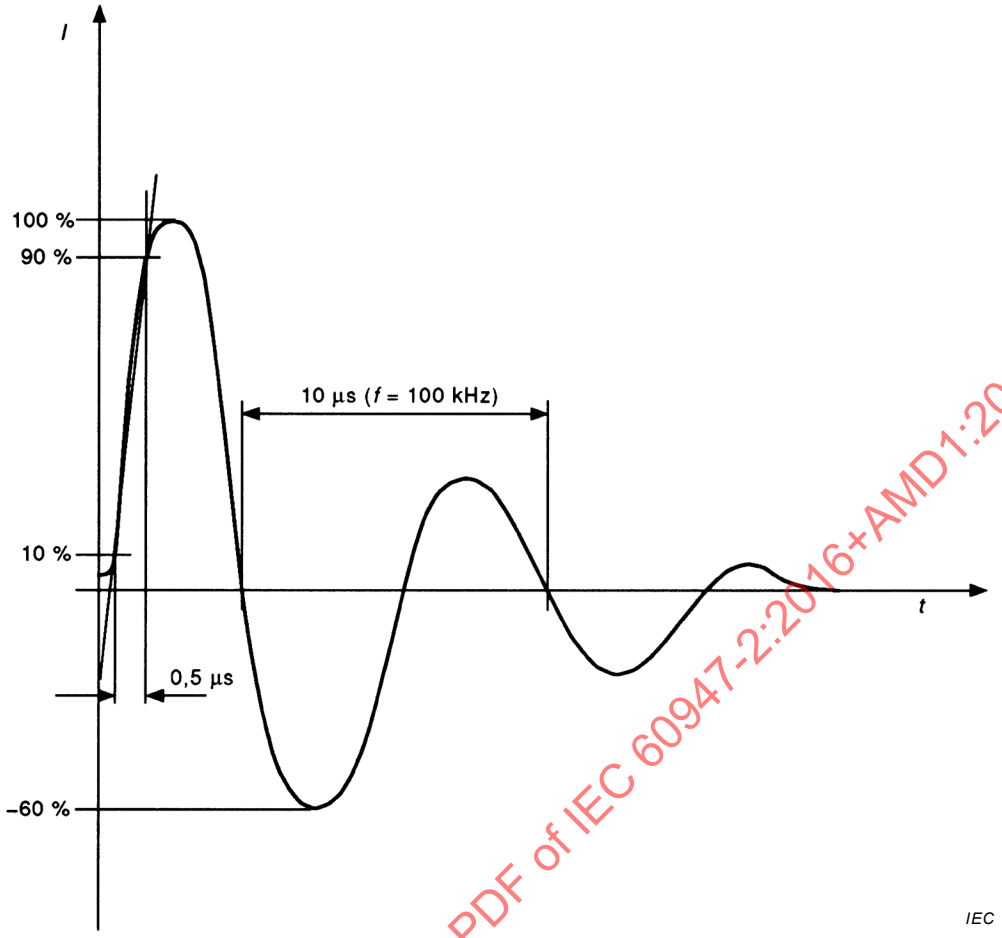
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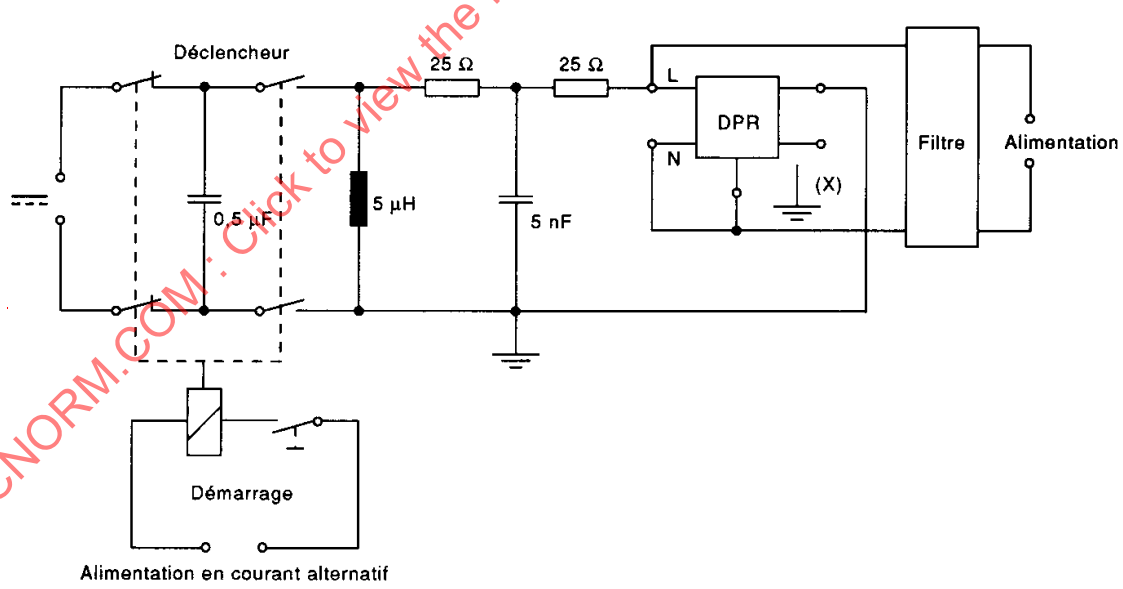
S = Alimentation
V = Voltmètre
A = Ampèremètre
S_1 = Interrupteur pour tous les pôles
S_2 = Interrupteur unipolaire
S_3, S_4, S_5 = Interrupteurs unipolaires coupant une phase à tour de rôle
D = DPR soumis à essai
R = Résistance réglable

Figure B.3 – Circuit d'essai pour la vérification du comportement des DPR classés selon B.3.1.2.2 (voir B.8.9)

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~~Figure B.4 – Onde de courant 0,5 µs/100 kHz~~



~~(X) Borne de terre, si elle existe, raccordée à la borne du neutre, si elle est repérée ou en l'absence d'un tel repérage à n'importe laquelle des bornes de phase.~~

~~NOTE Les valeurs des composants du circuit sont données seulement comme lignes directrices et peuvent nécessiter un réglage afin de satisfaire aux exigences concernant la forme d'onde de la Figure B.4.~~

~~Figure B.5 – Exemple de circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs~~

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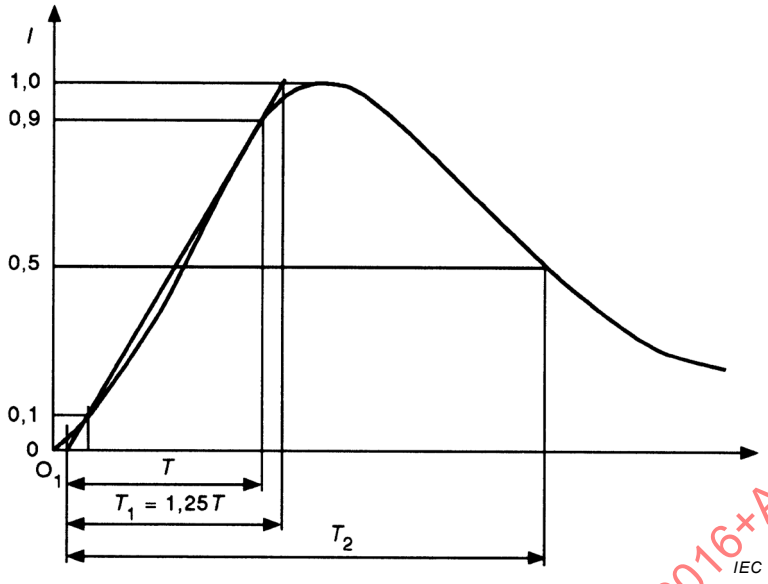
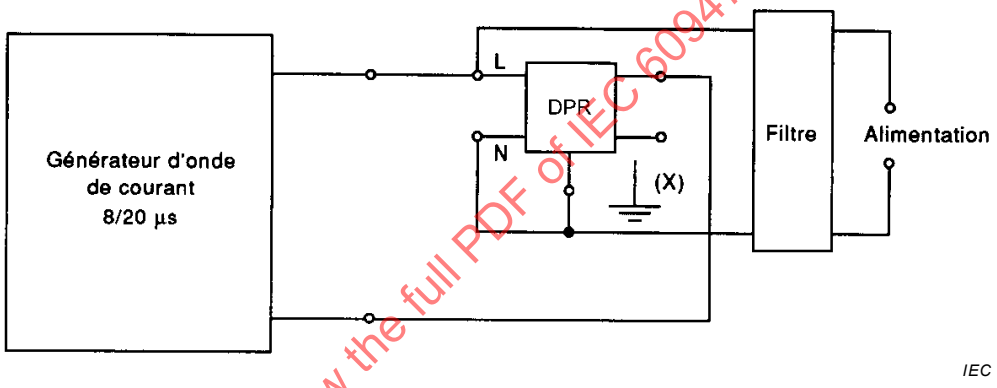


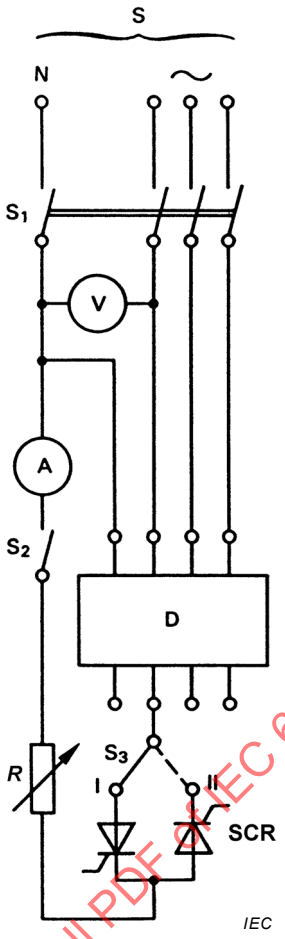
Figure B.6 – Onde de courant de choc 8/20 µs



(X) Borne de terre, si elle existe, raccordée à la borne du neutre, si elle est repérée ou en l'absence d'un tel repérage à n'importe laquelle des bornes de phase.

Figure B.7 – Circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs en cas d'amorçage sans courant de suite (B.8.6.3)

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S = Alimentation

V = Voltmètre

A = Ampèremètre (mesurant les valeurs efficaces)

D = DPR soumis à essai

SCR = Thyristors

R = Résistance variable

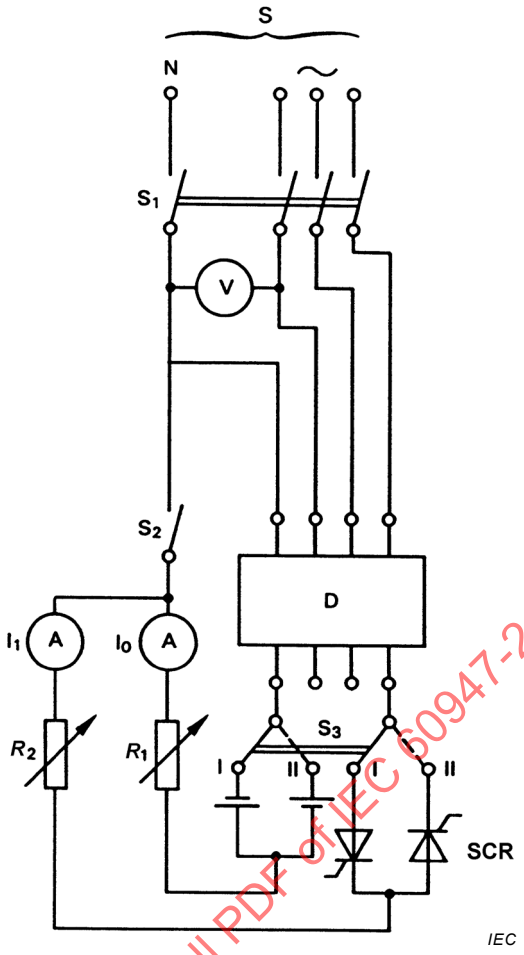
S_1 = Interrupteur pour tous les pôles

S_2 = Interrupteur unipolaire

S_3 = Interrupteur bipolaire

Figure B.8 – Circuit d'essai pour la vérification du fonctionnement correct des DPR, dans le cas de courants différentiels résiduels continus pulsés (voir B.8.7.2.1, B.8.7.2.2 et B.8.7.2.3)

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S = Alimentation

V = Voltmètre

A = Ampèremètre (mesurant les valeurs efficaces)

D = DPR soumis à essai

SCR = Thyristors

R_1, R_2 = Résistance variable

S_1 = Interrupteur pour tous les pôles

S_2 = Interrupteur unipolaire

S_3 = Interrupteur bipolaire

Figure B.9 – Circuit d'essai pour la vérification du fonctionnement correct des DPR, dans le cas d'un courant différentiel résiduel continu pulsé auquel est superposé un courant différentiel résiduel continu lissé (voir B.8.7.2.4)

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B.1 Généralités

B.1.1 Préambule

Pour assurer la protection contre les dangers occasionnés par les chocs électriques, des appareils agissant sous l'effet des courants différentiels résiduels sont utilisés comme mesure de protection. Ces appareils sont fréquemment utilisés en conjonction avec un disjoncteur ou comme partie intégrante de celui-ci pour répondre à un double objectif, c'est-à-dire:

– assurer la protection des installations contre les surcharges et contre les courants de court-circuit;

– assurer la protection des personnes contre les contacts indirects, c'est-à-dire les augmentations dangereuses du potentiel à la terre dues à une isolation défectueuse.

NOTE 1 Dans l'IEC 61140:2016, le terme "protection des personnes contre les contacts indirects" est remplacé par "protection en cas de défaut".

Les appareils à courant différentiel résiduel peuvent assurer également une protection supplémentaire contre les dangers d'incendie ou autres dangers qui peuvent se développer à la suite d'un défaut à la terre de nature persistante ne pouvant pas être détecté par l'appareil de protection contre les surintensités.

Les appareils à courant différentiel résiduel dont le courant différentiel résiduel assigné ne dépasse pas 30 mA sont également utilisés comme moyens de protection supplémentaires contre les contacts directs en cas de défaillance des dispositifs de protection prévus.

NOTE 2 Dans l'IEC 61140:2016, le terme "protection des personnes contre les contacts directs" est remplacé par "protection principale".

Les exigences pour l'installation de tels appareils sont spécifiées dans les différentes sections de la série IEC 60364.

La présente annexe inclut des définitions, des exigences supplémentaires et des essais pour les disjoncteurs à protection incorporée par courant différentiel résiduel de type B, pour couvrir l'utilisation de nouvelles technologies électroniques dans les matériels pouvant engendrer des courants différentiels résiduels particuliers, non couverts par les caractéristiques du type AC ou du type A.

NOTE 3 La présente annexe satisfait aux exigences pertinentes de l'IEC 60755.

B.1.2 Domaine d'application et objet

La présente annexe est applicable aux disjoncteurs assurant la protection par courant différentiel résiduel (DPR). Elle contient les exigences pour les appareils qui assurent à la fois la détection des courants différentiels résiduels, comparent ces mesurages à une valeur réglée au préalable et provoquent la coupure du circuit protégé lorsque cette valeur est dépassée.

La présente annexe est applicable:

- aux disjoncteurs conformes au présent document pour lesquels la fonction de courant différentiel résiduel constitue une partie intégrée (désignés ci-après DPR intégrés);
- aux DPR combinant un appareil à courant différentiel résiduel (désignés ci-après unités c.r.) et un disjoncteur conforme au présent document; ils peuvent être combinés, mécaniquement et électriquement, soit en usine, soit sur le site par l'utilisateur, suivant les instructions du fabricant.

La présente annexe couvre les DPR de type AC, de type A et de type B (voir B.4.4).

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La présente annexe n'est applicable qu'aux DPR destinés à être utilisés dans des circuits à courant alternatif.

NOTE Les organes de détection du courant du neutre peuvent, le cas échéant, être extérieurs au disjoncteur ou à la combinaison disjoncteur-appareil à courant différentiel résiduel, suivant le cas.

La fonction "courant différentiel résiduel" des DPR visés par la présente annexe peut ou non dépendre fonctionnellement de la tension d'alimentation. Les DPR dépendant d'une autre source d'alimentation ne sont pas visés par la présente annexe.

La présente annexe n'est pas applicable aux matériels dont les organes de détection du courant (à l'exception des organes de détection du courant du neutre) ou l'appareil de traitement sont montés séparément du disjoncteur. Les exigences pour de tels appareils sont données à l'Annexe M.

La présente annexe a pour objet de spécifier:

a) les caractéristiques spécifiques de la fonction de courant différentiel résiduel;

b) les exigences spécifiques auxquelles doivent satisfaire les DPR:
   – dans les conditions normales du circuit;
   – dans les conditions anormales du circuit, qu'elles se rapportent ou non au courant différentiel résiduel;

c) les essais qui doivent être effectués pour vérifier la conformité aux exigences du point b) ci-dessus, ainsi que les modes opératoires d'essai appropriés, comprenant les essais de compatibilité électromagnétique;

d) les informations correspondantes sur le matériel.

B.2 Termes et définitions

En complément de l'Article 2 du présent document, les termes et définitions suivants s'appliquent:

B.2.1 Termes et définitions relatifs aux courants circulant entre les parties actives et la terre

B.2.1.1
courant de défaut à la terre
courant qui s'écoule à la terre lors d'un défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
courant de fuite à la terre
courant qui s'écoule des parties actives de l'installation à la terre, en l'absence de tout défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Termes et définitions relatives à l'alimentation d'un DPR

B.2.2.1
grandeur d'alimentation
grandeur électrique qui, seule ou en combinaison avec d'autres grandeurs électriques, doit être appliquée à un DPR pour qu'il puisse fonctionner dans des conditions spécifiées

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B.2.2.2
grandeur d'alimentation d'entrée
grandeur d'alimentation par laquelle le DPR est mis en action, lorsqu'elle est appliquée dans des conditions spécifiées

Note 1 à l'article: Ces conditions peuvent impliquer, par exemple, l'alimentation de certains organes auxiliaires.

[SOURCE: IEC 60050-442:1998, 442-05-58, modifiée – Dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.2.3
courant différentiel résiduel
I_{Δ}
somme vectorielle des courants qui circulent dans le circuit principal du DPR, exprimée en valeur efficace

[SOURCE: IEC 60050-442:1998, 442-05-19, modifiée – La définition a été adaptée pour s'appliquer aux DPR.]

B.2.2.4
courant différentiel résiduel de fonctionnement
$I_{\Delta n}$
valeur du courant différentiel résiduel qui fait fonctionner le DPR dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-20, modifiée – Dans le terme, "résiduel" a été ajouté, et dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.2.5
courant différentiel résiduel de non-fonctionnement
$I_{\Delta no}$
valeur du courant différentiel résiduel pour laquelle (et au-dessous de laquelle) le DPR ne fonctionne pas dans des conditions spécifiées

[SOURCE: IEC 60050-442:1998, 442-05-21, modifiée – Symbole introduit, dans le terme, "résiduel" a été ajouté et, dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.3 Termes et définitions relatifs au fonctionnement et aux fonctions des DPR

B.2.3.1
disjoncteur à protection par courant différentiel résiduel incorporée
DPR
disjoncteur (voir 2.1) conçu pour provoquer l'ouverture des contacts lorsque le courant différentiel résiduel atteint une valeur donnée dans des conditions spécifiées

B.2.3.2
DPR fonctionnellement indépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et d'évaluation et le moyen de déclenchement (voir B.2.3.6) ne dépendent pas de la tension d'alimentation

B.2.3.3
DPR fonctionnellement dépendant de la tension d'alimentation
DPR pour lequel les fonctions de détection et/ou d'évaluation, et/ou le moyen de déclenchement (voir B.2.3.6) ne dépendent pas de la tension d'alimentation

Note 1 à l'article: Il est entendu que la tension d'alimentation pour la détection, l'évaluation ou l'interruption est celle appliquée au DPR.

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B.2.3.4
détection (d'un courant différentiel résiduel)
fonction consistant à détecter la présence d'un courant différentiel résiduel

Note 1 à l'article: Cette fonction peut être remplie, par exemple, par un transformateur intégrant la somme vectorielle des courants.

[SOURCE: IEC 60050-442:1998, 442-05-24, modifiée – "Résiduel" a été ajouté dans le terme et dans la définition.]

B.2.3.5
évaluation
fonction qui consiste à donner au DPR la possibilité de fonctionner quand le courant différentiel détecté dépasse une valeur de référence spécifiée

[SOURCE: IEC 60050-442:1998, 442-05-25, modifiée – Dans le terme, "(d'un courant différentiel résiduel)" a été supprimé et, dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.3.6
coupure
fonction consistant à amener automatiquement les contacts principaux du DPR de la position de fermeture à la position d'ouverture, interrompant ainsi le ou les courants qui les traversent

[SOURCE: IEC 60050-442:1998, 442-05-26, modifiée – Dans le terme, "(pour un dispositif de coupure différentiel)" a été supprimé et, dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.3.7
temps limite de non-réponse
temps maximal pendant lequel une valeur de courant différentiel résiduel supérieure à la valeur assignée du courant différentiel résiduel de non-fonctionnement peut être appliquée au DPR, sans provoquer son fonctionnement effectif

[SOURCE: IEC 60050-442:1998, 442-05-23, modifiée – Dans la définition, "dispositif de coupure différentiel" a été remplacé par "DPR" et "assignée" a été ajouté.]

B.2.3.8
DPR temporisé
DPR spécialement conçu pour atteindre une valeur prédéterminée du temps limite de non-réponse correspondant à une valeur donnée du courant différentiel résiduel

[SOURCE: IEC 60050-442:1998, 442-05-05, modifiée – Dans le terme et la définition, "dispositif de coupure différentiel" a été remplacé par "DPR".]

B.2.3.9
DPR à réarmement
DPR muni d'une unité c.r. qui doit être réarmé intentionnellement par des moyens différents des moyens de manœuvre du DPR, à la suite d'un courant différentiel résiduel, avant que celui-ci puisse se refermer

B.2.3.10
appareil d'essai
appareil destiné à vérifier, en simulant un courant différentiel résiduel, que le DPR fonctionne

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B.2.4 Termes et définitions relatifs aux valeurs et aux plages des grandeurs d'alimentation

B.2.4.1

valeur limite de surintensité de non-fonctionnement dans le cas d'une charge monophasée

valeur maximale de surintensité dans un circuit monophasé qui, en l'absence de courant différentiel résiduel, peut circuler dans un DPR (quel que soit le nombre de pôles) sans provoquer la manœuvre de celui-ci

Note 1 à l'article: Voir B.7.2.7

B.2.4.2

pouvoir de fermeture et de coupure différentiel résiduel en court-circuit

valeur de la composante alternative d'un courant différentiel résiduel de court-circuit présumé qu'un DPR est capable d'établir, de supporter pendant son temps de déclenchement et d'interrompre dans des conditions spécifiées d'utilisation et de comportement

B.3 Classification

B.3.1 Classification selon le mode de fonctionnement de la fonction de courant différentiel résiduel

B.3.1.1 DPR fonctionnellement indépendant de la tension d'alimentation (voir B.2.3.2)

B.3.1.2 DPR fonctionnellement dépendant de la tension d'alimentation (voir B.2.3.3 et B.7.2.12)

B.3.1.2.1 S'ouvrant automatiquement en cas de défaillance de la tension d'alimentation avec ou sans retard

B.3.1.2.2 Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation

Ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation, mais capable de déclencher dans des conditions spécifiées en cas de défaut à la terre apparaissant lors d'une défaillance de la tension d'alimentation.

NOTE Les cas indiqués dans ce paragraphe comprennent les DPR incapables de s'ouvrir automatiquement lorsqu'il n'existe pas de situation dangereuse.

B.3.2 Classification selon la possibilité de réglage du courant différentiel résiduel de fonctionnement

B.3.2.1 DPR à courant différentiel résiduel de fonctionnement unique

B.3.2.2 DPR à réglages multiples de courant différentiel résiduel de fonctionnement

– par échelons;

– par variation continue.

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B.3.3 Classification selon la temporisation de la fonction de courant différentiel résiduel

B.3.3.1 DPR sans temporisation: type non temporisé

B.3.3.2 DPR avec temporisation: type temporisé (voir B.2.3.8)

B.3.3.2.1 DPR à temporisation non réglable

B.3.3.2.2 DPR à temporisation réglable

– par échelons;

– par variation continue.

B.3.4 Classification selon le comportement en présence d'une composante continue

B.3.4.1 DPR de type AC (voir B.4.4.1)

B.3.4.2 DPR de type A (voir B.4.4.2)

B.3.4.3 DPR de type B (voir B.4.4.3)

B.4 Caractéristiques des DPR pour leur fonction de courant différentiel résiduel

B.4.1 Valeurs assignées

B.4.1.1 Courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)

Valeur efficace d'un courant sinusoïdal différentiel résiduel de fonctionnement (voir B.2.2.4) assignée par le fabricant au DPR, à laquelle celui-ci doit fonctionner dans des conditions spécifiées.

Pour un DPR à réglages multiples de courant différentiel résiduel de fonctionnement, le réglage le plus élevé pour désigner ses caractéristiques assignées est utilisé. Voir cependant l'Article B.5 concernant le marquage.

B.4.1.2 Courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)

Valeur efficace du courant sinusoïdal différentiel résiduel de non-fonctionnement (voir B.2.2.5) assignée par le fabricant, à laquelle le DPR ne fonctionne pas dans des conditions spécifiées.

B.4.1.3 Pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit ($I_{\Delta m}$)

Valeur efficace de la composante alternative du courant différentiel résiduel de court-circuit présumé (voir B.2.4.2), assignée au DPR par le fabricant, que le DPR peut fermer, véhiculer et couper dans des conditions spécifiées.

B.4.2 Valeurs préférentielles et valeurs limites

B.4.2.1 Valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)

Les valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné sont:

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A.

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Des valeurs plus élevées peuvent être exigées.

$I_{\Delta n}$ peut s'exprimer en pourcentage du courant assigné.

B.4.2.2 Valeur minimale du courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)

La valeur minimale du courant différentiel résiduel de non-fonctionnement assigné est 0,5 $I_{\Delta n}$.

B.4.2.3 Valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée

La valeur limite de la surintensité de non-fonctionnement dans le cas d'une charge monophasée doit être conforme à B.7.2.7.

B.4.2.4 Caractéristiques de fonctionnement

B.4.2.4.1 Type non temporisé

La caractéristique de fonctionnement pour un type non temporisé est donnée dans le Tableau B.1.

Tableau B.1 – Caractéristique de fonctionnement dans le cas d'un courant sinusoïdal différentiel résiduel pour le type non temporisé

Courant différentiel résiduel [c]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Durée maximale de coupure s	0,3	0,15	0,04	0,04

NOTE Ces valeurs sont obtenues à partir de l'IEC 60479-1 et sont valides pour une fréquence de 50 Hz et de 60 Hz.

[a] Pour les DPR avec $I_{\Delta n} \leq 30$ mA, 0,25 A peut être utilisé à la place de 5 $I_{\Delta n}$.

[b] Pour les DPR avec $I_{\Delta n} \leq 30$ mA, 0,5 A peut être utilisé à la place de 10 $I_{\Delta n}$.

[c] Pour les DPR de type A et de type B, des facteurs multiplicateurs peuvent être applicables – voir B.8.7 et B.8.8.

Les DPR avec $I_{\Delta n} \leq 30$ mA doivent être du type non temporisé.

B.4.2.4.2 Type temporisé

B.4.2.4.2.1 **Temps limite de non-réponse** (voir B.2.3.7)

Pour un type temporisé, le temps limite de non-réponse est défini à 2 $I_{\Delta n}$ et doit être déclaré par le fabricant.

Le temps limite de non-réponse minimal est 0,06 s.

Les valeurs préférentielles de temps limite de non-réponse sont:

0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s.

B.4.2.4.2.2 Caractéristiques de fonctionnement

Pour les DPR avec un temps limite de non-réponse de 0,06 s, les caractéristiques de fonctionnement sont données dans le Tableau B.2.

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Tableau B.2 – Caractéristiques de fonctionnement dans le cas de courants sinusoïdaux différentiels résiduels, pour le type temporisé ayant un temps limite de non-réponse de 0,06 s

Courant différentiel résiduel [a]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Durée maximale de coupure s	0,5	0,2	0,15	0,15
Temps limite de non-réponse s	-	0,06	-	-
NOTE Ces valeurs sont obtenues à partir de l'IEC 60479-1 et sont valides pour une fréquence de 50 Hz et de 60 Hz. [a] Pour les DPR de type A et de type B, des facteurs multiplicateurs peuvent être applicables – voir B.8.7 et B.8.8.				

Pour les DPR avec un temps limite de non-réponse supérieur à 0,06 s, le fabricant doit déclarer les durées maximales de coupure pour $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ et 10 $I_{\Delta n}$.

Dans le cas d'un DPR à caractéristique temps/courant inverse, le fabricant doit déclarer la caractéristique courant différentiel résiduel/durée de coupure.

B.4.3 Valeur du pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit ($I_{\Delta m}$)

La valeur minimale de $I_{\Delta m}$ est 25 % de I_{cu}.

Des valeurs supérieures peuvent être soumises à essai et déclarées par le fabricant.

B.4.4 Caractéristiques de fonctionnement dans le cas d'un courant de défaut à la terre avec ou sans composante continue

B.4.4.1 DPR du type AC

DPR pour lequel le déclenchement est assuré pour des courants différentiels résiduels alternatifs sinusoïdaux, sans composante continue, appliqués subitement ou de façon progressive.

B.4.4.2 DPR du type A

DPR pour lequel le déclenchement est assuré pour des courants différentiels résiduels alternatifs sinusoïdaux en présence de courants différentiels résiduels continus pulsés spécifiés, avec ou sans un niveau spécifié de courant continu superposé (± 6 mA), appliqués subitement ou de façon progressive.

B.4.4.3 DPR du type B

DPR pour lequel le déclenchement est assuré comme pour ceux du type A, et en supplément:

– pour des courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz;
– pour des courants différentiels résiduels composites, qu'ils soient appliqués subitement ou de façon progressive, et destinés à des circuits alimentés entre phase et neutre, ou entre phase et conducteur milieu relié à la terre;
– pour des courants différentiels résiduels alternatifs auxquels est superposé un courant continu lissé de valeur égale à 0,4 fois le courant différentiel résiduel assigné ($I_{\Delta n}$) ou 10 mA, la valeur retenue étant la plus élevée;

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– pour des courants différentiels résiduels continus pulsés auxquels est superposé un courant continu lissé de valeur égale à 0,4 fois le courant différentiel résiduel assigné ($I_{\Delta n}$) ou 10 mA, la valeur retenue étant la plus élevée;

– pour des courants différentiels résiduels continus qui peuvent provenir de circuits redresseurs, c'est-à-dire:

  • redresseur simple alternance entre phases pour les DPR bipolaires, tripolaires et tétrapolaires;

  • redresseur triphasé simple alternance ou pont redresseur triphasé double alternance pour les DPR tripolaires et tétrapolaires;

– pour des courants différentiels résiduels continus lissés.

B.5 Marquage

Chaque DPR doit être marqué comme spécifié en 5.2 et en outre, conformément au Tableau B.3.

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Tableau B.3 – Informations sur le matériel

Elément	Information	Emplacement du marquage	
		DPR intégré	Unité c.r.
B1.1	l'organe de manœuvre de l'appareil d'essai, par la lettre T (voir aussi B.7.2.6)	Visible	Visible
B1.2	caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composante continue: – pour les DPR de type AC avec le symbole  (IEC 60417-6148:2012-01) – pour les DPR de type A avec le symbole  (IEC 60417-6149:2012-01) – pour les DPR de type B avec le symbole  (IEC 60417-6398:2017-12) ou  (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	Visible
B1.3	courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$	Visible	Visible
B2.1	réglages du courant différentiel résiduel de fonctionnement, le cas échéant	Marqué	Marqué
B2.2	temps limite de non-réponse à 2 $I_{\Delta n}$, pour le type temporisé, par le symbole Δt suivi du temps limite de non-réponse	Marqué	Marqué
B2.3	aptitude à une utilisation avec une alimentation triphasée seulement, avec le symbole  (IEC 60417-6364:2016-07)	Marqué	Marqué
B2.4	tension(s) assignée(s) si elle(s) diffère(nt) de celle(s) du disjoncteur	-	Marqué
B2.5	valeur (ou plage de valeurs) de la fréquence assignée si elle diffère de celle du disjoncteur	-	Marqué
B2.6	l'indication $I_n \leq$ ...A (I_n étant le courant assigné maximal du disjoncteur auquel l'unité c.r. peut être associée)	-	Marqué
B2.7	nom du fabricant ou marque de fabrique	-	Marqué
B2.8	désignation du type ou référence du catalogue	-	Marqué
B2.9	identification du (des) disjoncteur(s) avec le(s)quel(s) l'unité c.r. peut être assemblée, sauf si un assemblage incorrect (rendant la protection inopérante) est impossible du fait de la conception	-	Marqué
B2.10	IEC 60947-2	-	Marqué
B3.1	pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit $I_{\Delta m}$ s'il est supérieur à 25 % de I_{cu} (voir B.4.3)	Documentation	Documentation
B3.2	schéma des connexions, y compris celles du circuit d'essai et, le cas échéant, celles de la ligne pour les DPR dépendant de la tension d'alimentation	Documentation	Documentation
B3.3	valeur du courant différentiel résiduel de non-fonctionnement assigné $I_{\Delta no}$ s'il est supérieur à 0,5 $I_{\Delta n}$	Documentation	Documentation

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Elément	Information	Emplacement du marquage	
		DPR intégré	Unité c.r.
Légende			
Visible:	visible depuis le devant lorsque le disjoncteur est installé en configuration de service et que l'organe de commande est accessible		
Marqué:	marqué sur le matériel		
Documentation:	spécifié dans la documentation du fabricant		

B.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

B.7 Exigences relatives à la conception et au fonctionnement

B.7.1 Exigences relatives à la conception

Il ne doit pas être possible de modifier la caractéristique de fonctionnement d'un DPR par des moyens autres que ceux spécifiquement destinés au réglage du courant différentiel résiduel de fonctionnement assigné ou de la temporisation définie.

Le passage d'un réglage à un autre ne doit être possible que par une action délibérée, telle que l'utilisation d'un outil, la saisie d'un mot de passe ou des moyens équivalents.

Les DPR combinant une unité c.r. appropriée et un disjoncteur associé doivent être conçus et réalisés de manière telle que:

– l'assemblage de l'unité c.r. adaptable et du disjoncteur associé n'exige aucune liaison mécanique et/ou électrique pouvant affecter défavorablement l'installation ou présentant des risques pour l'utilisateur;
– l'adjonction de l'unité c.r. adaptable ne compromet en aucune manière le fonctionnement normal ou les performances du disjoncteur;
– l'unité c.r. n'est pas endommagée de façon permanente à la suite des courants de court-circuit au cours des séquences d'essai.

B.7.2 Exigences relatives au fonctionnement

B.7.2.1 Fonctionnement en cas de courant différentiel résiduel

Le DPR doit s'ouvrir automatiquement lors de l'apparition d'un quelconque courant de fuite ou d'un quelconque courant de défaut à la terre supérieur ou égal au courant différentiel résiduel de fonctionnement assigné pendant une durée supérieure au temps limite de non-réponse.

Le fonctionnement des DPR doit être conforme aux exigences de durée spécifiées en B.4.2.4. La conformité doit être vérifiée par les essais décrits en B.8.1.2.

B.7.2.2 Pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit ($I_{\Delta m}$)

Les DPR doivent satisfaire aux exigences d'essai de B.8.11.

B.7.2.3 Aptitude au fonctionnement en service

Les DPR doivent satisfaire aux essais de B.8.1.2.1.

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B.7.2.4 Effets des conditions d'environnement

Les DPR doivent fonctionner de manière satisfaisante, compte tenu des effets des conditions d'environnement.

La conformité est vérifiée par l'essai décrit en B.8.12.

B.7.2.5 Propriétés diélectriques

Les DPR doivent satisfaire aux essais de B.8.3.

B.7.2.6 Appareil d'essai

Les DPR doivent être munis d'un appareil d'essai permettant à l'appareil de détection d'être traversé par un courant simulant un courant différentiel résiduel, afin de permettre de vérifier périodiquement par essai l'aptitude au fonctionnement des DPR.

L'appareil d'essai doit satisfaire aux essais de B.8.4.

Aucune tension ne doit apparaître sur le conducteur de protection lors du fonctionnement de l'appareil d'essai, s'il y a lieu.

Il ne doit pas être possible d'alimenter le circuit protégé par la manœuvre de l'appareil d'essai lorsque le DPR est en position d'ouverture.

L'appareil d'essai ne doit pas être le seul moyen d'effectuer la manœuvre d'ouverture et n'est pas destiné à être utilisé pour cette fonction.

L'organe de manœuvre de l'appareil d'essai doit être désigné par la lettre T et sa couleur ne doit être ni rouge ni verte; il convient d'employer, de préférence, une couleur claire.

NOTE L'appareil d'essai est seulement destiné à vérifier la fonction de déclenchement, et non la valeur à laquelle cette fonction s'accomplit, par rapport au courant assigné différentiel résiduel de fonctionnement et à la durée de coupure.

B.7.2.7 Valeur du courant de surcharge de non-fonctionnement pour un circuit de charge monophasé

Les DPR doivent supporter sans déclencher la plus faible des deux valeurs suivantes de surintensité:

– 6 I_n,
– 80 % du courant maximal de réglage du déclencheur de court-circuit.

La conformité est vérifiée par l'essai décrit en B.8.5.

Cet essai n'est toutefois pas nécessaire dans le cas de DPR de catégorie de sélectivité B puisque les exigences de ce paragraphe sont vérifiées pendant la séquence d'essai IV (ou la séquence d'essai VI).

NOTE Les essais pour les circuits de charge polyphasés en régime équilibré sont considérés comme étant satisfaits par les exigences du présent paragraphe.

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B.7.2.8 Résistance des DPR aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc

B.7.2.8.1 Résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

Les DPR doivent satisfaire à l'essai de B.8.6.2.

B.7.2.8.2 Résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Les DPR doivent satisfaire à l'essai de B.8.6.3.

B.7.2.9 Comportement des DPR du type A en cas de courant de défaut à la terre comprenant une composante continue

Le comportement des DPR en cas de courant de défaut à la terre comprenant une composante continue doit être tel que les durées maximales de coupure définies dans le Tableau B.1 et le Tableau B.2, suivant le cas, doivent également être respectées, les valeurs du courant d'essai spécifiées étant cependant multipliées:

– par le facteur 1,4 pour les DPR ayant $I_{\Delta n}$ ≥ 0,030 A;
– par le facteur 2 pour les DPR ayant $I_{\Delta n}$ < 0,030 A.

La conformité est vérifiée par les essais décrits en B.8.7.

B.7.2.10 Comportement des DPR du type B en réponse au type de courant différentiel résiduel

B.7.2.10.1 Courants différentiels résiduels composites

Les DPR du type B doivent fonctionner en réponse à une augmentation régulière des courants différentiels résiduels composites, comprenant une composante de 10 Hz et une composante de 1 kHz, comme défini dans le Tableau B.7.

Le courant différentiel résiduel de fonctionnement doit se situer dans les limites données dans le Tableau B.8.

La conformité est vérifiée par les essais décrits en B.8.8.1.

Les DPR du type B doivent fonctionner en réponse à une apparition subite d'un courant différentiel résiduel composite égal à 7 $I_{\Delta n}$, dans la durée de coupure maximale spécifiée en B.4.2.4 pour 5 $I_{\Delta n}$.

La conformité est vérifiée par les essais décrits en B.8.8.2.

B.7.2.10.2 Courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

Les DPR du type B doivent fonctionner en réponse à des courants différentiels résiduels de toute fréquence pouvant atteindre 1 000 Hz, conformément au Tableau B.9.

La conformité est vérifiée par les essais décrits en B.8.8.3.

B.7.2.10.3 Courant différentiel résiduel alternatif auquel est superposé un courant différentiel résiduel continu lissé

Les DPR du type B doivent fonctionner dans le cas de courants différentiels résiduels alternatifs à la fréquence assignée auxquels est superposé un courant différentiel résiduel

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continu lissé de valeur égale à 0,4 fois le courant différentiel résiduel assigné ($I_{\Delta n}$) ou 10 mA, la valeur retenue étant la plus élevée.

Le courant de déclenchement alternatif doit être inférieur ou égal à $I_{\Delta n}$.

La conformité est vérifiée par les essais décrits en B.8.8.4.

B.7.2.10.4 Courant différentiel résiduel continu pulsé auquel est superposé un courant différentiel résiduel continu lissé

Les DPR du type B doivent fonctionner dans le cas de courants différentiels résiduels continus pulsés auxquels est superposé un courant différentiel résiduel continu lissé de valeur égale à 0,4 fois le courant différentiel résiduel assigné ($I_{\Delta n}$) ou 10 mA, la valeur retenue étant la plus élevée.

Le courant de déclenchement ne doit pas être supérieur à 1,4 $I_{\Delta n}$ pour les DPR avec $I_{\Delta n}$ > 0,01 A ou 2 $I_{\Delta n}$ pour les DPR avec $I_{\Delta n}$ ≤ 0,01 A.

NOTE Le courant de déclenchement 1,4 $I_{\Delta n}$ ou 2 $I_{\Delta n}$, suivant le cas, est la valeur efficace due au courant continu pulsé simple alternance.

La conformité est vérifiée par les essais décrits en B.8.8.5.

B.7.2.10.5 Courants différentiels résiduels continus pulsés pouvant résulter de circuits redresseurs alimentés par deux phases

Les DPR du type B doivent fonctionner en réponse à une augmentation régulière des courants différentiels résiduels continus pulsés résultant de circuits redresseurs dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

La conformité est vérifiée par les essais décrits en B.8.8.6, a).

Les DPR du type B doivent fonctionner en réponse à une apparition subite de courants différentiels résiduels continus pulsés résultant de circuits redresseurs conformément aux limites spécifiées en B.4.2.4, les valeurs de courant d'essai spécifiées étant cependant augmentées d'un facteur de 2.

La conformité est vérifiée par les essais décrits en B.8.8.6, b).

B.7.2.10.6 Courants différentiels résiduels continus pulsés pouvant résulter de circuits redresseurs alimentés par trois phases

Les DPR du type B doivent fonctionner en réponse à une augmentation régulière des courants différentiels résiduels continus pulsés résultant de circuits redresseurs dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

La conformité est vérifiée par les essais décrits en B.8.8.7, a).

Les DPR du type B doivent fonctionner en réponse à une apparition subite de courants différentiels résiduels continus pulsés résultant de circuits redresseurs conformément aux limites spécifiées en B.4.2.4, les valeurs de courant d'essai spécifiées étant cependant augmentées d'un facteur de 2.

La conformité est vérifiée par les essais décrits en B.8.8.7, b).

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B.7.2.10.7 Courant différentiel résiduel continu lissé

Les DPR du type B doivent fonctionner en réponse à une augmentation régulière d'un courant différentiel résiduel continu lissé dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

La conformité est vérifiée par les essais décrits en B.8.8.8.1, a), et en B.8.8.8.2.

Les DPR du type B doivent fonctionner en réponse à une apparition subite d'un courant différentiel résiduel continu lissé conformément aux limites spécifiées en B.4.2.4, les valeurs de courant d'essai spécifiées étant cependant augmentées d'un facteur de 2.

La conformité est vérifiée par les essais décrits en B.8.8.8.1, b).

B.7.2.11 Conditions de fonctionnement des DPR à réarmement

Il ne doit pas être possible de remettre en position de fermeture, après déclenchement dû à un courant différentiel résiduel, les DPR à réarmement (voir B.2.3.9) s'ils n'ont pas été réarmés.

La conformité est vérifiée pendant l'essai décrit en 8.3.3.4.4, selon B.8.1.2.1.

B.7.2.12 Exigences supplémentaires relatives aux DPR fonctionnellement dépendants de la tension d'alimentation

Les DPR fonctionnellement dépendants de la tension d'alimentation doivent fonctionner correctement à une quelconque valeur de la tension d'alimentation comprise entre 0,85 et 1,1 fois sa valeur assignée.

La conformité est vérifiée par les essais décrits en B.8.2.3.

Lorsqu'un DPR a plus d'une fréquence assignée ou une plage de fréquences assignées, le DPR doit être capable de fonctionner selon ce paragraphe à toutes les fréquences.

La conformité est vérifiée en effectuant les essais de B.8.2 et B.8.4.

Suivant leur classification, les DPR fonctionnellement dépendants de la tension d'alimentation doivent satisfaire aux exigences données dans le Tableau B.4.

Tableau B.4 – Exigences relatives aux DPR fonctionnellement dépendants de la tension d'alimentation

Classification de l'appareil selon B.3.1		Comportement en cas de défaillance de la tension d'alimentation
DPR s'ouvrant automatiquement en cas de défaillance de la tension d'alimentation (B.3.1.2.1)	Sans retard	Ouverture sans retard selon B.8.9.3, point a)
	Avec retard	Ouverture avec retard selon B.8.9.3, point b)
DPR ne s'ouvrant pas automatiquement en cas de défaillance de la tension d'alimentation mais capables de s'ouvrir en cas de situation dangereuse (B.3.1.2.2)		Fonctionnement selon B.8.10

B.7.3 Compatibilité électromagnétique

Les exigences de l'Annexe J s'appliquent.

Des spécifications d'essai supplémentaires sont données en B.8.13.

L'immunité aux variations de tension est couverte par les exigences de B.7.2.12.

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B.8 Essais

B.8.1 Séquences d'essai

B.8.1.1 Généralités

Le présent paragraphe spécifie les essais pour les DPR de courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$ inférieur ou égal à 30 A.

La validité des essais spécifiés dans le présent paragraphe lorsque $I_{\Delta n} > 30$ A fait l'objet d'un accord entre le fabricant et l'utilisateur.

Les instruments de mesure du courant différentiel résiduel doivent indiquer (ou permettre de déterminer) la valeur efficace vraie.

Les essais spécifiés dans la présente annexe s'ajoutent aux essais de l'Article 8.

a) Essais de type

Les DPR doivent être soumis à toutes les séquences d'essai de l'Article 8 qui leur sont applicables. Pour les vérifications de la tenue diélectrique au cours de ces séquences d'essai (voir 8.3.3.6), le circuit de commande des appareils différentiels résiduels fonctionnellement dépendants de la tension d'alimentation doit être déconnecté du circuit principal.

Les essais doivent être réalisés avec des courants essentiellement sinusoïdaux.

Pour les DPR comprenant une unité c.r. distincte et un disjoncteur, l'assemblage doit être réalisé conformément aux instructions du fabricant.

Dans le cas des DPR avec plusieurs réglages du courant différentiel résiduel de fonctionnement, les essais doivent, sauf indication contraire, être effectués au réglage le plus bas.

Dans le cas des DPR à temporisation réglable (voir B.3.3.2.2), la temporisation doit, sauf indication contraire, être réglée à son maximum.

Dans le cas des DPR à déclenchement instantané réglable, le déclencheur instantané doit, sauf indication contraire, être réglé à son maximum.

b) Essais individuels de série

Le paragraphe 8.4.5 est applicable.

B.8.1.2 Essais à réaliser au cours des séquences d'essai de l'Article 8

B.8.1.2.1 Caractéristiques générales de fonctionnement (séquence d'essai I)

Pour éviter un fonctionnement involontaire de la fonction de courant différentiel résiduel, la vérification des limites et caractéristiques de déclenchement (8.3.3.2) doit être modifiée comme suit:

– pour la vérification des déclencheurs de court-circuit des déclencheurs de surintensité électroniques, le pôle à l'essai doit être soumis à essai en série avec un autre pôle choisi au hasard; pour la vérification des déclencheurs de court-circuit des déclencheurs de surintensité électromagnétiques, la vérification supplémentaire pour les essais sur un seul pôle peut ne pas être effectuée; pour la vérification du déclencheur de surcharge du pôle neutre, ce pôle doit être soumis à essai en série avec 2 autres pôles connectés en parallèle;

– en variante, lorsque cela est réalisable et avec l'accord du fabricant, la fonction de courant différentiel résiduel peut être rendue inopérante;

– les conditions d'essai doivent être indiquées dans le rapport d'essai.

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Au cours des cycles de manœuvres avec courant (voir 8.3.3.4.4) spécifiés dans le Tableau 8 (voir 7.2.4.2), un tiers des manœuvres de coupure doit être réalisé par la manœuvre de l'appareil d'essai et un autre tiers en appliquant à l'un des pôles un courant différentiel résiduel de valeur $I_{\Delta n}$ (ou, le cas échéant, de valeur égale au réglage le plus bas du courant différentiel résiduel de fonctionnement).

Dans le cas d'un DPR à réarmement, il doit être vérifié qu'il n'est pas possible de refermer le DPR après déclenchement sans manœuvre intentionnelle de réarmement. Cette vérification doit être faite au début et à la fin de l'essai d'aptitude au fonctionnement en service avec courant (8.3.3.4.4).

Aucun défaut de déclenchement ne doit être admis.

B.8.1.2.2 Vérification de l'aptitude à supporter les courants de court-circuit

B.8.1.2.2.1 Pouvoir assigné de coupure de service en court-circuit (séquence d'essai II)

Après les essais décrits en 8.3.4, la vérification du fonctionnement correct du DPR en cas de courant différentiel résiduel doit être effectuée conformément à B.8.2.4.2.

B.8.1.2.2.2 Pouvoir assigné de coupure ultime en court-circuit (séquence d'essai III)

Pour vérifier le fonctionnement correct des déclencheurs de surcharge, les essais sur un seul pôle spécifiés en 8.3.5.2 et 8.3.5.5 doivent être remplacés par des essais sur deux pôles, tour à tour sur toutes les combinaisons possibles des pôles de phase, les conditions d'essai étant celles spécifiées en 8.3.5.2 et 8.3.5.5, mais applicables à deux pôles.

Après les essais décrits en 8.3.5, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.2.2.3 Courant assigné de courte durée admissible (séquence d'essai IV ou séquence d'essai VI (combinée))

a) Comportement pendant l'essai au courant assigné de courte durée admissible

Aucun déclenchement ne doit se produire pendant l'essai décrit en 8.3.6.3 ou 8.3.8.3, suivant le cas.

b) Vérification des déclencheurs de surcharge

– Pour la séquence d'essai IV

Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.6.2 et 8.3.6.7, les essais sur un seul pôle spécifiés en 8.3.5.2 doivent être remplacés par des essais sur deux pôles, réalisés tour à tour selon toutes les combinaisons possibles de pôles de phase.

Pour la séquence d'essai combinée

Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.8.2, l'essai sur un seul pôle spécifié en 8.3.5.2 doit être remplacé par des essais sur deux pôles, réalisés tour à tour selon toutes les combinaisons possibles de pôles de phase.

Afin de vérifier le fonctionnement correct des déclencheurs de surcharge selon 8.3.8.7, l'essai spécifié en 8.3.3.8 doit être réalisé en utilisant une alimentation triphasée.

c) Vérification de l'appareil de déclenchement au courant différentiel résiduel

Après les essais de 8.3.6 ou 8.3.8, suivant le cas, la vérification de l'appareil de déclenchement au courant différentiel résiduel doit être effectuée selon B.8.2.4.4.

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B.8.1.2.2.4 Disjoncteurs à fusibles incorporés (séquence d'essai V)

Pour vérifier le fonctionnement correct des déclencheurs de surcharge, les essais sur un seul pôle spécifiés en 8.3.7.5 et 8.3.7.9 doivent être remplacés par des essais sur deux pôles, tour à tour sur toutes les combinaisons possibles des pôles de phase, les conditions d'essai étant celles spécifiées en 8.3.7.5 et 8.3.7.9, mais applicables à deux pôles.

Après les essais décrits en 8.3.7, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.2.2.5 Séquence d'essai VI (combinée)

Après les essais décrits en 8.3.8, la vérification du fonctionnement correct du DPR doit être effectuée conformément à B.8.2.4.4.

B.8.1.3 Séquences d'essai supplémentaires

Des séquences d'essai supplémentaires doivent être effectuées sur les DPR, conformément au Tableau B.5.

Tableau B.5 – Séquences d'essai supplémentaires

Séquence	Essai	Paragraphe
B I	Vérification des caractéristiques de fonctionnement	B.8.2
	Vérification des propriétés diélectriques	B.8.3
	Vérification de la manœuvre de l'appareil d'essai aux limites de la tension assignée	B.8.4
	Vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité	B.8.5
	Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc	B.8.6
	Vérifications supplémentaires pour les DPR de type A et de type B	B.8.7
	Vérifications supplémentaires pour les DPR de type B	B.8.8
	Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.1	B.8.9
	Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.2	B.8.10
B II	Vérification du pouvoir de fermeture et de coupure différentiel résiduel en court-circuit ($I_{\Delta m}$)	B.8.11
B III	Vérification des effets des conditions d'environnement	B.8.12
B IV	Vérification de la compatibilité électromagnétique	B.8.13
	Essais d'immunité	B.8.13.1
	Essais d'émission	B.8.13.2

Pour les DPR comportant des variantes avec différents nombres de pôles, les essais doivent être réalisés sur la variante avec le plus grand nombre de pôles. Pour une variante pour laquelle il n'existe pas de différences de construction par rapport à la variante soumise à essai, aucun essai supplémentaire n'est exigé. Si la construction des variantes n'est pas identique à celle de la variante soumise à essai, ces variantes doivent alors être aussi soumises à essai.

Un échantillon doit être soumis à essai pour chacune des séquences d'essai B I, B II et B III.

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Pour la séquence d'essai B IV, un nouvel échantillon peut être utilisé pour chaque essai ou un seul échantillon peut être utilisé pour plusieurs essais, ceci étant laissé à la discrétion du fabricant.

B.8.2 Vérification des caractéristiques de fonctionnement

B.8.2.1 Circuit d'essai

Le DPR doit être installé comme en usage normal.

Le circuit d'essai doit être conforme à la Figure B.1.

B.8.2.2 Tension d'essai pour les DPR fonctionnellement indépendants de la tension d'alimentation

Les essais peuvent être réalisés à une quelconque tension convenable.

B.8.2.3 Tension d'essai pour les DPR fonctionnellement dépendants de la tension d'alimentation

Les essais doivent être réalisés aux valeurs suivantes de la tension appliquée aux bornes correspondantes:

– 0,85 fois la tension assignée minimale pour les essais spécifiés en B.8.2.4 et B.8.2.5.2;

– 1,1 fois la tension assignée maximale pour les essais spécifiés en B.8.2.5.3.

Pour les DPR ayant des fonctions qui ne sont pas dépendantes de la tension d'alimentation, les essais relatifs à ces fonctions peuvent être réalisés sous une quelconque tension convenable.

Les DPR ayant plus d'une fréquence assignée ou une plage de fréquences assignées doivent être soumis à essai à la fréquence assignée la plus élevée et à la fréquence assignée la plus basse, dans chaque cas. Cependant, pour les DPR ayant des fréquences assignées égales à 50 Hz et 60 Hz, les essais à 50 Hz ou à 60 Hz sont considérés comme couvrant les exigences.

Pour les essais dans lesquels les pôles sont parcourus par un courant supérieur ou égal au courant assigné (voir par exemple B.8.2.5.3, B.8.7.2.3, B.8.8.8.2 et B.8.8.9), il est admis, pour des raisons pratiques, d'utiliser un échantillon dans lequel les conducteurs de la tension de déclenchement ont été séparés des pôles de phase, afin de permettre l'utilisation d'une source basse puissance pour l'application du courant de charge. Les détails de la modification doivent faire l'objet d'un accord entre le fabricant et la station d'essai, et doivent être indiqués dans le rapport d'essai.

B.8.2.4 Essai à vide à 20 °C ± 5 °C

B.8.2.4.1 Généralités

Les connexions étant comme représentées à la Figure B.1, le DPR doit subir les essais de B.8.2.4.2, B.8.2.4.3 et B.8.2.4.4 ainsi que celui de B.8.2.4.5, le cas échéant, tous ces essais étant effectués sur un seul pôle choisi au hasard. Chaque essai doit comprendre trois mesurages ou vérifications, suivant le cas.

Sauf spécification contraire, pour les DPR avec réglage, par variation continue ou par valeurs discrètes du courant différentiel résiduel de fonctionnement, les essais doivent être réalisés au réglage minimal et au réglage maximal, et à un réglage intermédiaire.

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B.8.2.4.2 Vérification du fonctionnement correct en cas d'augmentation régulière du courant différentiel résiduel

Pour les DPR avec des temporisations réglables, les essais doivent être réalisés au réglage minimal. Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$ afin d'atteindre la valeur $I_{\Delta n}$ en approximativement 30 s, le courant de déclenchement étant mesuré chaque fois. Les trois valeurs mesurées doivent être supérieures à $I_{\Delta no}$ et inférieures ou égales à $I_{\Delta n}$.

B.8.2.4.3 Vérification du fonctionnement correct en cas de fermeture sur le courant différentiel résiduel

Le circuit d'essai étant étalonné à la valeur assignée du courant différentiel résiduel de fonctionnement $I_{\Delta n}$ (ou aux réglages spécifiques du courant de fonctionnement différentiel résiduel, le cas échéant, voir B.8.2.4), les interrupteurs S_1 et S_2 étant en position de fermeture, le DPR est fermé sur le circuit de manière à simuler aussi fidèlement que possible les conditions de service. L'essai de mesurage de la durée de coupure doit être répété trois fois.

Aucun mesurage ne doit dépasser la valeur limite spécifiée pour $I_{\Delta n}$ en B.4.2.4.1 ou B.4.2.4.2.2, suivant le cas.

B.8.2.4.4 Vérification du fonctionnement correct en cas d'apparition subite du courant différentiel résiduel

Le circuit d'essai étant étalonné à chacune des valeurs du courant différentiel résiduel de fonctionnement I_{Δ} spécifiées en B.4.2.4.1 ou B.4.2.4.2.2, suivant le cas, et l'interrupteur S_1 et le DPR étant en position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

Le DPR doit déclencher au cours de chaque essai.

Trois mesurages de la durée de coupure sont effectués à chacune des valeurs de I_{Δ}. Aucune valeur ne doit dépasser la valeur limite spécifiée.

B.8.2.4.5 Vérification du temps limite de non-réponse des DPR du type temporisé

Le circuit d'essai étant étalonné à la valeur de 2 $I_{\Delta n}$, l'interrupteur S_1 et le DPR étant en position de fermeture, le courant différentiel résiduel est établi par la fermeture de l'interrupteur S_2 pendant un temps égal au temps limite de non-réponse déclaré par le fabricant, conformément à B.4.2.4.2.1.

Au cours de chacune des trois vérifications, le DPR ne doit pas déclencher. Si le DPR permet d'ajuster le courant différentiel résiduel et/ou la temporisation, l'essai doit être réalisé, suivant le cas, au réglage minimal du courant différentiel résiduel de fonctionnement et au réglage maximal de la temporisation.

B.8.2.5 Essais aux limites de température

B.8.2.5.1 Généralités

NOTE La limite supérieure de température peut être la température de référence.

Les limites de température du présent paragraphe peuvent être étendues par accord entre le fabricant et l'utilisateur; dans ce cas, les essais doivent être réalisés aux limites de température convenues.

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B.8.2.5.2 Essai à vide à –5 °C

Le DPR doit être placé dans une enceinte dont la température interne est stabilisée dans les limites de 7 °C à –5 °C. Après avoir atteint l'équilibre thermique, le DPR est soumis aux essais de B.8.2.4.4 et, le cas échéant, de B.8.2.4.5.

B.8.2.5.3 Essai en charge à la température de référence ou à +40 °C

Le DPR, raccordé conformément à la Figure B.1, doit être placé dans une enceinte dont la température interne est stabilisée à une valeur égale à la température de référence (voir 4.7.3) ou, en l'absence de température de référence, à une valeur égale à 40 °C ± 2 °C. Un courant de charge égal à I_n (non indiqué sur la Figure B.1) doit être appliqué à tous les pôles de phase.

Après avoir atteint l'équilibre thermique, le DPR doit être soumis aux essais de B.8.2.4.4 et, s'il y a lieu, de B.8.2.4.5.

B.8.3 Vérification des propriétés diélectriques

Les DPR doivent satisfaire à 8.3.3.3.

B.8.4 Vérification de la manœuvre de l'appareil d'essai aux limites de la tension assignée

La vérification comporte les essais suivants.

a) Le DPR étant alimenté à une tension égale à 1,1 fois la tension assignée maximale, l'appareil d'essai doit être manœuvré 25 fois, le DPR étant refermé avant chaque manœuvre.

b) L'essai a) doit ensuite être renouvelé à 0,85 fois la tension assignée minimale, l'appareil d'essai étant manœuvré 3 fois au lieu de 25 fois.

c) Le DPR étant dans la position de fermeture et alimenté à une tension égale à 1,1 fois la tension assignée maximale, l'appareil d'essai doit être manœuvré et maintenu dans la position manœuvrée pendant 5 s.

Pour ces essais:

– dans le cas des DPR dont les bornes d'alimentation et de charge sont identifiées, les connexions d'alimentation doivent être conformes au marquage;

– dans le cas des DPR dont les bornes d'alimentation et de charge ne sont pas identifiées, l'alimentation doit être raccordée tour à tour à chaque jeu de bornes ou, en variante, simultanément aux deux jeux de bornes.

Le DPR doit fonctionner à chaque essai.

Pour les DPR à courant différentiel résiduel de fonctionnement réglable:

– le réglage le plus bas doit être utilisé pour les essais a) et c);

– le réglage le plus élevé doit être utilisé pour l'essai b).

Pour les DPR à temporisation réglable, l'essai doit être réalisé à la temporisation maximale.

NOTE La vérification de l'endurance de l'appareil d'essai est considérée comme étant effectuée par les essais décrits en B.8.1.2.1.

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B.8.5 Vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité

L'essai doit être réalisé avec une charge monophasée, les raccordements étant réalisés selon la Figure B.2.

L'impédance Z doit être ajustée de manière à permettre le passage dans le circuit d'un courant égal à la plus faible des deux valeurs suivantes:

– 6 I_n;
– 80 % du courant maximal de réglage du déclencheur de court-circuit.

NOTE 1 Pour ce réglage du courant, le DPR D (voir Figure B.2) peut être remplacé par des connexions d'impédance négligeable.

Pour les DPR à courant différentiel résiduel réglable, l'essai doit être réalisé au réglage le plus bas.

Les DPR fonctionnellement indépendants de la tension d'alimentation sont soumis à essai sous une quelconque tension convenable.

Les DPR fonctionnellement dépendants de la tension d'alimentation sont alimentés côté source à leur tension assignée (ou, le cas échéant, à une tension quelconque dans la plage des tensions assignées).

L'essai doit être effectué à un facteur de puissance de 0,5.

L'interrupteur S_1, qui est en position d'ouverture, doit être fermé puis rouvert après 2 s. L'essai doit être répété trois fois pour chaque combinaison possible des voies de passage du courant, avec un intervalle d'au moins 1 min entre deux manœuvres de fermeture successives.

Le DPR ne doit pas déclencher.

NOTE 2 La durée de 2 s peut être réduite (mais pas à une valeur inférieure à celle de la durée de coupure minimale) pour éviter le risque de déclenchement sous l'action du ou des déclencheurs de surcharge du DPR.

B.8.6 Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc

B.8.6.1 Généralités

Pour les DPR à temporisations réglables (voir B.3.3.2.2), la temporisation doit être réglée au minimum.

B.8.6.2 Vérification de la résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

Le DPR doit être soumis à essai en utilisant un générateur de courant de choc capable de délivrer un courant oscillatoire amorti comme représenté à la Figure B.4.

Un exemple de circuit pour la connexion du DPR est représenté à la Figure B.5.

Un pôle du DPR choisi au hasard doit être soumis à 10 applications du courant de choc. La polarité de l'onde du courant de choc doit être inversée toutes les deux applications. L'intervalle entre deux applications successives doit être approximativement égal à 30 s. Le courant de choc doit être mesuré avec des moyens appropriés et réglé en utilisant un échantillon supplémentaire de DPR du même type (voir B.3.4) afin de satisfaire aux exigences suivantes:

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- valeur de crête: 200 A $^{+10}_{0}$ %;
- temps de montée virtuel: 0,5 µs ± 30 %;
- période de l'onde oscillatoire suivante: 10 µs ± 20 %;
- chacune des crêtes successives: environ 60 % de la crête précédente.

Pendant les essais, le DPR ne doit pas déclencher.

B.8.6.3 Vérification de la résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Le DPR doit être soumis à essai en utilisant un générateur de courant de choc capable de délivrer une onde de courant de choc de 8/20 µs, sans polarité inverse, comme représenté à la Figure B.6.

Un exemple de circuit pour la connexion du DPR est représenté à la Figure B.7.

Un pôle du DPR choisi au hasard doit être soumis à 10 applications de chacun des courants de choc énumérés ci-après. La polarité de l'onde du courant de choc doit être inversée toutes les deux applications. L'intervalle entre deux applications successives du courant de choc doit être d'approximativement 30 s.

Le courant de choc doit être mesuré avec des moyens appropriés et réglé, en utilisant un échantillon supplémentaire de DPR du même type (voir B.3.4), afin de satisfaire aux exigences suivantes:

– valeur de crête: 250 A $^{+10}_{0}$ %, lorsque le déclenchement n'est pas autorisé; et

– 3 000 A $^{+10}_{0}$ %, lorsque le déclenchement est autorisé;

– temps de montée virtuel (T_1): 8 µs ± 10 %;

– temps virtuel jusqu'à mi-valeur (T_2): 20 µs ± 10 %.

B.8.6.4 Vérification après les essais

Après les essais décrits en B.8.6.2 et B.8.6.3, le fonctionnement du DPR doit être vérifié conformément à B.8.2.4.4, avec un mesurage de la durée de coupure, uniquement à $I_{\Delta n}$.

B.8.7 Vérifications supplémentaires pour les DPR de type A et de type B

B.8.7.1 Conditions d'essai

Les conditions d'essai de B.8 et de B.8.2.1, B.8.2.2 et B.8.2.3 sont applicables, excepté que les circuits d'essai doivent être ceux définis à la Figure B.8 et la Figure B.9, suivant le cas.

B.8.7.2 Vérifications

B.8.7.2.1 Vérification du fonctionnement correct dans le cas d'une augmentation régulière du courant différentiel résiduel continu pulsé

Le circuit d'essai doit être conforme à la Figure B.8. Dans le cas d'un DPR avec une temporisation réglable (voir B.3.3.2.2), la temporisation doit être réglée au minimum.

Les interrupteurs auxiliaires S_1 et S_2 et le DPR D doivent être fermés. Le thyristor approprié doit être commandé de façon à obtenir des angles de retard du courant α de 0°, 90° et 135°.

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Chaque pôle du DPR doit être soumis à essai pour chaque angle de retard du courant, deux fois dans la position I et deux fois dans la position II de l'interrupteur auxiliaire S_3.

A chaque essai, le courant démarrant de zéro doit être augmenté progressivement avec un taux de variation approximatif de:

– 1,4 $I_{\Delta n}$ / 30 s pour les DPR de $I_{\Delta n}$ ≥ 0,030 A;
– 2 $I_{\Delta n}$ / 30 s pour les DPR de $I_{\Delta n}$ < 0,030 A.

Le courant de déclenchement doit être conforme aux valeurs indiquées dans le Tableau B.6.

Tableau B.6 – Plage de courants de déclenchement pour les DPR dans le cas d'un défaut à la terre comprenant des composantes continues

Angle α	Courant de déclenchement A	
	Limite inférieure	Limite supérieure
0° 90° 135°	0,35 $I_{\Delta n}$ 0,25 $I_{\Delta n}$ 0,11 $I_{\Delta n}$	2 $I_{\Delta n}$ pour $I_{\Delta n}$ < 0,030 A ou 1,4 $I_{\Delta n}$ pour $I_{\Delta n}$ ≥ 0,030 A

B.8.7.2.2 Vérification du fonctionnement correct dans le cas d'une apparition subite de courants différentiels résiduels continus pulsés

L'essai doit être réalisé selon la Figure B.8.

Le circuit étant successivement étalonné selon les valeurs spécifiées ci-après et l'interrupteur auxiliaire S_1 et le DPR étant en position fermée, le courant différentiel résiduel est appliqué subitement en fermant l'interrupteur S_2.

NOTE Dans le cas d'un DPR fonctionnellement dépendant de la tension d'alimentation, classé selon B.3.1.2.2, le circuit de commande étant alimenté du côté source du circuit principal, cette vérification ne prend pas en compte le temps nécessaire pour alimenter le DPR. En conséquence, dans ce cas, la vérification est considérée comme étant faite en établissant le courant différentiel résiduel par la fermeture de S_1, le DPR soumis à essai et S_2 étant fermés au préalable.

Quatre mesurages sont effectués pour chaque valeur de courant d'essai avec un angle de retard de courant α = 0°: deux mesurages avec l'interrupteur auxiliaire dans la position I et deux mesurages avec l'interrupteur auxiliaire dans la position II.

Pour les DPR de $I_{\Delta n}$ ≥ 0,030 A, l'essai doit être réalisé à chacune des valeurs de $I_{\Delta n}$ spécifiées dans le Tableau B.1, multipliées par le facteur 1,4.

Pour les DPR de $I_{\Delta n}$ < 0,030 A, l'essai doit être réalisé à chacune des valeurs de $I_{\Delta n}$ spécifiées dans le Tableau B.1, multipliées par le facteur 2.

Aucune valeur ne doit dépasser les valeurs limites spécifiées (voir B.7.2.9).

B.8.7.2.3 Vérification du fonctionnement correct avec charge à la température de référence

Les essais décrits en B.8.7.2.1 et B.8.7.2.2 doivent être répétés, le pôle soumis à essai et un autre pôle du DPR étant parcourus par le courant assigné, ce courant étant établi juste avant l'essai.

NOTE La charge avec le courant assigné n'est pas représentée à la Figure B.8.

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B.8.7.2.4 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pulsés auxquels est superposé un courant continu lissé de 0,006 A

Cet essai peut ne pas être appliqué aux DPR de type B car ces exigences sont couvertes par l'essai décrit en B.8.8.5.

Le DPR doit être soumis à essai selon la Figure B.9, avec un courant différentiel résiduel à redressement simple alternance (angle de retard de courant α = 0°) auquel est superposé un courant continu lissé de 0,006 A.

Chaque pôle du DPR doit être soumis à essai tour à tour, deux fois pour chacune des positions I et II.

Pour les DPR avec $I_{\Delta n}$ ≥ 0,030 A, le courant redressé simple alternance, démarrant de 0, étant augmenté progressivement selon un taux d'accroissement d'environ 1,4 $I_{\Delta n}$ / 30 s, le déclenchement doit se produire avant que le courant dépasse une valeur de 1,4 $I_{\Delta n}$ + 0,006 A.

Pour les DPR avec $I_{\Delta n}$ < 0,030 A, le courant redressé simple alternance, démarrant de 0, étant augmenté progressivement selon un taux d'accroissement d'environ 2 $I_{\Delta n}$ / 30 s, le déclenchement doit se produire avant que le courant dépasse une valeur de 2 $I_{\Delta n}$ + 0,006 A.

B.8.8 Vérifications supplémentaires pour les DPR de type B

B.8.8.1 Vérification du fonctionnement correct en cas d'augmentation régulière du courant différentiel résiduel composite

Le fonctionnement du DPR doit être vérifié à l'aide d'un courant différentiel résiduel composite conforme au Tableau B.7. L'installation d'essai doit être conforme à la Figure B.14.

Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel est augmenté progressivement, en démarrant de la valeur donnée dans le Tableau B.7, de manière à atteindre, en moins de 30 s environ, la limite supérieure de courant différentiel résiduel de fonctionnement donnée dans le Tableau B.8.

Les proportions des différentes fréquences doivent être maintenues depuis la valeur initiale jusqu'à la valeur de fonctionnement.

Cet essai doit être répété trois fois sur un pôle pris au hasard. Les valeurs de fonctionnement doivent se situer dans les limites données dans le Tableau B.8.

La tolérance sur la fréquence d'essai est de ± 2 %.

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Tableau B.7 – Définition du courant composite d'essai et valeur du courant de départ

Valeurs des composantes fréquentielles du courant composite de départ			Valeur résultante du courant composite de départ (en valeur efficace)
I à la fréquence assignée	I 1 kHz	I F moteur (10 Hz)	I_Δ
0,138 $I_{\Delta n}$	0,138 $I_{\Delta n}$	0,035 $I_{\Delta n}$	0,2 $I_{\Delta n}$
NOTE 1 $I_{\Delta n}$ correspond au courant différentiel résiduel de fonctionnement assigné de l'appareil à la fréquence assignée. NOTE 2 Pour les besoins de l'essai, les valeurs de 10 Hz et 1 kHz ont été utilisées respectivement pour la fréquence de sortie et la fréquence d'horloge, représentant la condition la plus sévère.			

Tableau B.8 – Plage de courant de fonctionnement pour le courant différentiel résiduel composite

Courant de fonctionnement (en valeur efficace)	
Limite inférieure	**Limite supérieure**
0,5 $I_{\Delta n}$	1,4 $I_{\Delta n}$

B.8.8.2 Vérification du fonctionnement correct dans le cas d'une apparition subite d'un courant différentiel résiduel composite

Des essais sont réalisés pour vérifier la durée de coupure du DPR, le courant d'essai étant étalonné à une valeur égale à 5 fois la limite supérieure donnée dans le Tableau B.8.

L'essai doit être réalisé selon la Figure B.14.

L'interrupteur S_1 et le DPR étant dans la position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

Trois mesurages de la durée de coupure sont effectués.

Pour les DPR du type non temporisé, les durées de coupure doivent être inférieures à 0,04 s.

Pour le type temporisé, la durée de coupure doit être conforme au Tableau B.2 ou à la valeur déclarée par le fabricant pour 5 $I_{\Delta n}$, suivant le cas.

Les DPR du type temporisé doivent en outre être soumis à essai pour vérifier le temps de non-réponse, le courant d'essai étant subitement établi par la fermeture de l'interrupteur S_2 pendant une durée de 0,06 s, ou pendant la valeur du temps de non-réponse déclaré par le fabricant, suivant le cas, avec une tolérance de $^{0}_{-5}$ %.

Trois essais sont réalisés, en respectant un intervalle d'au moins 1 min entre chacun d'eux. Le DPR ne doit déclencher pendant aucun de ces essais.

B.8.8.3 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

L'essai doit être réalisé selon la Figure B.14.

L'essai est réalisé en deux étapes; une première étape a) visant à vérifier le courant de déclenchement, et une deuxième étape b) visant à vérifier la durée de coupure.

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a) Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de courant différentiel résiduel de fonctionnement donnée dans le Tableau B.9 en moins de 30 s environ, le courant de déclenchement étant mesuré.

L'essai doit être réalisé sur un pôle choisi au hasard, à chaque fréquence donnée dans le Tableau B.9, et il est répété cinq fois; les valeurs de déclenchement doivent être conformes au Tableau B.9.

b) Le circuit d'essai étant étalonné sur le courant différentiel résiduel de fonctionnement correspondant à 1 000 Hz, conformément au Tableau B.9, et l'interrupteur S_1 et le DPR étant dans la position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

Deux mesurages de la durée de coupure sont effectués sur un pôle choisi au hasard.

Pour le type non temporisé, la durée de coupure maximale ne doit pas dépasser 0,3 s.

Pour le type temporisé, la durée de coupure maximale ne doit pas dépasser 0,5 s ou la valeur déclarée par le fabricant pour $I_{\Delta n}$, suivant le cas.

Tableau B.9 – Limites de fonctionnement pour des courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

Fréquence Hz	Courant différentiel résiduel de non-fonctionnement	Courant différentiel résiduel de fonctionnement
150	0,5 $I_{\Delta n}$	2,4 $I_{\Delta n}$ [a]
400	0,5 $I_{\Delta n}$	6 $I_{\Delta n}$ [a]
1 000	$I_{\Delta n}$	14 $I_{\Delta n}$ [a b]

[a] Ces valeurs sont obtenues à partir de la protection contre la fibrillation ventriculaire, selon l'IEC 60479-1, en combinaison avec le facteur de fréquence de la fibrillation ventriculaire, selon l'IEC 60479-2.

[b] L'IEC 60479-2 ne donne pas de facteur pour les fréquences supérieures à 1 kHz.

B.8.8.4 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel alternatif auquel est superposé un courant différentiel résiduel continu lissé

L'essai doit être réalisé selon la Figure B.10.

Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel continu lissé doit être appliqué à un pôle choisi au hasard et doit être ajusté à 0,4 $I_{\Delta n}$ ou 10 mA, la valeur retenue étant la plus élevée.

Le courant différentiel résiduel alternatif à la fréquence assignée doit être appliqué à un autre pôle choisi au hasard et est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de $I_{\Delta n}$ en moins de 30 s environ, le courant de déclenchement étant mesuré.

Le DPR doit être soumis à essai deux fois pour chacune des positions I et II de l'interrupteur S_3.

Le courant de déclenchement alternatif doit être inférieur ou égal à $I_{\Delta n}$.

B.8.8.5 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu pulsé auquel est superposé un courant différentiel résiduel continu lissé

L'essai doit être réalisé conformément à la Figure B.9.

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Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel continu lissé doit être appliqué à un pôle choisi au hasard et doit être ajusté à 0,4 $I_{\Delta n}$ ou 10 mA, la valeur retenue étant la plus élevée.

Le courant différentiel résiduel continu pulsé doit être appliqué à un autre pôle choisi au hasard avec un angle de retard de courant α de 0° et est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, de manière à atteindre en moins de 30 s environ la valeur de 1,4 $I_{\Delta n}$, pour les DPR avec $I_{\Delta n} \geq 0{,}030$ A, ou 2 $I_{\Delta n}$, pour les DPR avec $I_{\Delta n} < 0{,}030$ A, le courant de déclenchement étant mesuré.

Le DPR doit être soumis à essai deux fois pour chacune des positions I et II de l'interrupteur S_3.

Le DPR doit déclencher avant que le courant différentiel résiduel pulsé dépasse une valeur de 1,4 $I_{\Delta n}$, pour les DPR avec $I_{\Delta n} \geq 0\ 030$ A, ou 2 $I_{\Delta n}$, pour les DPR avec $I_{\Delta n} < 0{,}030$ A.

B.8.8.6 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par deux phases

L'essai doit être réalisé conformément à la Figure B.11.

L'essai est réalisé en deux étapes; une première étape a) visant à vérifier le courant de déclenchement, et une deuxième étape b) visant à vérifier la durée de coupure.

a) Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel continu pulsé est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de 2 $I_{\Delta n}$ en moins de 30 s environ, le courant de déclenchement étant mesuré.

   Le DPR doit être connecté au circuit d'essai par deux bornes d'alimentation choisies au hasard.

   Le DPR doit être soumis à essai cinq fois pour chacune des positions I et II de l'interrupteur S_3.

   Le DPR doit déclencher dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

b) Le circuit d'essai étant successivement étalonné au double de chaque valeur de courant donnée dans le Tableau B.1, l'interrupteur S_1 et le DPR étant dans la position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

   Le DPR étant connecté à deux bornes d'alimentation choisies au hasard, cinq mesurages de la durée de coupure sont effectués pour chacune de ces valeurs de courant différentiel résiduel données dans le Tableau B.1, pour chacune des positions I et II de l'interrupteur S_3.

   Les durées de coupure doivent être conformes au B.4.2.4.

B.8.8.7 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par trois phases

Cet essai n'est pas applicable aux DPR bipolaires de type B.

L'essai doit être réalisé conformément à la Figure B.12.

L'essai est réalisé en deux étapes; une première étape a) visant à vérifier le courant de déclenchement, et une deuxième étape b) visant à vérifier la durée de coupure.

a) Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel continu pulsé est augmenté de façon régulière, à partir d'une valeur

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ne dépassant pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de 2 $I_{\Delta n}$ en moins de 30 s environ, le courant de déclenchement étant mesuré.

Le DPR doit être soumis à essai cinq fois pour chacune des positions I et II de l'interrupteur S_3.

Le DPR doit déclencher dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

b) Le circuit d'essai étant successivement étalonné au double de chaque valeur de courant donnée dans le Tableau B.1, l'interrupteur S_1 et le DPR étant dans la position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

Cinq mesurages de la durée de coupure sont effectués pour chacune de ces valeurs de courant différentiel résiduel et pour chacune des positions I et II de l'interrupteur S_3.

Les durées de coupure doivent être conformes au B.4.2.4.

B.8.8.8 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé

B.8.8.8.1 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé sans charge

L'essai doit être réalisé selon la Figure B.13.

L'essai est réalisé en deux étapes; une première étape a) visant à vérifier le courant de déclenchement, et une deuxième étape b) visant à vérifier la durée de coupure.

a) Les interrupteurs S_1 et S_2, ainsi que le DPR, étant en position de fermeture, le courant différentiel résiduel continu lissé est augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$ afin d'atteindre la valeur de 2 $I_{\Delta n}$ en moins de 30 s, le courant de déclenchement étant mesuré.

Un pôle du DPR, choisi au hasard et représenté à titre d'exemple à la Figure B.14, doit être soumis à essai deux fois pour chacune des positions I et II de l'interrupteur S_3.

Le DPR doit déclencher dans les limites de 0,5 $I_{\Delta n}$ à 2 $I_{\Delta n}$.

b) Le circuit d'essai étant successivement étalonné au double de chaque valeur de courant différentiel résiduel de fonctionnement donnée dans le Tableau B.1, l'interrupteur S_1 et le DPR étant dans la position de fermeture, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2. L'interrupteur S_3 doit être dans la position I ou II, celle-ci étant choisie au hasard.

Deux mesurages de la durée de coupure sont effectués sur un pôle choisi au hasard pour chaque courant d'essai.

Les durées de coupure doivent être conformes au B.4.2.4.

B.8.8.8.2 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé avec charge

L'essai décrit en B.8.8.8.1 a) doit être répété, le DPR étant parcouru par le courant assigné comme en usage normal, pendant une durée suffisante pour permettre d'atteindre l'équilibre thermique.

NOTE La charge avec le courant assigné n'est pas représentée à la Figure B.13.

B.8.8.9 Essais aux limites de température

Le DPR doit être soumis aux essais spécifiés en B.8.8.6 b), B.8.8.7 b) et B.8.8.8.1 b), successivement dans les conditions suivantes:

a) température de l'air ambiant: –5 °C, sans charge;

b) température de l'air ambiant: +40 °C, le DPR ayant été précédemment parcouru par le courant assigné, jusqu'à ce qu'il ait atteint l'équilibre thermique. Dans la pratique, cet

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équilibre thermique est atteint lorsque la variation de l'échauffement, mesurée sur l'une des bornes principales, n'excède pas 1 K par heure. La charge du circuit principal peut être appliquée à tension réduite mais l'alimentation de la fonction de courant différentiel résiduel, pour un DPR fonctionnellement dépendant de la tension d'alimentation, doit être raccordée à sa tension assignée maximale – voir aussi B.8.2.3.

Dans le cas des DPR intégrant plusieurs réglages du courant différentiel résiduel de fonctionnement, les essais sont réalisés au réglage minimal et au réglage maximal.

B.8.8.10 Essai des DPR tripolaires et tétrapolaires alimentés entre deux pôles de phase uniquement

En supplément, les essais décrits en B.8.8.3 et en B.8.8.8.1 sont répétés, le DPR étant alimenté entre deux pôles de phase choisis au hasard.

B.8.9 Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.1

B.8.9.1 Généralités

Pour les DPR ayant un courant différentiel résiduel de fonctionnement réglable, l'essai doit être réalisé au réglage minimal.

Pour les DPR à temporisation réglable, l'essai doit être réalisé à l'un quelconque des réglages de la temporisation.

B.8.9.2 Détermination de la valeur limite de la tension d'alimentation

Une tension égale à la tension assignée doit être appliquée aux bornes d'alimentation du DPR et doit ensuite être diminuée progressivement jusqu'à zéro, en un délai correspondant à la plus longue des deux valeurs suivantes jusqu'à ce que se produise l'ouverture automatique:

– environ 30 s;

– un temps suffisamment long pour tenir compte du retard à l'ouverture du DPR, s'il y a lieu (voir B.7.2.12).

La tension correspondante est mesurée.

Trois mesurages sont effectués. Toutes les valeurs doivent être inférieures à 0,85 fois la tension assignée minimale du DPR.

Après ces mesurages, il doit être vérifié que le DPR déclenche lorsqu'un courant différentiel résiduel égal à $I_{\Delta n}$ est appliqué, la tension appliquée étant juste supérieure à la plus forte valeur mesurée.

Il doit alors être vérifié que, pour une quelconque valeur de tension inférieure à la valeur mesurée la plus faible, il n'est pas possible de fermer le DPR à l'aide de ses organes de manœuvre manuels.

B.8.9.3 Vérification de l'ouverture automatique en cas de défaillance de la tension d'alimentation

Le DPR étant en position de fermeture, une tension égale à sa tension assignée ou, dans le cas d'une plage de tensions assignées, à l'une quelconque des tensions assignées, doit être appliquée à ses bornes d'alimentation. La tension est ensuite interrompue. Le DPR doit déclencher. L'intervalle de temps entre l'interruption de la tension et l'ouverture des contacts principaux est mesuré.

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Trois mesurages sont effectués:

a) pour les DPR à ouverture sans temporisation (voir B.7.2.12), aucune valeur ne doit dépasser 0,2 s;

b) pour les DPR à ouverture avec temporisation, les valeurs minimale et maximale doivent se situer à l'intérieur de la plage indiquée par le fabricant.

B.8.10 Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon B.3.1.2.2

B.8.10.1 Généralités

Pour les DPR ayant un courant différentiel résiduel de fonctionnement réglable, l'essai doit être réalisé au réglage minimal.

Pour les DPR à temporisation réglable, l'essai doit être réalisé à l'un quelconque des réglages de la temporisation.

B.8.10.2 Cas d'une perte d'une phase dans un réseau triphasé (pour les DPR tripolaires et tétrapolaires)

Le DPR doit être raccordé comme indiqué à la Figure B.3 et alimenté du côté source à 0,85 fois la tension assignée ou, dans le cas d'une plage de tensions assignées, à 0,85 fois la valeur de tension assignée la plus basse.

Une phase est alors interrompue en ouvrant l'interrupteur S_4; le DPR doit alors être soumis à l'essai décrit en B.8.2.4.4. L'interrupteur S_4 étant refermé, un autre essai doit être réalisé en ouvrant l'interrupteur S_5; le DPR doit alors être soumis à l'essai décrit en B.8.2.4.4.

Ce mode opératoire d'essai doit être répété en raccordant la résistance variable *R* tour à tour à chacune des deux autres phases.

B.8.10.3 Cas de chute de tension causée par une surintensité résultant d'un défaut, à basse impédance, à la terre

Le DPR doit être raccordé selon la Figure B.3 et alimenté du côté source avec la tension assignée ou, dans le cas d'une plage de tensions assignées, avec la tension assignée la plus basse.

L'alimentation est ensuite interrompue en ouvrant S_1. Le DPR ne doit pas déclencher.

S_1 est ensuite refermé et la tension est réduite de la manière suivante:

a) pour les DPR destinés à être utilisés avec une alimentation triphasée: à 70 % de la tension assignée la plus basse;

b) pour les DPR destinés à être utilisés avec une alimentation monophasée: à une tension de 85 V appliquée comme suit:

- pour les DPR unipolaires ou bipolaires: entre les pôles;
- pour les DPR tripolaires ou tétrapolaires, déclarés aptes à une utilisation avec une alimentation monophasée (voir B.5): entre chaque combinaison de deux pôles, raccordés selon les spécifications du fabricant.

NOTE Pour les besoins de la présente annexe, un DPR à un pôle est un appareil avec un pôle protégé contre les surintensités et un neutre non coupé (deux voies de passage de courant).

Un courant de valeur égale à $I_{\Delta n}$ doit ensuite être appliqué à a) et/ou à b), suivant le cas. Le DPR doit déclencher.

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B.8.11 Vérification du pouvoir de fermeture et de coupure différentiel résiduel en court-circuit

B.8.11.1 Généralités

Cet essai est destiné à vérifier l'aptitude du DPR à établir, supporter pendant une durée spécifiée, et interrompre les courants différentiels résiduels de court-circuit.

B.8.11.2 Conditions d'essai

Le DPR doit être soumis à essai conformément aux conditions générales d'essai spécifiées en 8.3.2.6, suivant la Figure 9 de l'IEC 60947-1:2007/AMD1:2010, mais en étant raccordé d'une manière telle que le courant de court-circuit soit un courant différentiel résiduel.

L'essai doit être réalisé sous une tension entre phase et neutre sur un seul pôle qui ne doit pas être le pôle neutre. Les parties conductrices que le courant différentiel résiduel de court-circuit n'a pas à parcourir sont raccordées à la tension d'alimentation par leurs bornes d'alimentation.

Le cas échéant, le DPR doit être réglé à la valeur minimale du courant différentiel résiduel de fonctionnement et à la valeur maximale de la temporisation.

Si le DPR a plus d'une valeur de I_{cu}, chacune d'elles ayant une valeur correspondante de $I_{\Delta m}$, l'essai doit être réalisé à la valeur maximale de $I_{\Delta m}$, sous la tension correspondante entre phase et neutre.

B.8.11.3 Mode opératoire d'essai

La séquence de manœuvres à effectuer est:

O – *t* – CO

B.8.11.4 Conditions du DPR après essai

Après l'essai de B.8.11.3, le DPR doit satisfaire aux exigences suivantes:

a) Le DPR ne doit présenter aucun dommage susceptible de compromettre son emploi ultérieur et doit être capable, sans entretien:
   - de supporter une tension égale à deux fois sa tension assignée d'emploi maximale, dans les conditions décrites en 8.3.3.4.1, point 4) de l'IEC 60947-1:2007. Pour les besoins du présent document, les circuits comprenant des appareils à semiconducteurs doivent être déconnectés pour les essais;
   - d'établir et de couper son courant assigné sous sa tension assignée d'emploi maximale.

b) Le DPR doit pouvoir satisfaire aux essais spécifiés en B.8.2.4.4, mais à une valeur égale à 1,25 $I_{\Delta n}$ et sans mesurage de la durée de coupure. L'essai doit être réalisé sur un pôle choisi au hasard.

   Si le DPR a un courant différentiel résiduel de fonctionnement réglable, l'essai doit être réalisé au réglage le plus bas, à un courant correspondant à 1,25 fois celui du réglage.

c) Le cas échéant, le DPR doit aussi être soumis à l'essai de B.8.2.4.5.

d) Les DPR fonctionnellement dépendants de la tension d'alimentation doivent aussi satisfaire aux essais de B.8.9 ou B.8.10, suivant le cas.

e) Les DPR du type B doivent déclencher avec un courant d'essai de 2,5 $I_{\Delta n}$ avec un courant continu lissé. Un seul essai est réalisé, sans mesurage de la durée de coupure.

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B.8.12 Vérification des effets des conditions d'environnement

L'essai doit être réalisé conformément à l'IEC 60068-2-30.

La température supérieure doit être de 55 °C ± 2 °C (variante 1) et le nombre de cycles doit être:

– de 6 pour $I_{\Delta n} > 1$ A,
– de 28 pour $I_{\Delta n} \leq 1$ A.

L'essai de 28 cycles doit être appliqué aux DPR ayant plusieurs réglages de courant différentiel résiduel de fonctionnement si l'un des réglages possibles est ≤ 1 A.

A la fin des cycles, le DPR doit pouvoir satisfaire aux essais de B.8.2.4.4, mais avec un courant différentiel résiduel d'essai de 1,25 $I_{\Delta n}$ et sans mesurage de la durée de coupure. Il est nécessaire de n'effectuer qu'une seule vérification.

Le cas échéant, le DPR doit aussi être soumis à l'essai de B.8.2.4.5. Il est nécessaire de n'effectuer qu'une seule vérification.

Les DPR du type B doivent déclencher avec un courant d'essai de 2,5 $I_{\Delta n}$ avec un courant continu lissé. Un seul essai est réalisé, sans mesurage de la durée de coupure.

B.8.13 Vérification de la compatibilité électromagnétique

B.8.13.1 Essais d'immunité

B.8.13.1.1 Généralités

L'Annexe J est applicable avec les exigences supplémentaires suivantes.

Pour les DPR avec réglage du courant différentiel résiduel de fonctionnement et/ou de la temporisation, les essais doivent être réalisés au réglage minimal.

Le DPR doit être alimenté à la tension assignée d'emploi ou, dans le cas d'une plage de tensions assignées d'emploi, à une quelconque tension convenable comprise dans cette plage.

Les essais sont réalisés sans courant de charge mais avec le courant différentiel résiduel, lorsque celui-ci est spécifié.

Les résultats des essais d'immunité doivent être appréciés sur la base des critères de comportement donnés en J.2.1, avec les spécifications suivantes:

Critère de comportement A:

Pour l'étape 1, le DPR ne doit pas déclencher lorsqu'il est chargé à 0,3 $I_{\Delta n}$ sur un pôle choisi au hasard; les fonctions de surveillance, le cas échéant, doivent indiquer correctement l'état.

Pour l'étape 2, le DPR doit déclencher à chaque fréquence d'essai lorsqu'il est chargé à 1,25 $I_{\Delta n}$; le temps de maintien à chaque fréquence ne doit pas être inférieur à la durée maximale de coupure spécifiée pour $I_{\Delta n}$ en B.4.2.4.1 ou en B.4.2.4.2, suivant le cas.

Après ces essais, le fonctionnement correct du DPR doit être vérifié dans le cas d'une apparition soudaine d'un courant différentiel résiduel, selon B.8.2.4.4, mais à $I_{\Delta n}$ seulement.

Les DPR du type B doivent déclencher avec un courant d'essai de 2,5 $I_{\Delta n}$ avec un courant continu lissé. Un seul essai est réalisé, sans mesurage de la durée de coupure.

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Critère de comportement B:

Pendant l'essai, le DPR ne doit pas déclencher lorsqu'il est chargé à 0,3 $I_{\Delta n}$ sur un pôle choisi au hasard; les fonctions de surveillance, le cas échéant, peuvent être temporairement affectées.

Après l'essai, le fonctionnement correct du DPR doit être vérifié dans le cas d'une apparition soudaine d'un courant différentiel résiduel, selon B.8.2.4.4, mais à $I_{\Delta n}$ seulement.

Les DPR du type B doivent déclencher avec un courant d'essai de 2,5 $I_{\Delta n}$ avec un courant continu lissé. Un seul essai est réalisé, sans mesurage de la durée de coupure.

B.8.13.1.2 Décharges électrostatiques

L'Annexe J est applicable, en particulier J.2.2.

L'installation d'essai doit être conforme à la Figure J.1 et à la Figure J.3.

Le critère de comportement B est applicable, mis à part que le DPR peut déclencher pendant l'essai. Si c'est le cas, un nouvel essai doit être réalisé au niveau immédiatement inférieur, et le DPR ne doit pas déclencher.

B.8.13.1.3 Champs électromagnétiques RF rayonnés

L'Annexe J est applicable, en particulier J.2.3.

L'installation d'essai doit être conforme à la Figure J.4.

Les raccordements d'essai doivent être conformes à la Figure 5 ou la Figure 6 de l'IEC 61000-4-3:2006, suivant le cas, en prenant en considération les instructions du fabricant pour l'installation. Le type de câble utilisé doit être indiqué dans le rapport d'essai.

Le critère de comportement A est applicable.

B.8.13.1.4 Transitoires électriques rapides en salves (TER/S)

L'Annexe J est applicable, en particulier J.2.4.

Les raccordements d'essai doivent être conformes à la Figure 4 de l'IEC 61000-4-4:2012.

L'installation d'essai doit être conforme à la Figure J.5 pour l'essai des lignes d'alimentation et à la Figure J.6 pour l'essai des lignes de signaux, en prenant en considération les instructions du fabricant pour l'installation.

Le critère de comportement B est applicable.

B.8.13.1.5 Ondes de choc

L'Annexe J est applicable, en particulier J.2.5.

Les conditions d'essai de 7.2 de l'IEC 61000-4-5:2014 sont applicables.

Par commodité, le montage spécifié en B.8.13.1.4 peut être utilisé mais l'emploi du plan de référence de terre est facultatif.

Les raccordements d'essai doivent être conformes aux Figures 6, 7, 8 ou 9 de l'IEC 61000-4-5:2014, en prenant en considération les instructions du fabricant pour l'installation.

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Le critère de comportement B est applicable.

B.8.13.1.6 Perturbations conduites, induites par les champs RF (mode commun)

L'Annexe J est applicable, en particulier J.2.6.

Le critère de comportement A est applicable.

B.8.13.2 Essais d'émission

B.8.13.2.1 Généralités

L'Annexe J est applicable avec les exigences supplémentaires suivantes.

Le DPR doit être alimenté à la tension assignée d'emploi ou, dans le cas d'une plage de tensions assignées d'emploi, à une quelconque tension convenable comprise dans cette plage.

Les essais doivent être réalisés sans courant de charge et sans courant différentiel résiduel.

B.8.13.2.2 Perturbations conduites aux fréquences radioélectriques (150 kHz à 30 MHz)

L'Annexe J est applicable, en particulier J.3.2.

B.8.13.2.3 Perturbations rayonnées aux fréquences radioélectriques (30 MHz à 1 000 MHz)

L'Annexe J est applicable, en particulier J.3.3.

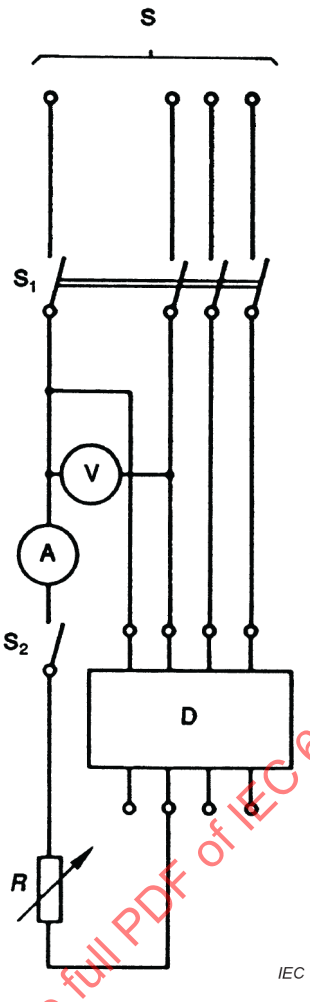
B.8.14 Essais pour des variations ou des interruptions de tension et pour des creux de tension

NOTE Pour une définition des creux de tension, voir l'IEC 61000-4-11.

Les essais correspondants de B.8.8 et B.8.10 sont considérés comme adaptés pour couvrir les exigences de CEM.

Aucun essai supplémentaire n'est donc exigé.

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Légende

S alimentation

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

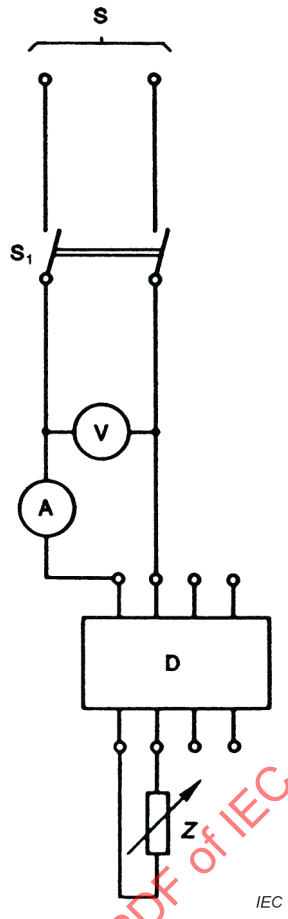
S_2 interrupteur unipolaire

D DPR soumis à essai

R résistance réglable

Figure B.1 – Circuit d'essai pour la vérification de la caractéristique de fonctionnement (voir B.8.2)

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Légende

S alimentation

V voltmètre

A ampèremètre

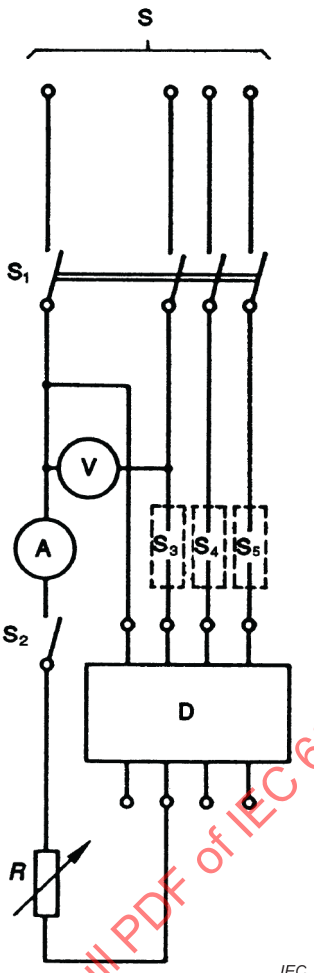
D DPR soumis à essai

Z impédance réglable

S_1 interrupteur bipolaire

Figure B.2 – Circuit d'essai pour la vérification de la valeur limite du courant de non-fonctionnement en cas de surintensités (voir B.8.5)

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Légende

S	alimentation	S_2	interrupteur unipolaire
V	voltmètre	S_3, S_4, S_5	interrupteurs unipolaires ouvrant tour à tour une phase
A	ampèremètre	D	DPR soumis à essai
S_1	interrupteur multipolaire	*R*	résistance réglable

Figure B.3 – Circuit d'essai pour la vérification du comportement des DPR classés selon B.3.1.2.2 (voir B.8.10)

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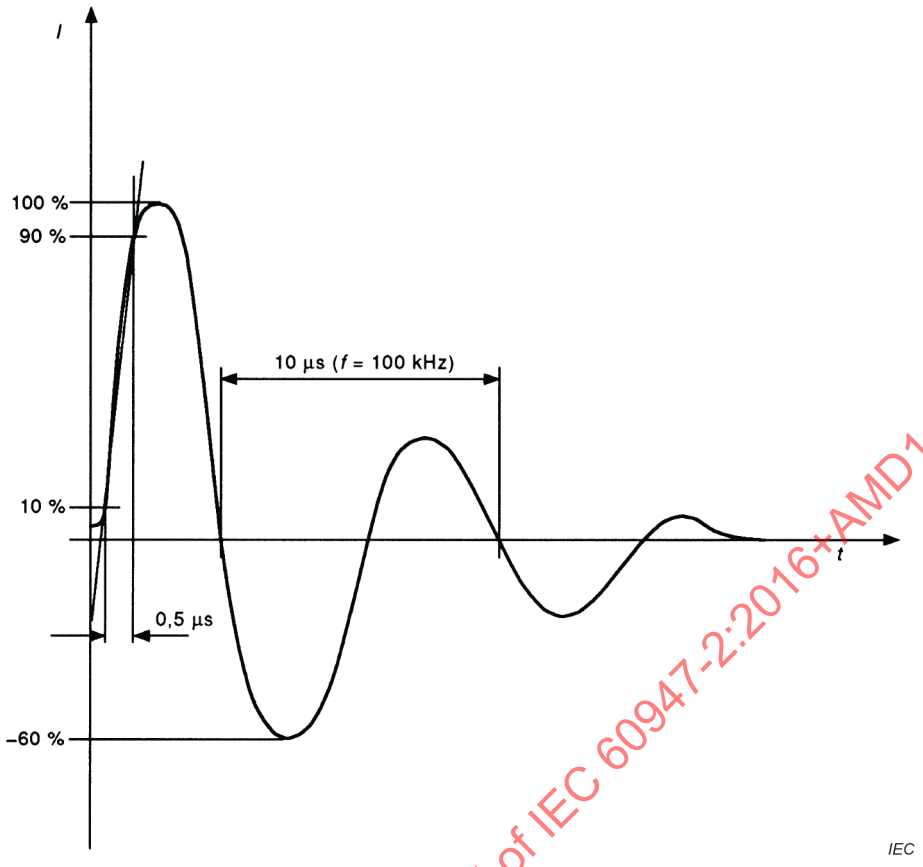
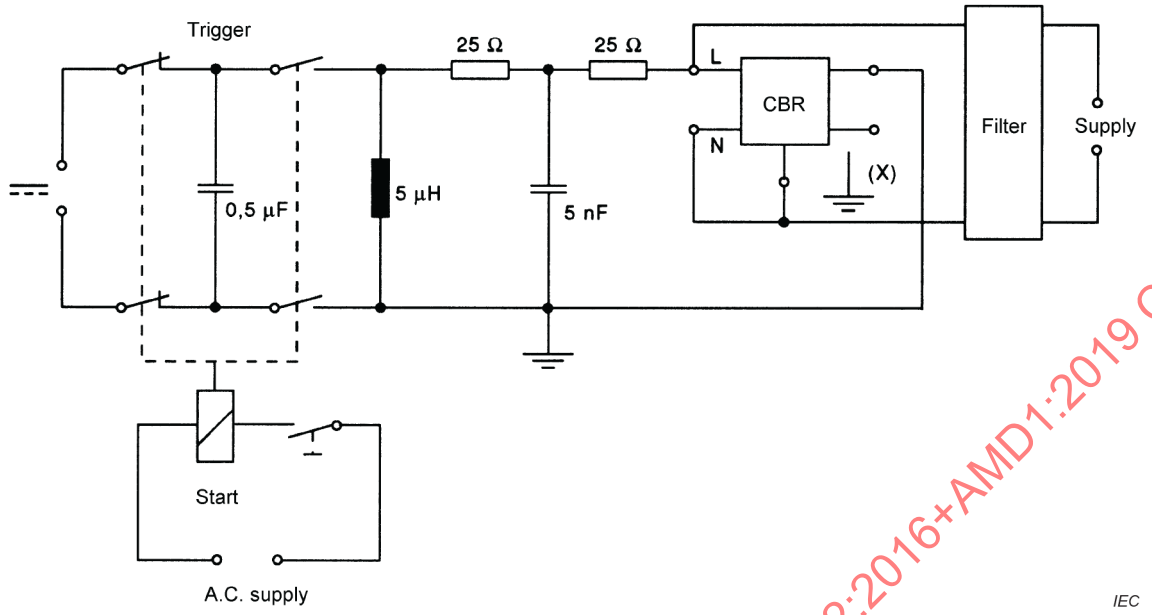


Figure B.4 – Onde de courant 0,5 µs/100 kHz

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Anglais	Français
Trigger	Déclencheur
CBR	DPR
Filter	Filtre
Supply	Alimentation
Start	Courant de départ
A.C. supply	Alimentation c.a.

(X) Borne de terre, si elle existe, raccordée à la borne du neutre, si elle est repérée ou en l'absence d'un tel marquage, à l'une quelconque des bornes de phase.

Les valeurs des composants du circuit sont données seulement comme recommandations et peuvent exiger un réglage afin de satisfaire aux exigences concernant la forme d'onde de la Figure B.4.

Figure B.5 – Exemple de circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs

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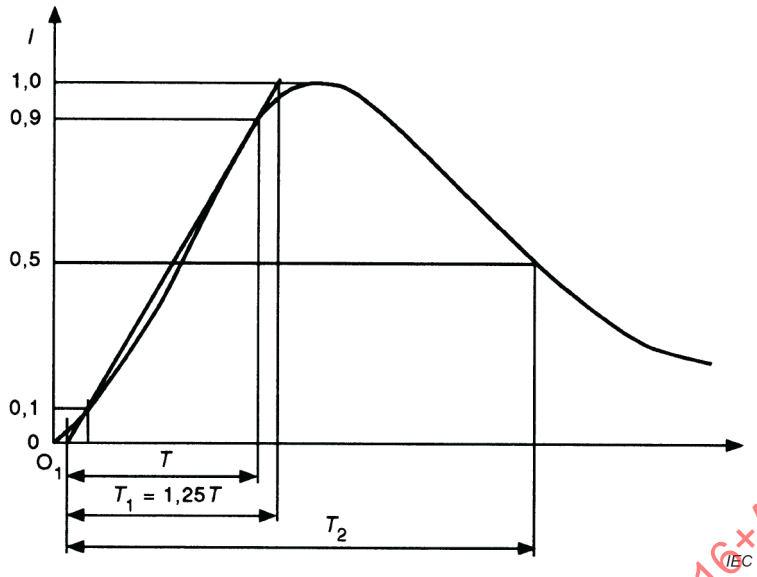
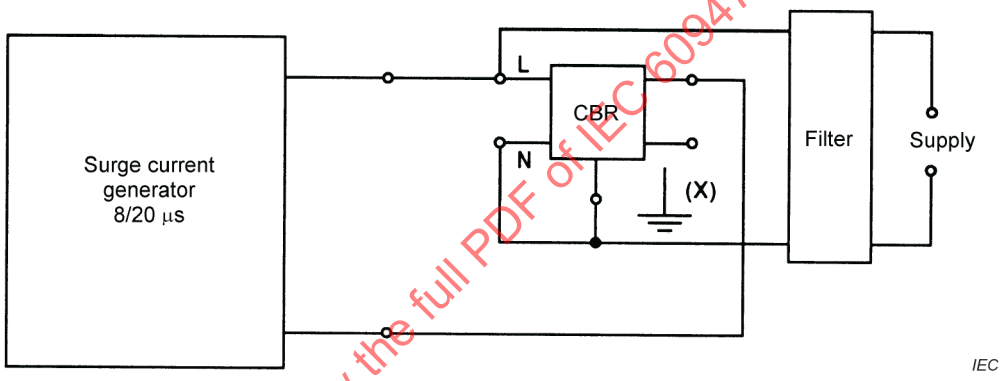


Figure B.6 – Onde de courant de choc 8/20 µs

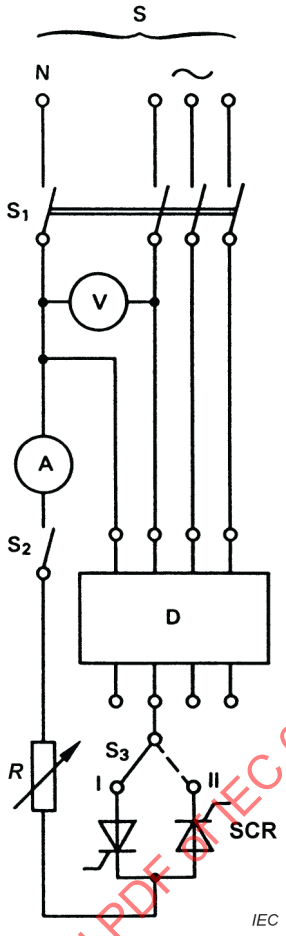


Anglais	Français
Surge current generator 8/20 µs	Onde de courant de choc 8/20 µs
CBR	DPR
Filter	Filtre
Supply	Alimentation

(X) Borne de terre, si elle existe, raccordée à la borne du neutre, si elle est repérée ou en l'absence d'un tel marquage, à l'une quelconque des bornes de phase.

Figure B.7 – Circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs en cas d'amorçage sans courant de suite

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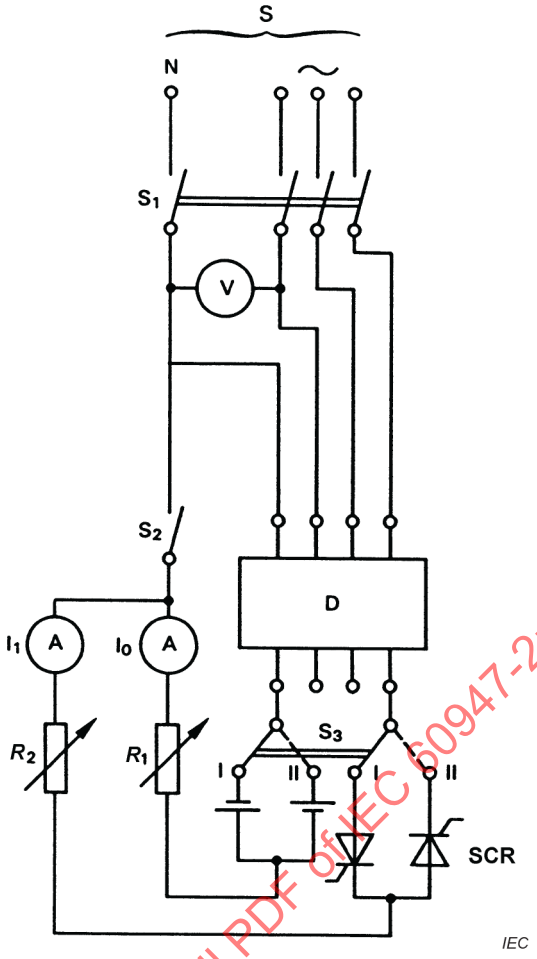


Légende

S alimentation
V voltmètre
A ampèremètre
D DPR soumis à essai
SCR thyristors
R résistance réglable
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire
S_3 interrupteur bidirectionnel

Figure B.8 – Circuit d'essai pour la vérification du fonctionnement correct des DPR, dans le cas de courants différentiels résiduels continus pulsés

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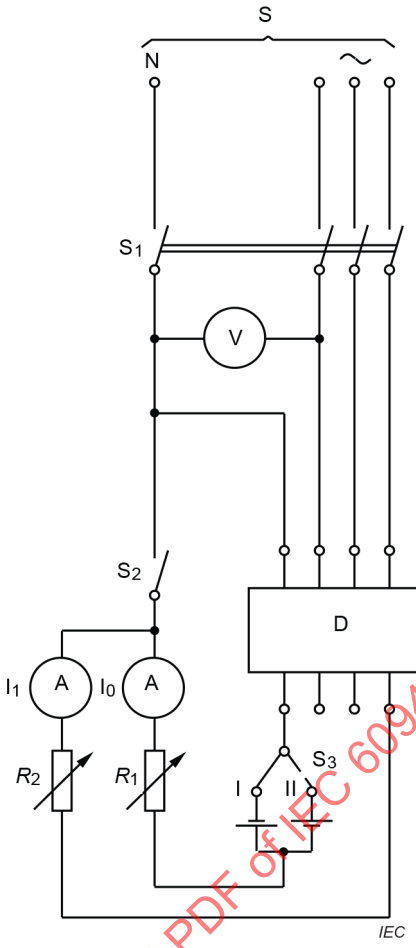


Légende

S	alimentation	R_1, R_2	résistances variables
V	voltmètre	S_1	interrupteur multipolaire
A	ampèremètre	S_2	interrupteur unipolaire
D	DPR soumis à essai	S_3	interrupteur bidirectionnel
SCR	thyristors		

Figure B.9 – Circuit d'essai pour le courant différentiel résiduel continu pulsé auquel est superposé un courant continu lissé

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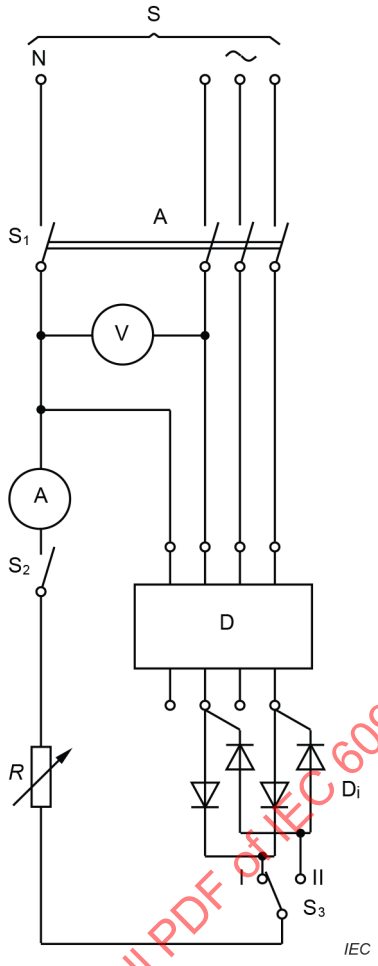


Légende

S	alimentation	R_1, R_2	résistances variables
V	voltmètre	S_1	interrupteur multipolaire
A	ampèremètre	S_2	interrupteur unipolaire
D	DPR soumis à essai	S_3	interrupteur bidirectionnel

Figure B.10 – Circuit d'essai pour les courants différentiels résiduels alternatifs auxquels est superposé un courant continu lissé

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Légende

Alimentation en A par 2 phases choisies au hasard

S alimentation

V voltmètre

A ampèremètre

D DPR soumis à essai

D_i diodes

R résistance réglable

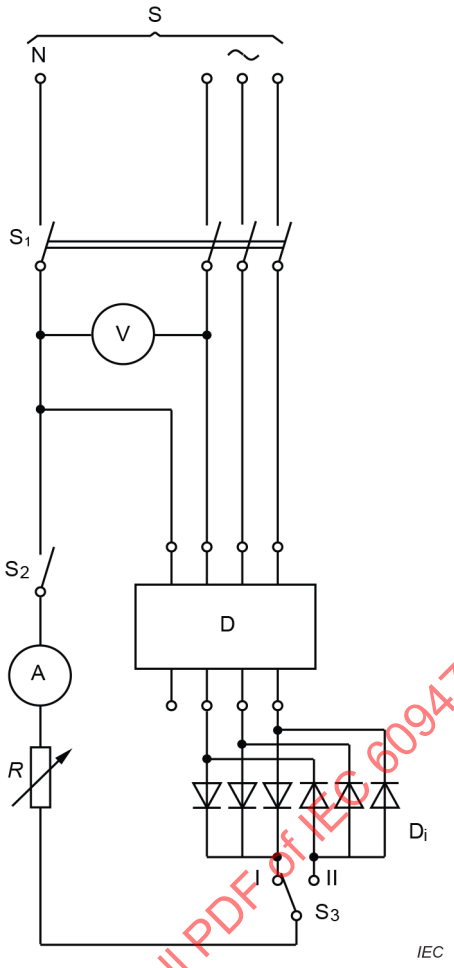
S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_3 interrupteur bidirectionnel

Figure B.11 – Circuit d'essai pour les courants différentiels résiduels continus pulsés pouvant résulter de circuits redresseurs alimentés par deux phases

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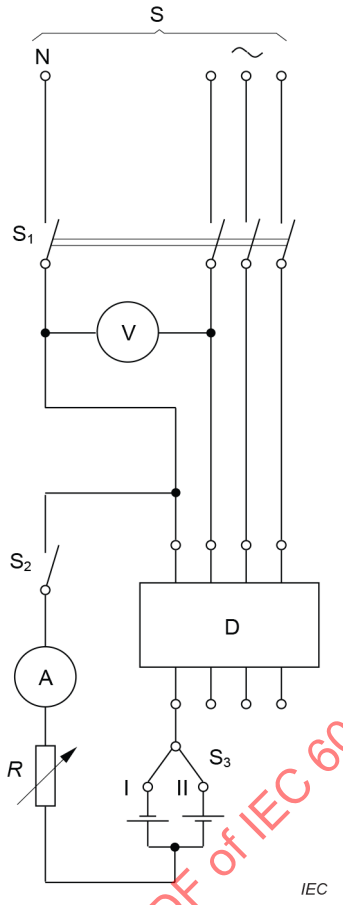


Légende

S alimentation
V voltmètre
A ampèremètre
D DPR soumis à essai
D_i diodes
R résistances réglables
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire
S_3 interrupteur bidirectionnel

Figure B.12 – Circuit d'essai pour les courants différentiels résiduels continus pulsés pouvant résulter de circuits redresseurs alimentés par trois phases

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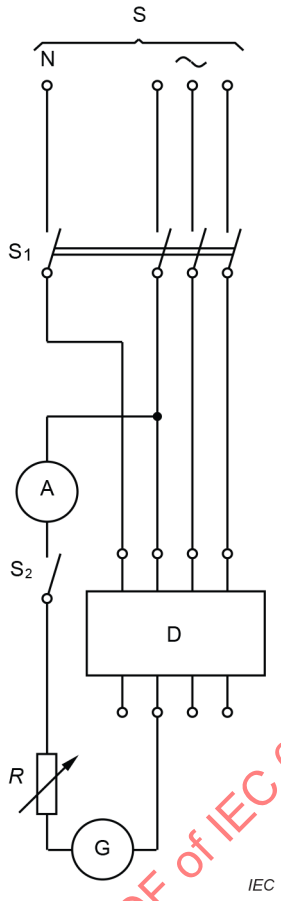


Légende

S alimentation
V voltmètre
A ampèremètre
D DPR soumis à essai
R résistance réglable
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire
S_3 interrupteur bidirectionnel

Figure B.13 – Circuit d'essai pour le courant différentiel résiduel continu lissé

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Légende

S alimentation
A ampèremètre
D DPR soumis à essai
G générateur
R résistance réglable
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire

Figure B.14 – Circuit d'essai pour les courants différentiels résiduels composites et les courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

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Annexe C
(normative)

Séquence d'essai en court-circuit sur un pôle séparément

C.1 Généralités

Cette séquence d'essai est applicable aux disjoncteurs multipolaires pour emploi sur des réseaux ayant une phase reliée à la terre et identifiés comme précisé en 4.3.2.1; elle comprend les essais suivants:

Essai	Article
Pouvoir de coupure en court-circuit sur un pôle séparément (I_{su})	C.2
Vérification de la tenue diélectrique	C.3
Vérification des déclencheurs de surcharge	C.4

C.2 Essai de pouvoir de coupure en court-circuit sur un pôle séparément

Un essai de court-circuit est effectué dans les conditions générales de 8.3.2, avec une valeur de courant présumé I_{su} égale à 25 % du pouvoir assigné de coupure ultime en court-circuit I_{cu}.

NOTE Des valeurs supérieures à 25 % de I_{cu} peuvent être soumises à essai et déclarées par le fabricant.

La tension d'essai doit être la tension phase-phase correspondant à la tension assignée de fonctionnement maximale du disjoncteur adaptée pour les réseaux ayant une phase reliée à la terre, en tenant compte des exigences pour la tension de rétablissement de 8.3.2.2.6. Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10. Le facteur de puissance doit être conforme au Tableau 11, adapté au courant d'essai.

Le circuit d'essai doit être conforme au 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 et à la Figure 9 de l'IEC 60947-1:2007/AMD1:2010, l'alimentation S provenant de deux phases d'une alimentation triphasée, l'élément fusible F étant raccordé à la phase restante. Le ou les pôles disponibles doivent aussi être raccordés à cette phase par l'élément fusible F.

La séquence de manœuvres doit être:

$$O - t - CO$$

et doit être effectuée sur chaque pôle pris séparément, à tour de rôle.

C.3 Vérification de la tenue diélectrique

Après l'essai selon l'Article C.2, la tenue diélectrique doit être vérifiée conformément à 8.3.5.4.

C.4 Vérification des déclencheurs de surcharge

Après l'essai selon l'Article C.3, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.5.

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Annexe D
(normative)

~~**Disponible**~~

Exigences supplémentaires relatives aux disjoncteurs destinés au raccordement de conducteurs en aluminium

D.1 Généralités

L'objectif de la présente annexe est de répondre au besoin de raccorder des conducteurs en aluminium, en variante au cuivre, en spécifiant les essais appropriés et les autres exigences, tout en assurant la sécurité et le fonctionnement correct.

La présente annexe spécifie les exigences relatives à l'utilisation de conducteurs en aluminium à âme massive et à âme divisée, et de jeux de barres en aluminium, avec les disjoncteurs relevant du domaine d'application du présent document, comme suit:

a) les conducteurs d'essai en aluminium qui sont équivalents à, et qui peuvent être utilisés en variante des conducteurs en cuivre donnés dans les Tableaux 9, 10 et 11 de l'IEC 60947-1:2007, pour les bornes représentées aux Figures D.1, D.2, D.3, D.4, D.5 (comprenant les jeux de barres) et D.6 de l'IEC 60947-1:2007/AMD1:2010, ou des organes de serrage similaires;

b) méthode de vérification des organes de raccordement des conducteurs en aluminium conformément à un usage normal, pour les bornes représentées aux Figures D.1, D.2, D.3, D.4 et D.6 de l'IEC 60947-1:2007/AMD1:2010, ou des organes de serrage similaires. Les essais portant sur les organes de serrage pour cosses représentés à la Figure D.5 de l'IEC 60947-1:2007/AMD1:2010 sont couverts par l'IEC 61238-1 (toutes les parties).

Les bornes couvertes par la présente annexe peuvent faire partie intégrante du disjoncteur ou bien être fournies sous forme d'accessoire.

NOTE Le terme "borne" utilisé dans la présente annexe est équivalent au terme "organe de serrage" utilisé dans l'IEC 60947-1.

Les bornes sans vis telles qu'elles sont représentées à la Figure D.7 de l'IEC 60947-1:2007/AMD1:2010, et le raccordement de conducteurs en aluminium à âme souple ne sont pas couverts par la présente annexe. Le raccordement simultané de conducteurs en aluminium et de conducteurs en cuivre dans un même organe de serrage n'est pas couvert par la présente annexe.

D.2 Termes et définitions

L'Article 2 est applicable avec les ajouts suivants:

D.2.1
conducteur de référence
longueur continue de conducteur, de même type et de même section que celui utilisé dans la borne soumise à essai, et reliée au même circuit en série pour permettre de déterminer la température de référence et, si cela est exigé, la résistance de référence

D.2.2
égaliseur
dispositif utilisé dans la boucle d'essai pour assurer un point équipotentiel et une densité de courant uniforme dans un conducteur à âme divisée, sans affecter défavorablement la température du ou des conducteurs

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D.2.3
facteur de stabilité
Sf
mesure de la stabilité de température d'une borne pendant l'essai de cycle de courant

Note 1 à l'article: Les définitions pour les différents types de bornes figurent dans l'Annexe D de l'IEC 60947-1:2007/AMD1:2010.

D.3 Classification

L'Article 3 est applicable avec les ajouts suivants:

Suivant le raccordement du conducteur:

– utilisable uniquement avec des conducteurs en cuivre, ou
– utilisable avec des conducteurs en cuivre ou des conducteurs en aluminium, ou
– utilisable uniquement avec des conducteurs en aluminium.

D.4 Caractéristiques

L'Article 4 est applicable.

D.5 Informations sur le matériel

D.5.1 Nature des informations

Le paragraphe 5.1 est applicable.

D.5.2 Marquage

Le paragraphe 5.2 est applicable avec l'ajout suivant:

L'aptitude de la borne à une utilisation uniquement avec des conducteurs en aluminium (Al), ou à une utilisation avec des conducteurs en cuivre et des conducteurs en aluminium (Cu/Al) doit être marquée sur le disjoncteur ou les bornes du disjoncteur, ou mentionnée dans la documentation du fabricant, suivant le cas. Lorsque le marquage figure sur le disjoncteur ou ses bornes, les abréviations "AL" et "CU/AL" peuvent également être utilisées.

Si le courant assigné des bornes est inférieur au courant assigné du disjoncteur, il doit être marqué sur le disjoncteur ou les bornes du disjoncteur, ou mentionné dans la documentation du fabricant, suivant le cas.

D.5.3 Instructions d'installation, de fonctionnement et d'entretien

Le paragraphe 5.3 est applicable avec l'ajout suivant:

La documentation du fabricant peut recommander des bonnes pratiques d'installation, telles que:

(i) après avoir retiré l'isolation du conducteur, et préalablement au raccordement, l'âme en aluminium du conducteur doit être nettoyée à l'aide d'une brosse métallique, puis un composé antioxydant doit être appliqué afin de limiter l'oxydation de l'aluminium;

(ii) traitement du jeu de barres aux points de raccordement, par nettoyage de l'aluminium à l'aide d'une brosse métallique puis application d'un composé antioxydant, ou bien par application d'une couche conductrice d'électricité, telle que l'étamage;

(iii) utilisation de matériel spécifique pour le raccordement.

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D.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

D.7 Exigences relatives à la construction et au fonctionnement

L'Article 7 est applicable avec l'ajout suivant:

Les organes de serrage destinés à être utilisés avec un ou des conducteurs en aluminium doivent recevoir un traitement de surface électriquement conducteur, tel que l'étamage, ou d'autres moyens visant à empêcher une corrosion due à des potentiels électrochimiques différents.

Le fabricant doit spécifier si les bornes sont appropriées pour des conducteurs à âme divisée, à âme massive, ou les deux. Des essais de fonctionnement doivent être réalisés avec tous les types de conducteurs spécifiés par le fabricant.

Les sections de conducteurs en aluminium données pour les différents courants dans le Tableau D.7 et le Tableau D.8 correspondent à celles du Tableau 9, du Tableau 10 et du Tableau 11 de l'IEC 60947-1:2007 pour les conducteurs en cuivre.

NOTE Les sections de conducteurs ont été extraites de l'IEC 60898-1 et des documents UL 486E et IS 13947-1.

D.8 Essais

D.8.1 Généralités

Les essais doivent être réalisés avec des conducteurs en aluminium présentant une section conforme à celles données dans le Tableau D.7, correspondant à la plus faible valeur soit du courant assigné de l'appareil, soit du courant assigné des bornes.

Le câble en aluminium à utiliser doit être un câble à âme massive avec une isolation noire, présentant des propriétés électriques et mécaniques conformes à l'IEC 60228.

Un conducteur en aluminium de classe A, fabriqué avec de l'alliage d'aluminium 1350, tel qu'il est spécifié dans l'IEC 61545, doit être utilisé pour les essais.

NOTE 1 L'alliage d'aluminium 1350 est généralement considéré comme étant le cas le plus défavorable et son usage à des fins d'essai est conforme aux normes UL 486.

NOTE 2 Les exigences définissant l'adéquation de bornes destinées à être utilisées avec des conducteurs à âme sectorale sont à l'étude.

Les essais suivants doivent être réalisés sur le matériel ou le spécimen de borne à utiliser dans le produit fini, comme spécifié dans le Tableau D.1 ci-après. Chaque spécimen se compose d'une paire de bornes et d'une partie conductrice.

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Tableau D.1 – Liste des essais pour les raccordements[a] de câbles en aluminium dans les bornes

Essai		Paragraphe	Essai portant sur	Nombre de spécimens
Essai de cycle de courant		D.8.2	Spécimen de borne	4 spécimens
Propriétés mécaniques des bornes	Essai de flexion	D.8.3.1	Disjoncteur	Conformément au 8.2.4.3 de l'IEC 60947-1:2007/AMD1:2010
	Essai de traction	D.8.3.2		Conformément au 8.2.4.4 de l'IEC 60947-1:2007/AMD1:2010
Essai d'insertion		D.8.4	Disjoncteur	Conformément au 8.2.4.5 de l'IEC 60947-1:2007/AMD1:2010

[a] Type de raccordement limité aux types d'organes de serrage représentés aux Figures D.1, D.2, D.3, D.4 et D.6, conformément à l'Annexe D de l'IEC 60947-1:2007/AMD1:2010.

D.8.2 Essai de cycle de courant

D.8.2.1 Généralités

La finalité de cet essai est de vérifier la stabilité de la borne en comparant sa température avec celle du conducteur de référence, dans des conditions de cycle de courant. Cet essai doit être réalisé sur les bornes seules, et non sur le disjoncteur.

D.8.2.2 Préparation

L'essai doit être réalisé sur quatre spécimens, chacun d'eux étant constitué d'une paire de bornes, assemblées de manière telle qu'elles soient représentatives de l'utilisation des bornes dans le disjoncteur. Les bornes qui ont été retirées du matériel doivent être solidarisées à des parties conductrices de section, de forme, de composition métallique et de finition identiques à celles sur lesquelles elles sont montées sur le matériel. La partie conductrice ne doit pas dépasser:

(i) trois fois la longueur de la borne,

(ii) la largeur de la borne,

comme représenté à la Figure D.2. Les bornes doivent être solidarisées aux parties conductrices de la même manière (position, couple, etc.) que sur le matériel.

Pour éviter une oxydation excessive du conducteur et pour assurer un raccordement approprié, une longueur d'isolation suffisante doit être retirée juste avant l'installation (c'est-à-dire sans retard intentionnel).

Le fil doit être positionné de telle sorte qu'une longueur de conducteur nu comprise entre 6 mm et 13 mm soit exposée entre la face d'insertion du fil dans la borne et le bord de l'isolation. Il ne doit pas y avoir d'élimination mécanique ou par traitement chimique d'une quelconque oxydation à la surface du conducteur pénétrant dans la borne, sauf si les instructions du fabricant l'exigent explicitement, auquel cas cela doit être indiqué dans le rapport d'essai.

D.8.2.3 Dispositif d'essai

La disposition générale des échantillons doit être telle qu'elle est représentée à la Figure D.1.

L'essai doit être réalisé avec des conducteurs conformes au Tableau D.7, en spécifiant la section équivalente pour les conducteurs en aluminium.

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La longueur du conducteur d'essai, depuis le point d'entrée des spécimens de borne jusqu'à l'égaliseur, doit être conforme au Tableau D.2.

Les conducteurs d'essai doivent être raccordés en série à un conducteur de référence de section identique. La longueur du conducteur de référence doit être approximativement égale à deux fois celle du conducteur d'essai.

90 % de la valeur du couple stipulé par le fabricant, ou en l'absence d'une telle indication, du couple sélectionné dans le Tableau 4 de l'IEC 60947-1:2007/AMD2:2014, doit être appliqué pour raccorder les câbles en aluminium aux spécimens de bornes.

Chaque extrémité libre du ou des conducteurs d'essai et de référence, non raccordée à un spécimen de borne, doit être soudée ou brasée à une courte longueur d'égaliseur dont la section ne dépasse pas celle donnée dans le Tableau D.3. Tous les brins du conducteur doivent être soudés ou brasés afin d'établir une connexion électrique avec l'égaliseur. En variante, des raccordements par sertissage à compression à l'aide d'un outil sans soudage ni brasage, peuvent être utilisés pour l'égaliseur, sous réserve d'accord du fabricant.

Pour une borne de câblage d'équipement destinée au raccordement en parallèle de conducteurs, l'espacement entre les orifices dans l'égaliseur doit être identique à celui de la borne de câblage de l'équipement.

La distance entre les conducteurs d'essai et de référence doit être d'au moins 150 mm.

Le spécimen d'essai doit être suspendu à l'air libre à l'horizontale ou à la verticale, en soutenant l'égaliseur par le biais de supports non conducteurs, de façon à réduire le plus possible la charge de traction sur les bornes. Des barrières thermiques doivent être installées à mi-chemin entre les conducteurs, et doivent s'étendre sur 25 mm ± 5 mm dans le sens de la largeur et sur 150 mm ± 10 mm dans le sens de la longueur au-delà des bornes (voir Figure D.1). Les barrières thermiques ne sont pas exigées lorsque les spécimens sont distants d'au moins 450 mm. Les spécimens doivent être disposés à au moins 600 mm du sol, d'une paroi ou du plafond.

Les spécimens d'essai doivent être disposés dans un environnement essentiellement exempt de vibrations et de courants d'air, et à une température ambiante comprise entre 15 °C et 35 °C. Une fois l'essai démarré, la variation maximale admissible est de ± 4 K, sous réserve de ne pas dépasser les limites autorisées.

D.8.2.4 Mesurages de température

Les mesurages de température sont effectués au moyen de thermocouples. Le positionnement des thermocouples ne doit pas endommager la borne ni le conducteur de référence.

NOTE 1 Le perçage d'un petit trou suivi de la fixation du thermocouple constitue une méthode acceptable, sous réserve que le fonctionnement n'en soit pas affecté et sous réserve de l'accord du fabricant.

Pour le mesurage de la température de la borne, le thermocouple doit être disposé du côté de l'insertion du conducteur dans la borne, à proximité de l'interface de contact.

Pour le mesurage de la température du conducteur de référence, le thermocouple doit être disposé à mi-chemin entre les extrémités du conducteur et sous son isolant.

La température ambiante doit être mesurée avec deux thermocouples, de manière à assurer une lecture moyenne et stable à proximité de la boucle d'essai, sans influence externe indésirable. Les thermocouples doivent être disposés dans un plan horizontal passant par les spécimens, à une distance minimale de ceux-ci de 600 mm.

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NOTE 2 Une méthode satisfaisante pour atteindre la stabilité du mesurage consiste, par exemple, à fixer le thermocouple à des plaques en cuivre sans traitement de surface, d'environ 50 mm x 50 mm et d'une épaisseur comprise entre 6 mm et 10 mm.

D.8.2.5 Méthode d'essai

La boucle d'essai doit être soumise à 500 cycles; chaque cycle se compose d'une durée à l'état passant et d'une durée d'arrêt, comme spécifié, en commençant à la valeur de courant d'essai donnée dans le Tableau D.4.

La durée à l'état passant doit correspondre au temps nécessaire à la borne éprouvette pour atteindre une température stable. La durée d'arrêt doit correspondre au temps nécessaire pour atteindre la température ambiante du local. Ces durées doivent être déterminées au cours des 25 premiers cycles de l'essai. Une borne éprouvette a atteint une température stable lorsque trois lectures, effectuées à au moins 10 min d'intervalle, ne révèlent pas de variation supérieure à 2 °C entre deux quelconques des lectures. La durée de stabilisation en température correspond à la première des trois lectures indiquant une température stable.

Un refroidissement à air pulsé peut être utilisé pour réduire la durée d'arrêt, si cela est admis par le fabricant. Dans ce cas, il doit être appliqué sur l'ensemble de la boucle d'essai et la température résultant de l'application de l'air pulsé ne doit pas être inférieure à la température de l'air ambiant.

En variante, pour les bornes avec un seul conducteur, les durées à l'état passant et/ou d'arrêt du Tableau D.4 peuvent être utilisées.

A l'approche de la fin de chaque durée à l'état passant pour les 24 premiers cycles, la température de chaque borne doit avoir atteint un minimum de 105 °C. Si nécessaire, le courant doit être ajusté pour satisfaire cette condition.

Lorsque le fabricant atteste que l'échauffement maximal des bornes est inférieur à 70 K, la température de 105 °C peut être réduite à cette valeur de l'échauffement plus 35 °C. Ceci doit être attesté au moyen d'un essai d'échauffement, conformément aux conditions générales du 8.3.3.3.4 de l'IEC 60947-1:2007, réalisé sur l'appareil en appliquant la plus faible de la valeur de courant, entre le courant assigné de l'appareil et le courant assigné des bornes. Cet essai doit être réalisé sur un appareil neuf, équipé des bornes à l'étude et des conducteurs en aluminium tels qu'ils sont spécifiés dans le Tableau D.7. L'échauffement maximal de toutes les bornes doit être utilisé afin de déterminer la température cible pour l'essai de cycle de courant.

Au 25^{e} cycle, le courant d'essai doit être ajusté pour la dernière fois et la température correspondante, une fois stabilisée avec le courant de charge final, doit être consignée comme étant le premier mesurage. Il ne doit y avoir aucun ajustement ultérieur du courant d'essai pendant le restant de l'essai.

Les températures doivent en outre être consignées après environ 50, 75, 100, 125, 175, 225, 275, 350, 425 et 500 cycles. La température doit être mesurée pendant les 5 dernières minutes de la durée à l'état passant. Si le nombre d'éprouvettes ou la vitesse d'acquisition des données est tel(le) que tous les mesurages ne peuvent pas être réalisés en moins de 5 min, la durée à l'état passant doit être étendue autant que nécessaire de manière à effectuer ces mesurages.

D.8.2.6 Critères d'acceptation

L'appréciation des performances est basée sur la limite d'échauffement de la borne et la variation de température (facteur de stabilité) au cours de l'essai.

Le facteur de stabilité, *Sf*, pour chacun des 11 mesurages de température, doit être déterminé comme suit:

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– calculer l'écart de température *d* pour chacun des 11 mesurages de température en soustrayant la température du conducteur de référence associé de la température de la borne;

– calculer l'écart de température moyen *D* à partir des 11 valeurs *d*;

– calculer *S*f = *d* − *D* pour chaque valeur *d*.

Voir l'exemple de calcul du facteur de stabilité dans le Tableau D.5.

NOTE La valeur *d* est positive si la température de la borne est supérieure à celle du conducteur de référence, et négative si la température de la borne est inférieure à celle du conducteur de référence.

Pour chaque borne:

– l'échauffement ne doit pas dépasser 125 K; et

– le facteur de stabilité *S*f ne doit pas dépasser ± 10 K.

S'agissant d'un essai de vieillissement accéléré, l'isolation peut être endommagée en raison des températures élevées, mais cela n'est pas considéré comme un échec à cet essai.

D.8.3 Propriétés mécaniques des bornes

D.8.3.1 Essai de flexion

Le paragraphe 8.2.4.3 de l'IEC 60947-1:2007/AMD1:2010 est applicable avec la modification suivante:

Les valeurs d'essai doivent être conformes au Tableau D.6.

D.8.3.2 Essai de traction

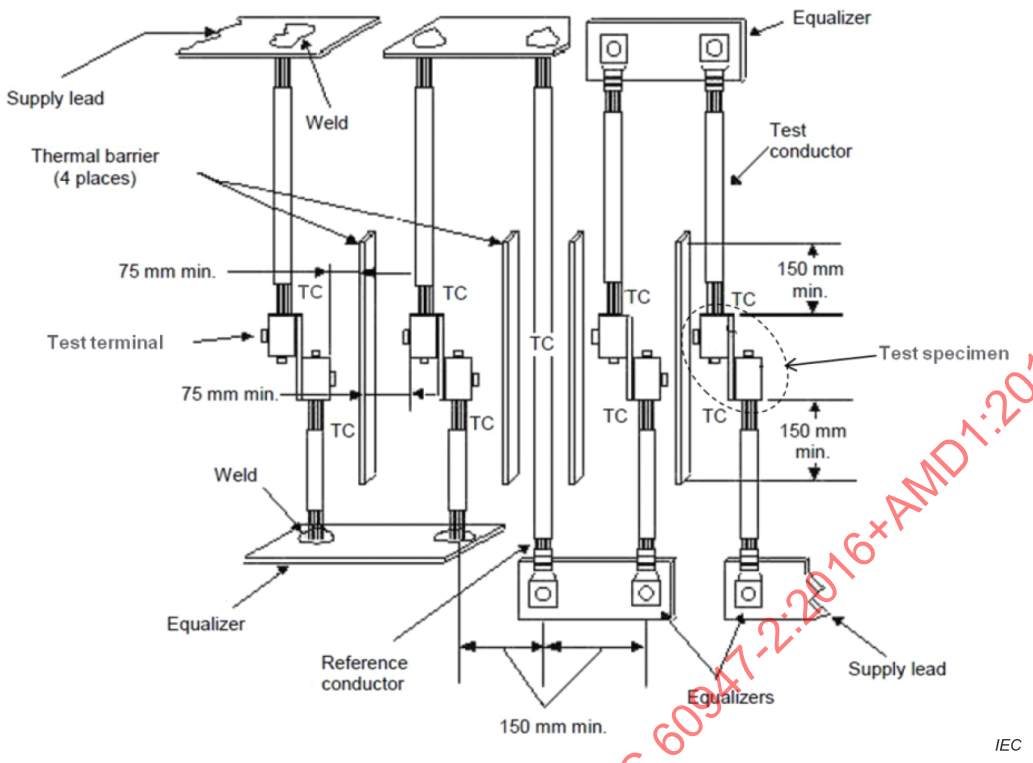
Le paragraphe 8.2.4.4 de l'IEC 60947-1:2007/AMD1:2010 est applicable avec la modification suivante:

Les valeurs d'essai doivent être conformes au Tableau D.6.

D.8.4 Essai d'insertion de conducteurs ronds en aluminium et non préparés de section maximale

Le paragraphe 8.2.4.5 de l'IEC 60947-1:2007/AMD1:2010 est applicable. Le Tableau 7 de l'IEC 60947-1:2007 est applicable, à l'exception de la colonne dédiée aux conducteurs à âme souple.

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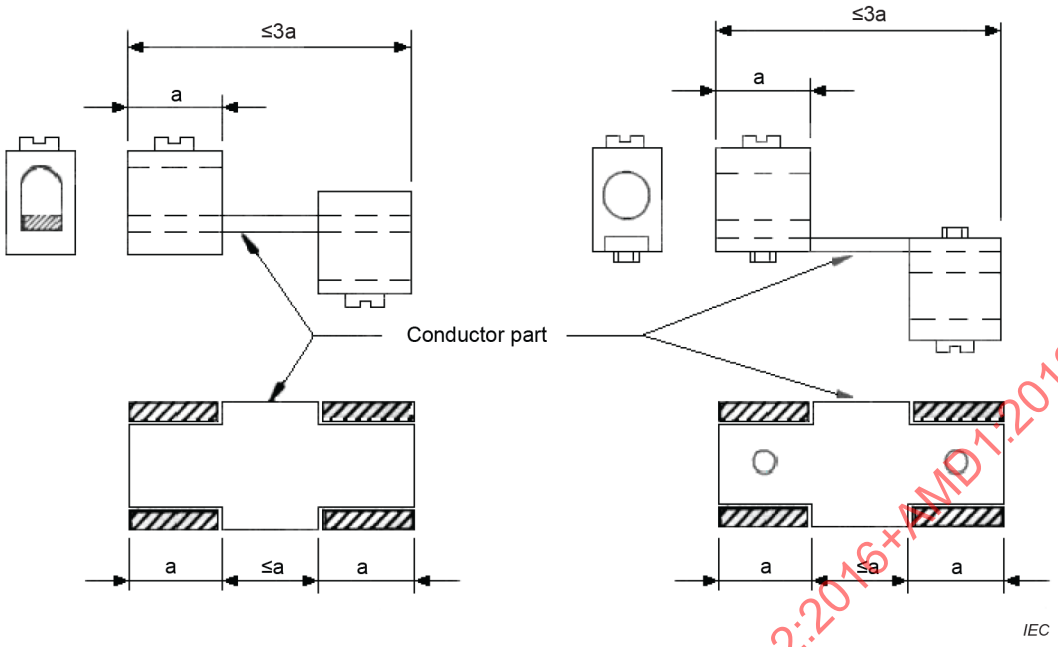
Anglais	Français
Supply lead	Conducteur d'alimentation
Thermal barrier (4 places)	Barrière thermique (4 éléments)
75 mm min.	75 mm min.
Test terminal	Borne éprouvette
Weld	Soudure
Equalizer	Egaliseur
Reference conductor	Conducteur de référence
150 mm min.	150 mm min.
Equalizers	Egaliseurs
Test specimen	Eprouvette
Test conductor	Conducteur d'essai
TC	TC

Légende

TC thermocouple

Figure D.1 – Disposition d'essai générale

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Anglais	Français
Conductor part	Partie conductrice

Figure D.2 – Montage des bornes pour l'essai de cycle de courant

Tableau D.2 – Longueur de conducteur pour l'essai de cycle de courant en fonction de la section du conducteur

Section de conducteur		Longueur de conducteur minimale
mm^2	Valeur AWG/kcmil	mm
0 à 10	30 à 8	200
16 à 25	6 à 3	300
35 à 240	2 à 500	460
Supérieure à 240	Supérieure à 500	660

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Tableau D.3 – Dimensions de l'égaliseur

Plage de courant d'essai A		Dimensions maximales[a] (épaisseur x largeur)			
		Cuivre		Aluminium	
>	≤	mm	pouces	mm	pouces
0	50	3,2 × 12,7	1/8 × 1/2	3,2 × 12,7	1/8 × 1/2
50	125	3,2 × 25	1/8 × 1	3,2 × 32	1/8 × 1-1/4
125	225	3,2 × 48	1/8 × 1-7/8	3,2 × 57	1/8 × 2-1/4
225	400	6,4 × 38	1/4 × 1-1/2	6,4 × 50	1/4 × 2
400	600	6,4 × 50	1/4 × 2	6,4 × 76	1/4 × 3
600	800	6,4 × 76	1/4 × 3	6,4 × 102	1/4 × 4
800	1 000	6,4 × 102	1/4 × 4	9,5 × 89	3/8 × 3-1/2
1 000	1 400	12,7 × 76	1/2 × 3	12,7 × 89	1/2 × 3-1/2
1 400	2 000	12,7 × 102	1/2 × 4	12,7 × 127	1/2 × 5

[a] L'équivalence entre mm et pouces est uniquement approximative; il est admis que l'égaliseur satisfasse aux colonnes en millimètres ou en pouces. D'autres dimensions peuvent être utilisées sous réserve que la densité de courant pour la limite supérieure du courant d'essai (2ème colonne) soit supérieure à 1,16 A/mm^2 (750 A/in^2) pour un égaliseur en aluminium, ou supérieure à 1,55 A/mm^2 (1 000 A/in^2) pour un égaliseur en cuivre.

Tableau D.4 – Courant d'essai de départ pour l'essai de cycle de courant

Section du ou des câbles			Courant d'essai	Durée à l'état passant et durée d'arrêt
Nombre	mm^2	Valeur AWG/kcmil	A	heures
1	4	12	33	1
1	6	10	45	1
1	10	8	60	1
1	16	6	85	1
1	25	4	110	1
1	35	2	150	1
1	50	0	200	1
1	70	00	230	1
1	95	000	270	1
1	120	250 kcmil	350	1,5
1	150	300 kcmil	390	1,5
1	185	350 kcmil	435	1,5
1	240	500 kcmil	540	2
2	120	250 kcmil	460	-
2	150	300 kcmil	510	-
2	240	500 kcmil	707	-
2	300	600 kcmil	907	-
3	240	500 kcmil	1 060	-

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Tableau D.5 – Exemple de calcul du facteur de stabilité

Mesurage de température	Nombre de cycles	Températures		Ecart de température d = a) – b)	Facteur de stabilité $S_f = d - D$ [a]
		a) De la borne[b] °C	b) Du conducteur de référence °C	K	K
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	-0,82
4	100	76	77	-1	-1,82
5	125	77	77	0	-0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	-1	-1,82
10	425	77	79	-2	-2,82
11	500	81	78	3	2,18

[a] Ecart de température moyen $D = \frac{\sum d}{\text{nombre de mesurages}} = \frac{9}{11} = 0,82$.

[b] L'exemple concerne une borne pour câble présentant une température maximale de 75 °C.

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Tableau D.6 – Valeurs d'essai pour l'essai de flexion et l'essai de traction des câbles

Section de conducteur		Diamètre du trou du manchon[a, b]	Hauteur H[a]	Masse	Force de traction
mm^2	Valeur AWG/kcmil	mm	mm	kg	N
4	12	9,5	280	0,7	44
6	10	9,5	280	0,7	44
10	8	9,5	280	1,4	44
16	6	12,7	300	4	124
25	4	12,7	300	4,5	160
-	3	14,3	320	5,9	187
35	2	14,3	320	6,8	222
-	1	15,8	343	8,6	271
50	0	15,8	343	9,5	320
70	00	19,1	368	10,4	347
95	000	19,1	368	13,6	432
-	0000	19,1	368	13,6	516
120	250 kcmil	22,2	406	13,6	516
150	300 kcmil	22,2	406	15,4	516
185	350 kcmil	25,4	432	17,2	574
-	400 kcmil	25,4	432	17,2	574
240	500 kcmil	28,6	464	20,4	685
300	600 kcmil	28,6	464	20,4	685

NOTE Le Tableau D.6 est basé sur le document UL 486E.

[a] La tolérance pour la hauteur *H* est de ± 15 mm, la tolérance pour le diamètre du trou du manchon est de ± 2 mm.

[b] Si le diamètre du trou du manchon n'est pas suffisant pour accueillir le conducteur sans retenue, un manchon dont la taille du trou est immédiatement supérieure peut être utilisé.

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Tableau D.7 – Câbles d'essai en aluminium pour des courants d'essai pouvant atteindre 800 A[a,d]

Plage de courants d'essai A		Section de câble		
>	≤	Nombre	mm²	Valeur AWG/kcmil
0	8	1	c	c
8	12	1	c	c
12	15	1	4[b]	12[b]
15	20	1	4[b]	12[b]
20	25	1	6[b]	10[b]
25	32	1	10	8
32	50	1	16	6
50	65	1	25	4
65	85	1	35	2
85	100	1	50	0
100	115	1	50	0
115	130	1	70	00
130	150	1	95	000
150	175	1	120	250 kcmil
175	200	1	150	300 kcmil
200	225	1	150	300 kcmil
225	250	1	185	350 kcmil
250	275	1	240	500 kcmil
275	300	2	120	250 kcmil
300	350	2	120	250 kcmil
350	400	2	150	300 kcmil
400	500	2	240	500 kcmil
500	630	2	300	600 kcmil
630	800	3	240	500 kcmil

[a] Voir 8.3.3.3.4 de l'IEC 60947-1:2007.

[b] Les règlementations nationales peuvent exiger des sections plus élevées. Les câbles en aluminium de section inférieure à 10 mm² ne sont pas recommandés conformément à l'IEC 60364-5-52.

[c] Les câbles en aluminium de section inférieure à 4 mm² ne sont pas recommandés.

[d] Les câbles d'essai pour les courants supérieurs à 800 A sont à l'étude.

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Tableau D.8 – Barres d'essai en aluminium pour des courants d'essai supérieurs à 400 A[g] et pouvant atteindre 3 150 A[a, f]

Plage de courant d'essai A		Barres en aluminium [b c d]	
>	≤	Nombre	Dimensions (mm)
400	500	2	25 × 10
500	630	2	30 × 12
630	800	2	40 × 10
800	1 000	2	50 × 10
1 000	1 250	2	80 × 10
1 250	1 600	2	100 × 10
1 600	2 000	3	100 × 10
2 000	2 500	4	100 × 10
2 500	3 150	4	150 × 10[e]

[a] Voir 8.3.3.3.4 de l'IEC 60947-1:2007.

[b] Pour une plus grande praticité lors des essais, et sous réserve d'accord du fabricant, des conducteurs de dimensions inférieures à celles données pour un courant d'essai indiqué peuvent être utilisés.

[c] Les barres sont par hypothèse disposées avec leur côté long dans le sens vertical. Les dispositions avec le côté long dans le sens horizontal peuvent être utilisées, si le fabricant le spécifie.

[d] Lorsque quatre barres sont utilisées, elles doivent être réparties en deux ensembles de deux barres, sans dépasser un écartement de 100 mm entre le centre de chaque paire.

[e] Les dimensions données sont uniquement des recommandations. Des dimensions différentes peuvent être utilisées sous réserve d'accord entre le fabricant et l'utilisateur.

[f] Pour les courants assignés supérieurs à 3 150 A, un accord doit être passé entre le fabricant et l'utilisateur concernant tous les points pertinents de l'essai, tels que: type d'alimentation, nombre de phases et fréquence (le cas échéant), section des connexions d'essai, etc. Ces informations doivent faire partie intégrante du rapport d'essai.

[g] Des barres en aluminium pour des courants d'essai inférieurs ou égaux à 400 A sont à l'étude.

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Annexe E
(informative)

Points faisant l'objet d'un accord entre le fabricant et l'utilisateur

NOTE Pour les besoins de la présente annexe:

– le mot «accord» s'entend dans un sens très large;

– le mot «utilisateur» comprend les stations d'essai.

L'Annexe J de l'IEC 60947-1:2007 est applicable en ce qui concerne les articles et les paragraphes auxquels se réfère la présente norme, avec les compléments suivants:

Numéro d'article ou de paragraphe de la présente norme	Elément
4.3.6.3	Disjoncteurs de pouvoir de fermeture en court-circuit supérieur aux valeurs du Tableau 2
7.2.1.2.1	Manœuvre d'ouverture automatique autre qu'à déclenchement libre mais à accumulation d'énergie
Tableau 10	Réglage des déclencheurs de surcharge aux valeurs intermédiaires pour les essais de court-circuit
8.3.3.5	Méthode à suivre pour les essais d'échauffement des disjoncteurs tétrapolaires de courant thermique conventionnel supérieur à 63 A
8.3.2.6.4.3	Valeur du courant d'essai pour les essais de court-circuit des disjoncteurs tétrapolaires sur le quatrième pôle
8.3.3.2.3, point b)	Valeur du courant d'essai pour la vérification des caractéristiques temps/courant inverses
8.3.3.5	Augmentation de la sévérité des conditions d'essai de fonctionnement en surcharge
8.3.3.8 8.3.4.6	Délai admissible entre la vérification de l'échauffement et celle des relais de surcharge dans les séquences d'essai I et II
8.4.3	Etalonnage des déclencheurs autres que les déclencheurs de surintensité, les déclencheurs shunt et les déclencheurs à minimum de tension
8.5	Essais spéciaux – Chaleur humide, brouillard salin, vibrations et chocs
B.8	Applicabilité des essais lorsque $I_{\Delta n} > 30$ A
B.8.2.5	Extension des limites de l'essai à température ambiante

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Annexe F
(normative)

Essais supplémentaires pour les disjoncteurs à protection électronique contre les surintensités

F.1 Généralités

La présente annexe s'applique aux disjoncteurs destinés à être installés dans des circuits à courant alternatif et dont la protection contre les surintensités est assurée par des moyens électroniques, incorporés dans le disjoncteur et indépendants de la tension d'alimentation ou de toute source auxiliaire.

Les essais vérifient les performances des disjoncteurs dans les conditions d'environnement spécifiées dans cette annexe.

Les essais spécifiques concernant des dispositifs électroniques prévus pour des fonctions autres que la protection contre les surintensités ne sont pas couverts par cette annexe. Cependant, les essais de cette annexe doivent être effectués pour s'assurer que ces moyens électroniques n'affectent pas les performances des fonctions de protection contre les surintensités.

F.2 Liste des essais

F.2.1 Généralités

Les essais spécifiés dans cette annexe sont des essais de type et sont complémentaires aux essais de l'Article 8.

NOTE Lorsqu'il existe une norme pour des conditions spécifiques d'environnement, il est fait systématiquement référence à la présente norme, si elle est pertinente.

F.2.2 Essais de compatibilité électromagnétique (CEM)

F.2.2.1 Généralités

Les disjoncteurs avec protection électronique contre les surintensités doivent être soumis à essai conformément au Tableau J.1 et à la Figure J.3.

F.2.2.2 Critères de comportement

Les résultats des essais d'immunité doivent être évalués sur la base des critères de comportement indiqués en J.2.1, avec les spécifications suivantes:

Critère de comportement A:

Pour l'étape 1, le disjoncteur, chargé à 0,9 fois le courant de réglage, ne doit pas déclencher et les fonctions de surveillance, le cas échéant, doivent indiquer correctement l'état du disjoncteur.

Pour l'étape 2, le disjoncteur, chargé à 2,0 fois le courant de réglage, doit déclencher dans un temps compris entre 0,9 fois la valeur minimale et 1,1 fois la valeur maximale de la caractéristique temps-courant fournie par le fabricant, et les fonctions de surveillance, le cas échéant, doivent indiquer correctement l'état du disjoncteur.

Critère de comportement B:

Pendant l'essai, le disjoncteur, chargé à 0,9 fois le courant de réglage, ne doit pas déclencher. Après l'essai, le disjoncteur doit être conforme à la caractéristique temps-

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courant du fabricant lorsqu'il est chargé à 2,0 fois le courant de réglage, et les fonctions de surveillance, le cas échéant, doivent indiquer correctement l'état du disjoncteur.

F.2.3 Aptitude au fonctionnement à des fréquences multiples

L'essai doit être effectué selon F.6.

F.2.4 Essai de chaleur sèche

L'essai doit être effectué selon F.7.

F.2.5 Essai de chaleur humide

L'essai doit être effectué selon F.8.

F.2.6 Cycles de variation de température avec un taux de variation spécifié

L'essai doit être effectué selon F.9.

F.3 Conditions générales d'essai

F.3.1 Généralités

Les essais de la présente annexe peuvent être effectués indépendamment des essais de l'Article 8.

Dans le cas des essais CEM, l'Annexe J est applicable avec les exigences complémentaires spécifiées en F.4 et F.5.

F.3.2 Essais de compatibilité électromagnétique

Pour les essais d'immunité (F.4), un disjoncteur par taille et par type de conception du capteur de courant doit être soumis à essai; dans ce contexte, un changement du nombre de spires n'est pas considéré comme une différence de conception. Dans le cas d'un disjoncteur débrochable, l'appareil doit être monté à l'intérieur de l'enveloppe conformément aux instructions du fabricant, l'installation d'essai étant modifiée en conséquence.

Le courant de réglage I_r doit être réglé à la valeur minimale.

Les courants de déclenchement de courte durée et instantané doivent être réglés, le cas échéant, chacun à la valeur minimale sans être inférieurs à 2,5 fois I_r.

Les essais doivent être effectués au moyen d'un circuit d'essai approprié, comme spécifié dans les paragraphes qui suivent, en prenant en compte tous les dispositifs sensibles à la perte de phase.

Pour les disjoncteurs équipés d'une protection électronique contre les surintensités, il peut être pris pour hypothèse que les caractéristiques de déclenchement soient les mêmes, si les essais sont effectués:

– sur chaque pôle individuel des disjoncteurs multipolaires,
– sur deux ou trois pôles de phase en série,
– en raccordement triphasé.

NOTE Cela permet d'effectuer des comparaisons entre les résultats d'essai obtenus sur des combinaisons de pôles de phase différentes, comme cela est exigé par les différentes séquences d'essai.

Pour les disjoncteurs intégrant une fonction à courant différentiel résiduel (voir aussi l'Annexe B et l'Annexe M):

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– en ce qui concerne F.4.4, F.4.5 et F.4.6, les essais sont effectués sur deux pôles de phase dans le cas de disjoncteurs multipolaires afin d'éviter un déclenchement non intentionnel provoqué par un courant différentiel résiduel;

– en ce qui concerne F.4.1 et F.4.7, les essais peuvent être effectués sur n'importe quelle combinaison de pôles de phase, à condition d'éviter un déclenchement non intentionnel provoqué par un courant différentiel résiduel.

F.4 Essais d'immunité

F.4.1 Courants harmoniques

F.4.1.1 Généralités

Ces essais s'appliquent aux disjoncteurs dont les moyens électroniques de détection du courant sont déclarés par le fabricant comme sensibles à la valeur efficace.

Cette information doit être, soit marquée «eff.» sur le disjoncteur, soit mentionnée dans la documentation du fabricant, soit les deux.

L'EUT doit être soumis à essai à l'air libre à moins qu'il ne soit prévu pour être utilisé uniquement dans une enveloppe individuelle spécifiée, auquel cas il doit être soumis à essai dans cette enveloppe. Les éléments détaillés comprenant les dimensions de l'enveloppe doivent être consignés dans le rapport d'essai.

Lorsque cela est applicable, les essais doivent être effectués à la fréquence assignée.

NOTE Les courants d'essai peuvent être fournis par une source d'alimentation basée sur l'emploi de thyristors (voir Figure F.1), de noyaux saturés, d'alimentations programmables ou d'autres sources appropriées.

F.4.1.2 Courants d'essai

La forme d'onde du courant d'essai doit correspondre à l'une des deux options suivantes:

– option a): deux formes d'onde appliquées successivement:
  - une forme d'onde consistant en une composante fondamentale et une composante harmonique de rang trois,
  - une forme d'onde consistant en une composante fondamentale et une composante harmonique de rang cinq.

– option b): une forme d'onde consistant en une composante fondamentale et des composantes harmoniques de rangs trois, cinq et sept.

Les courants d'essai doivent être

– pour l'option a):

  essai de l'harmonique de rang trois et du facteur de crête
  - 72 % de la fondamentale ≤ harmonique de rang trois ≤ 88 % de la fondamentale,
  - facteur de crête: 2,0 ± 0,2,

  essai de l'harmonique de rang cinq et du facteur de crête
  - 45 % de la fondamentale ≤ harmonique de rang cinq ≤ 55 % de la fondamentale,
  - facteur de crête: 1,9 ± 0,2,

– pour l'option b):

  le courant d'essai, pour chaque période, est constitué de deux demi-ondes égales et opposées, définies comme suit:
  - durée de conduction du courant de chaque demi-onde ≤ 21 % de la période,

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- facteur de crête: ≥ 2,1.

NOTE 1 Le facteur de crête est la valeur de crête du courant divisée par la valeur efficace du courant de choc. Pour la formule pertinente, voir Figure F.1.

NOTE 2 Ce courant d'essai a pour l'option b) au minimum le contenu harmonique suivant de la composante fondamentale:

– harmonique de rang trois > 60 %,

– harmonique de rang cinq >14 %,

– harmonique de rang sept > 7 %,

– harmonique de rang vingt et un > 1 %.

D'autres harmoniques peuvent également être présentes.

NOTE 3 La forme d'onde du courant d'essai pour l'option b) peut être obtenue, par exemple, au moyen de deux thyristors dos à dos (voir Figure F.1).

NOTE 4 Les courants d'essai 0,9 I_r et 2,0 I_r (voir critère de comportement A de la F.2.2.2) sont les valeurs efficaces des formes d'ondes composites.

F.4.1.3 Mode opératoire d'essai

Les essais doivent être effectués sur n'importe quelle paire de pôles, choisie au hasard conformément à 7.2.1.2.4 point b), parcourue par le courant d'essai sous toute tension convenable, les connexions étant réalisées conformément à la Figure F.2. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, les connexions doivent être réalisées conformément à la Figure F.3 ou la Figure F.4, suivant le cas.

Les déclencheurs à minimum de tension éventuels doivent être, soit alimentés, soit désactivés. Tous les autres auxiliaires doivent être débranchés pendant l'essai.

La durée de l'essai permettant de vérifier l'immunité aux déclenchements indésirables (à 0,9 fois le courant de réglage) doit être de 10 fois le temps de déclenchement, correspondant à deux fois le courant de réglage.

F.4.1.4 Résultats d'essai

Le critère de comportement A de F.2.2.2 doit s'appliquer.

F.4.2 Décharges électrostatiques

L'Annexe J, en particulier J.2.2, est applicable avec les ajouts suivants.

L'installation d'essai doit être conforme à la Figure F.16 et la Figure J.3.

Le circuit d'essai doit être conforme à la Figure F.2. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Le cheminement du jeu de barres indiqué à la Figure F.2, la Figure F.3 et la Figure F.4 peut être modifié dans la mesure où les distances de 0,1 m, avec une tolérance de $^{+10}_{0}$ %, à l'enveloppe sont maintenues. La configuration réelle utilisée doit être indiquée dans le rapport d'essai.

Le critère de comportement B de F.2.2.2 est applicable.

F.4.3 Champs électromagnétiques RF rayonnés

L'Annexe J, en particulier J.2.3, est applicable avec les ajouts suivants.

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L'installation d'essai doit être conforme à la Figure F.16 et la Figure F.17.

Le circuit d'essai doit être conforme à la Figure F.2. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Le critère de comportement A de F.2.2.2 est applicable.

F.4.4 Transitoires électriques rapides en salves (TER/S)

L'Annexe J, en particulier J.2.4, est applicable avec les ajouts suivants.

L'installation d'essai doit être conforme à la Figure F.16 et la Figure F.18 pour l'essai des lignes d'alimentation, et à la Figure F.16 et la Figure F.19 pour l'essai des lignes de signaux.

Les perturbations aux accès du circuit principal à courant alternatif doivent être appliquées sur un pôle de phase choisi au hasard, le disjoncteur étant alimenté à partir des autres pôles de phase, conformément à la Figure F.16.

Pour les déclencheurs comportant un dispositif sensible à la perte de phase, l'essai doit être effectué conformément à la Figure F.7 pour une connexion des trois pôles de phase en série ou conformément à la Figure F.8 sur un pôle choisi au hasard pour une connexion triphasée.

Le critère de comportement A de F.2.2.2 est applicable. Toutefois, des changements temporaires des fonctions de surveillance (par exemple, l'allumage indésirable d'une diode électroluminescente) pendant l'essai sont acceptables; dans un tel cas, le fonctionnement correct des fonctions de surveillance doit être vérifié après les essais. Pour l'étape 2, la perturbation doit être appliquée jusqu'au déclenchement du disjoncteur.

F.4.5 Ondes de choc

L'Annexe J, en particulier J.2.5, est applicable avec les ajouts suivants.

Les perturbations aux accès du circuit principal à courant alternatif doivent être appliquées sur un pôle de phase choisi au hasard, l'EUT étant alimenté à partir des deux autres pôles de phase, conformément à la Figure F.9 (phase-terre) et la Figure F.12 (entre phases).

Pour les déclencheurs comportant un dispositif sensible à la perte de phase, l'essai doit être effectué conformément à la Figure F.10 (phase-terre) et la Figure F.13 (entre phases) pour une connexion des trois pôles de phase en série ou conformément à la Figure F.11 (phase-terre) et la Figure F.14 (entre phases) sur un pôle de phase choisi au hasard pour une connexion triphasée.

Le critère de comportement B de F.2.2.2 est applicable.

F.4.6 Perturbations conduites, induites par les champs RF (mode commun)

L'Annexe J, en particulier J.2.6, est applicable avec les ajouts suivants.

L'installation d'essai doit être conforme à la Figure F.16, la Figure F.20 et la Figure F.21, la Figure F.22 ou la Figure F.23 pour l'essai des lignes d'alimentation, et à la Figure F.16 pour l'essai des lignes de signaux.

Les perturbations aux accès du circuit principal à courant alternatif doivent être appliquées sur un pôle de phase choisi au hasard, le disjoncteur étant alimenté à partir des autres pôles de phase, conformément à la Figure F.2.

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Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Le critère de comportement A de F.2.2.2 est applicable.

F.4.7 Creux de courant

F.4.7.1 Mode opératoire d'essai

L'EUT doit être soumis à essai à l'air libre à moins qu'il ne soit prévu pour être utilisé uniquement dans une enveloppe individuelle spécifiée, auquel cas il doit être soumis à essai dans cette enveloppe. Les éléments détaillés comprenant les dimensions de l'enveloppe doivent être consignés dans le rapport d'essai.

Le circuit d'essai doit être conforme à la Figure F.2 avec n'importe quelle paire de pôles de phase choisie au hasard. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Les essais doivent être effectués avec un courant sinusoïdal sous toute tension convenable. Le courant doit être appliqué conformément à la Figure F.5 et au Tableau F.1 ci-dessous, où I_r est le courant de réglage, I_D le creux de courant d'essai et T la période du courant sinusoïdal.

La durée de chaque essai doit être la plus petite des deux valeurs suivantes: entre trois et quatre fois le temps de déclenchement maximal correspondant à deux fois le courant de réglage ou 10 min.

Tableau F.1 – Paramètres d'essai pour les creux et interruptions de courant

Essai n°	I_D	Δt
1	0	0,5 T
2		1 T
3		5 T
4		25 T
5		50 T
6	0,4 I_r	10 T
7		25 T
8		50 T
9	0,7 I_r	10 T
10		25 T
11		50 T

F.4.7.2 Résultats d'essai

Le critère de comportement B de F.2.2.2 doit s'appliquer, à l'exception du contrôle après essai qui n'est pas exigé.

F.5 Essais d'émission

F.5.1 Harmoniques

Les circuits de commande électroniques fonctionnent à très basse puissance, créant ainsi des perturbations négligeables; en conséquence, aucun essai n'est exigé.

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F.5.2 Fluctuations de tension

Les circuits de commande électroniques fonctionnent à très basse puissance, créant ainsi des perturbations négligeables; en conséquence, aucun essai n'est exigé.

F.5.3 Perturbations conduites aux fréquences radioélectriques (150 kHz à 30 MHz)

Les disjoncteurs couverts par la présente annexe sont indépendants de la tension d'alimentation ou de toute source auxiliaire. Les circuits électroniques n'ont aucun couplage direct avec l'alimentation et fonctionnent à une puissance très faible. Ces disjoncteurs créent des perturbations négligeables et aucun essai n'est par conséquent exigé.

F.5.4 Perturbations rayonnées aux fréquences radioélectriques (30 MHz à 1 GHz)

L'Annexe J, en particulier J.3.3, est applicable avec les ajouts suivants.

Le circuit d'essai doit être conforme à la Figure F.2. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Les déclencheurs à minimum de tension éventuels doivent être, soit alimentés, soit désactivés. Tous les autres auxiliaires doivent être débranchés pendant l'essai.

Les limites du Tableau J.3 s'appliquent.

F.6 Aptitude au fonctionnement à des fréquences multiples

F.6.1 Généralités

L'essai vérifie les caractéristiques de déclenchement des disjoncteurs déclarés comme étant aptes au fonctionnement à des fréquences multiples. Il ne s'applique pas aux disjoncteurs de fréquence assignée de 50 Hz à 60 Hz seulement.

F.6.2 Conditions d'essai

Les essais doivent être effectués à chaque fréquence assignée ou, lorsqu'une plage de fréquences assignées est déclarée, à la plus basse et à la plus haute fréquence assignée.

F.6.3 Mode opératoire d'essai

Les essais doivent être effectués sur n'importe quelle paire de pôles choisie au hasard sous toute tension convenable.

Le circuit d'essai doit être conforme à la Figure F.2. Pour les déclencheurs comportant un dispositif sensible à la perte de phase, le circuit d'essai doit être conforme à la Figure F.3 ou la Figure F.4, suivant le cas.

Les déclencheurs à minimum de tension éventuels doivent être, soit alimentés, soit désactivés. Tous les autres auxiliaires doivent être débranchés pendant l'essai.

Les réglages des courants de déclenchement de courte durée et instantané doivent être chacun, si cela convient, réglés à 2,5 fois le courant de réglage. Si cette valeur de réglage n'est pas disponible, les réglages doivent être effectués à la valeur immédiatement supérieure.

Les essais doivent être réalisés comme suit:

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a) Un courant de 0,95 fois le courant conventionnel de non-déclenchement (voir Tableau 6) est appliqué pendant un temps égal à 10 fois le temps de déclenchement correspondant à 2,0 fois le courant de réglage.

b) Immédiatement après l'essai de a), un courant de 1,05 fois le courant conventionnel de déclenchement est appliqué (voir Tableau 6).

c) Un essai supplémentaire, à partir de l'état froid, est effectué à 2,0 fois le courant de réglage.

F.6.4 Résultats d'essai

Pour chaque fréquence d'essai, les caractéristiques de déclenchement en surcharge doivent être conformes aux spécifications suivantes:

– pour l'essai a), aucun déclenchement ne doit se produire;

– pour l'essai b), le déclenchement doit se produire pendant le temps conventionnel (voir Tableau 6);

– pour l'essai c), le déclenchement doit se produire entre 1,1 fois le temps maximal et 0,9 fois le temps minimal de la caractéristique temps-courant déclarée par le fabricant.

F.7 Essai de chaleur sèche

F.7.1 Mode opératoire d'essai

L'essai doit être effectué sur le disjoncteur, conformément à 7.2.2, au courant assigné maximal pour une taille donnée, sur tous les pôles de phase, à une température ambiante de 40 °C. La durée de l'essai, lorsque l'équilibre thermique est atteint, doit être de 168 h.

Les couples de serrage appliqués aux vis des bornes doivent être conformes aux instructions du fabricant (voir ~~5.2 e)~~ Tableau 13, point 3.1).

En variante, l'essai peut également être effectué comme suit:

– mesurer et enregistrer l'échauffement maximal de l'air au voisinage des composants électroniques pendant l'essai d'échauffement de la séquence d'essai I;

– installer les commandes électroniques dans la chambre d'essai;

– alimenter les commandes électroniques avec leurs valeurs d'alimentation d'entrée;

– régler la température de la chambre d'essai à une valeur de 40 K au-dessus de l'échauffement enregistré dans l'air du voisinage des composants électroniques et maintenir cette température pendant 168 h.

F.7.2 Résultats d'essai

Le disjoncteur et les commandes électroniques doivent satisfaire aux exigences suivantes:

– aucun déclenchement du disjoncteur ne doit se produire;

– aucun fonctionnement des commandes électroniques qui entraînerait le déclenchement du disjoncteur ne doit se produire.

F.7.3 Vérification des déclencheurs de surcharge

Après l'essai de F.7.1, le fonctionnement des déclencheurs de surcharge du disjoncteur doit être vérifié selon 7.2.1.2.4, point b).

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F.8 Essai de chaleur humide

F.8.1 Mode opératoire d'essai

L'essai doit être effectué conformément à l'IEC 60068-2-30.

La température la plus élevée doit être de 55 °C ± 2 °C (variante 1) et le nombre de cycles doit être de six.

L'essai peut être effectué avec seulement les commandes électroniques présentes dans la chambre d'essai.

F.8.2 Vérification des déclencheurs de surcharge

Après l'essai de F.8.1, le fonctionnement des déclencheurs de surcharge du disjoncteur doit être vérifié selon 7.2.1.2.4, point b).

F.9 Cycles de variation de température avec un taux de variation spécifié

F.9.1 Conditions d'essai

Chaque conception des commandes électroniques doit être soumise à des cycles de variation de température comme cela est défini à la Figure F.15.

La montée et la descente en température pendant le taux de variation doit être de 1 K/min ± 0,2 K/min. Une fois atteinte, la température doit être maintenue pendant au moins 2 h.

Le nombre de cycles doit être de 28.

F.9.2 Mode opératoire d'essai

L'essai doit être effectué conformément à l'IEC 60068-2-14.

Pour ces essais, les commandes électroniques peuvent être montées à l'intérieur du disjoncteur ou séparément.

Les commandes électroniques doivent être alimentées pour simuler les conditions de service.

Lorsque les commandes électroniques sont montées à l'intérieur du disjoncteur, le circuit principal ne doit pas être alimenté.

F.9.3 Résultats d'essai

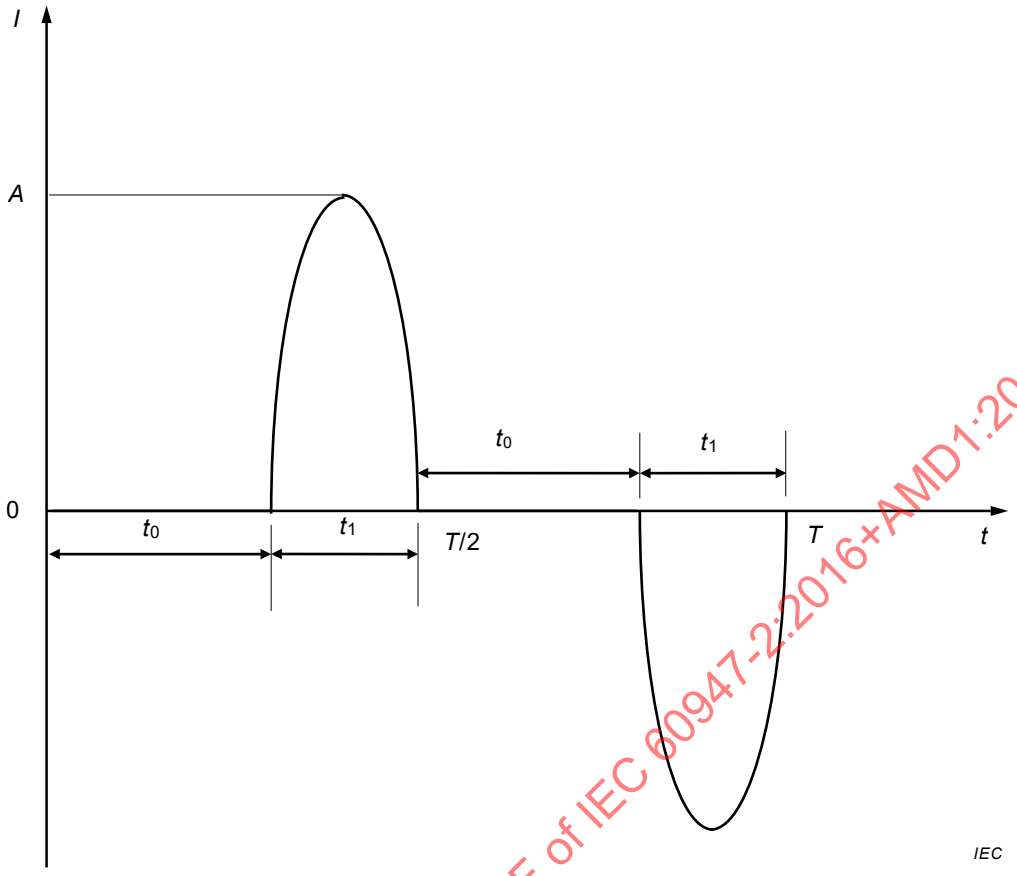
Les commandes électroniques doivent satisfaire à l'exigence suivante.

Aucun fonctionnement des commandes électroniques qui provoquerait le déclenchement du disjoncteur pendant les 28 cycles ne doit se produire.

F.9.4 Vérification des déclencheurs de surcharge

Après l'essai de F.9.2, le fonctionnement des déclencheurs de surcharge du disjoncteur doit être vérifié selon 7.2.1.2.4, point b).

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Légende

A courant de crête

T période

t_1 temps de conduction pendant chaque demi-cycle

t_0 retard

$$\text{Facteur de crete} = \frac{A}{\sqrt{\frac{2}{T}\int_0^{T/2} i^2(t)\,dt}}$$

Figure F.1 – Représentation du courant d'essai produit par des thyristors dos à dos selon F.4.1

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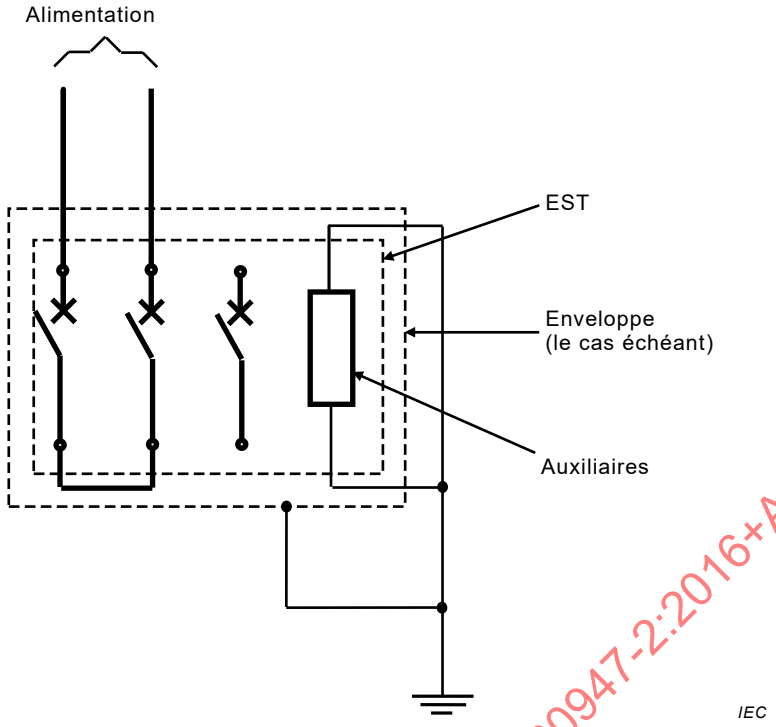


Figure F.2 – Circuit d'essai pour les essais d'immunité et d'émission selon F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 et F.6.3 – Deux pôles de phase en série

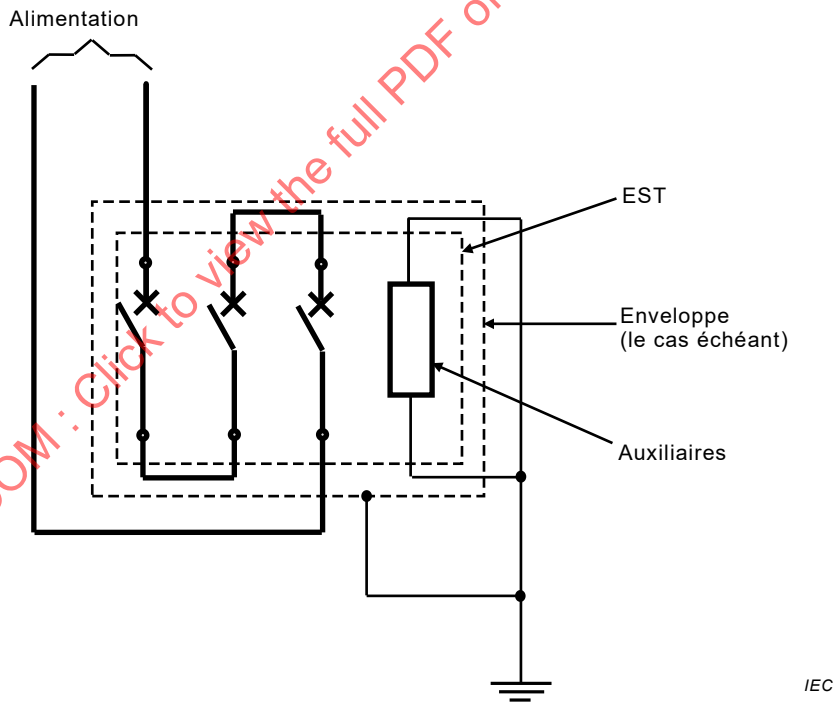
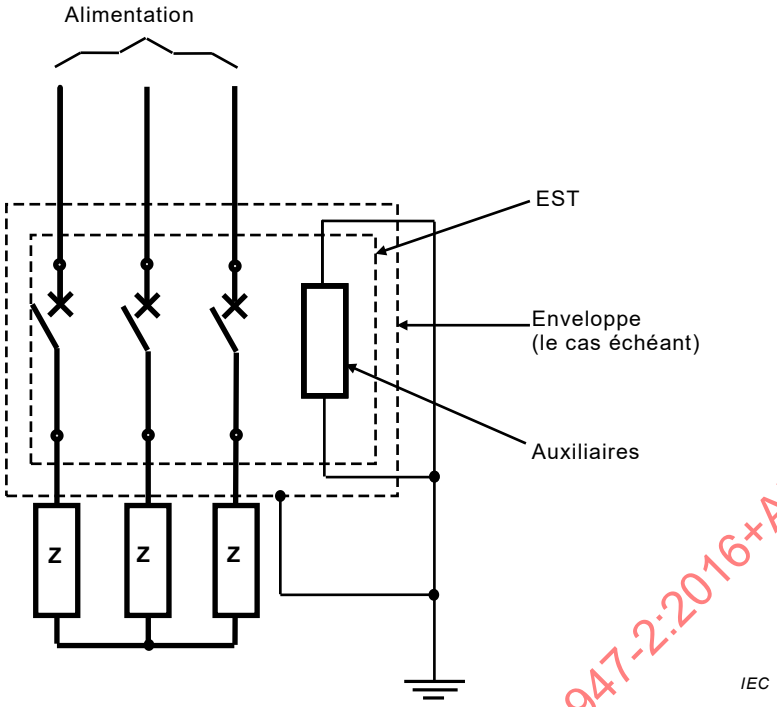


Figure F.3 – Circuit d'essai pour les essais d'immunité et d'émission selon F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 et F.6.3 – Trois pôles de phase en série

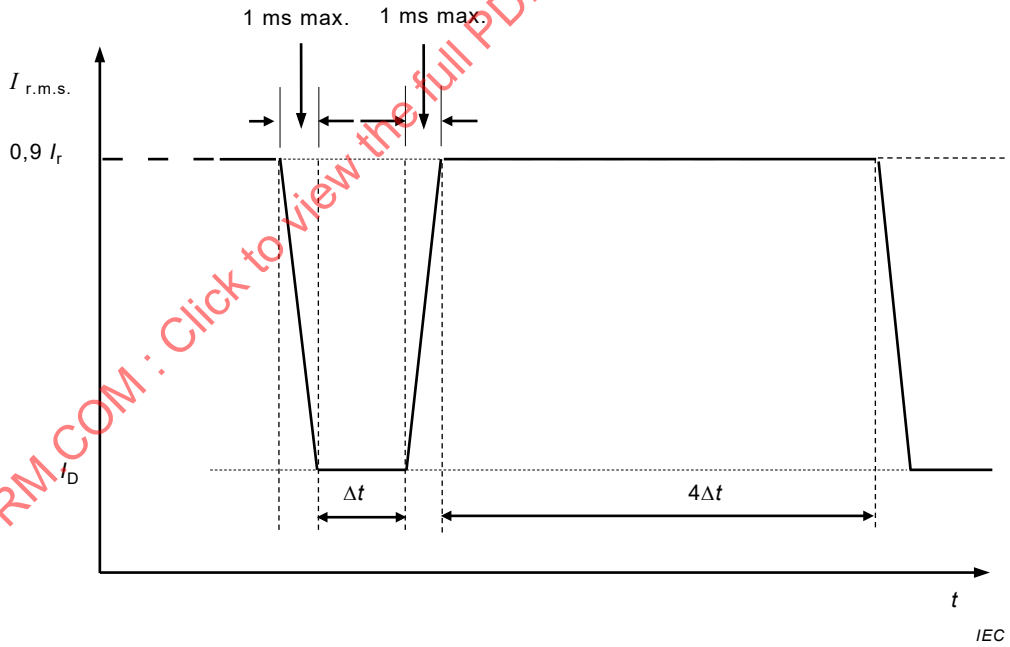
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Légende

Z impédance de réglage du courant (si exigé)

Figure F.4 – Circuit d'essai pour les essais d'immunité et d'émission selon F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 et F.6.3 – Raccordement triphasé



Légende

I_r courant de réglage

I_D courant d'essai de creux

Δt temps de creux

$4\Delta t$ temps de palier

Figure F.5 – Courant d'essai pour la vérification de l'influence des creux et des interruptions de courant selon F.4.7.1

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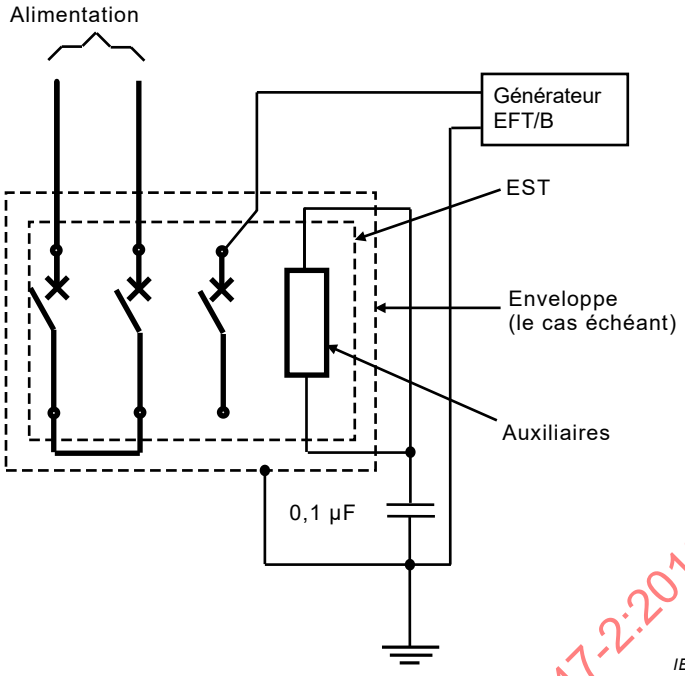


Figure F.6 – Circuit pour l'essai d'immunité aux transitoires électriques rapides en salves (TER/S) selon F.4.4 – Deux pôles de phase en série

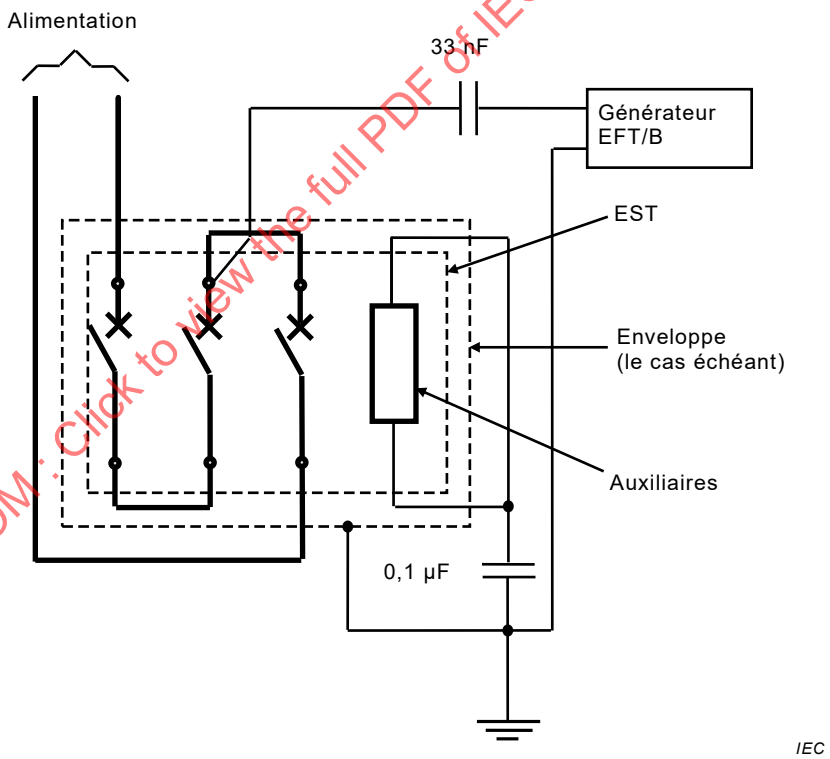
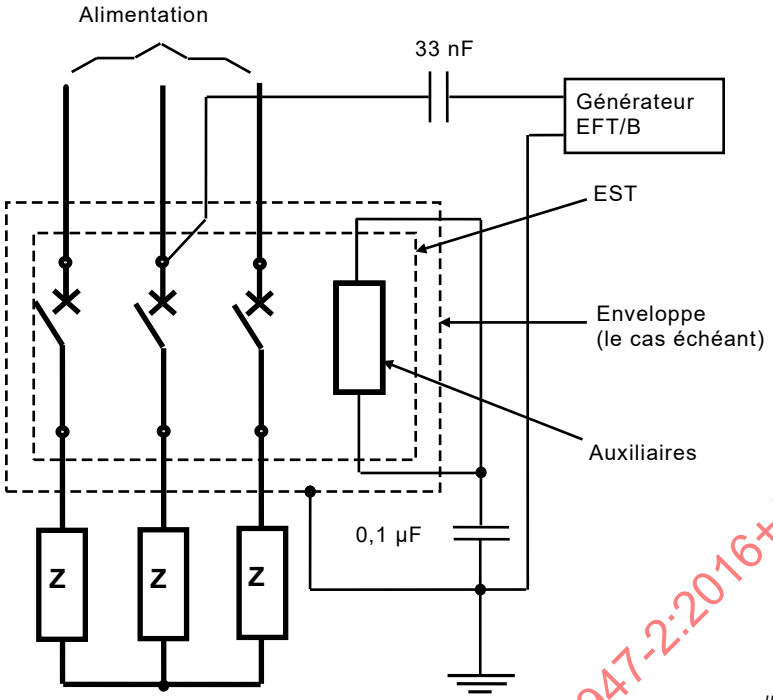


Figure F.7 – Circuit pour l'essai d'immunité aux transitoires électriques rapides en salves (TER/S) selon F.4.4 – Trois pôles de phase en série

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Légende

Z impédance de réglage du courant (si exigé)

Figure F.8 – Circuit pour l'essai d'immunité aux transitoires électriques rapides en salves (TER/S) selon F.4.4 – Raccordement triphasé

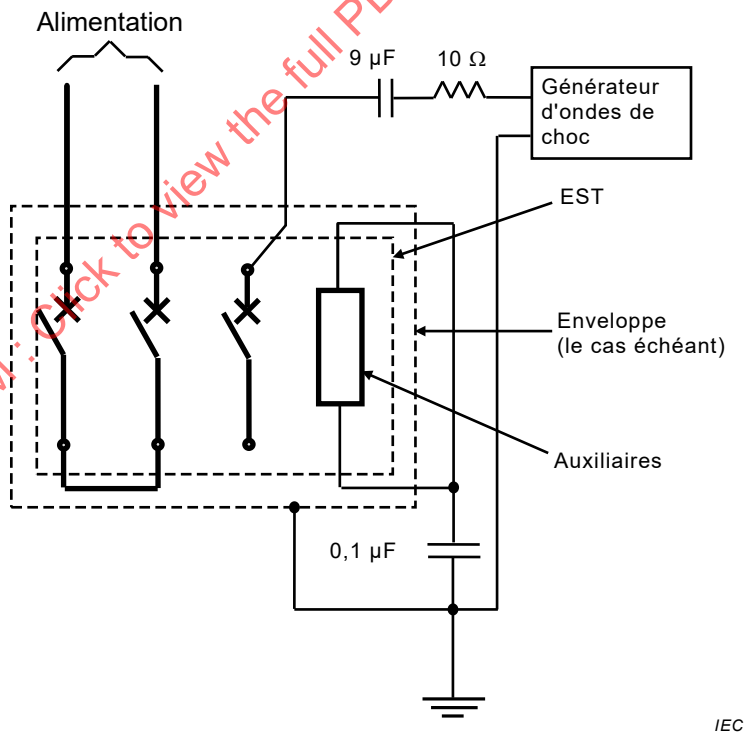


Figure F.9 – Circuit d'essai pour la vérification de l'influence des ondes de choc sur le circuit principal (phase-terre) selon F.4.5 – Deux pôles de phase en série

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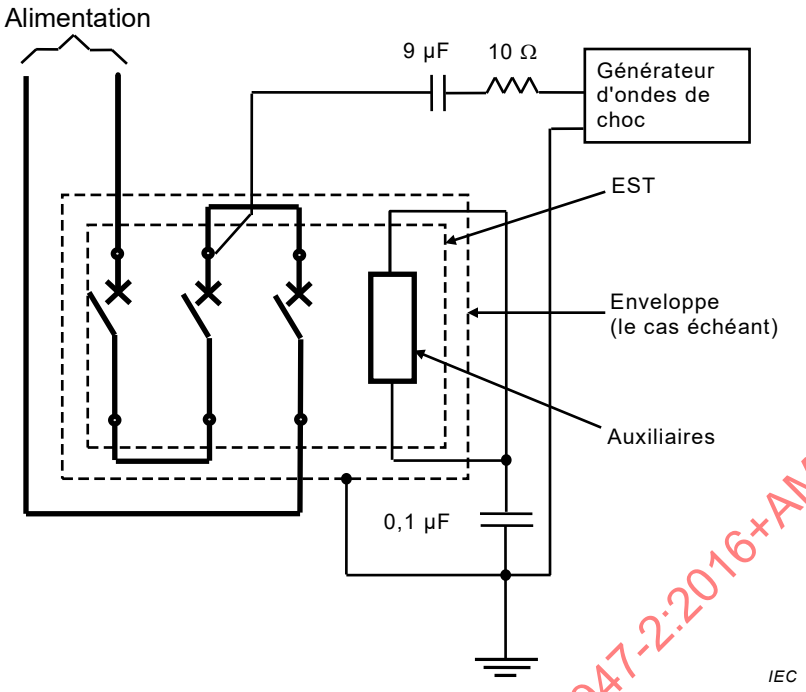
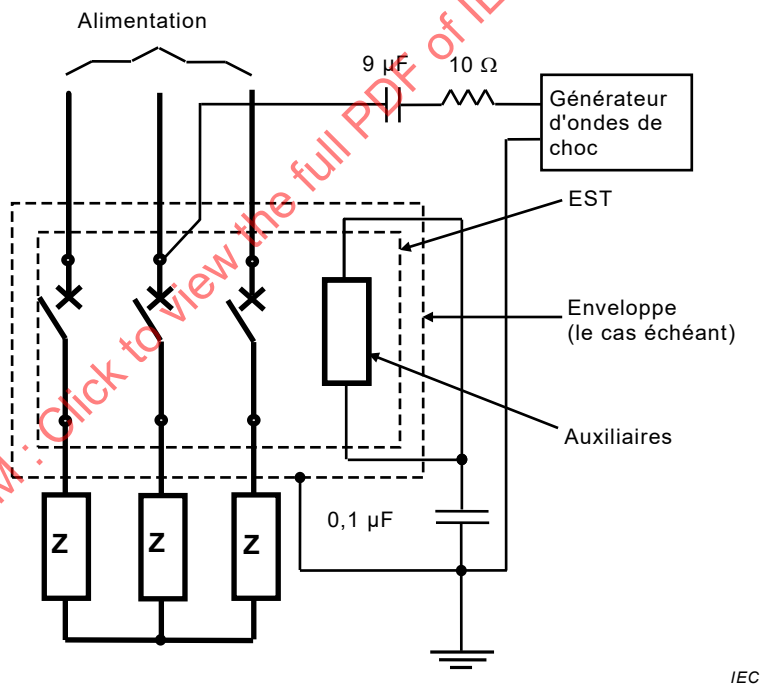


Figure F.10 – Circuit d'essai pour la vérification de l'influence des ondes de choc sur le circuit principal (phase-terre) selon F.4.5 – Trois pôles de phase en série



Légende

Z impédance de réglage du courant (si exigé)

Figure F.11 – Circuit d'essai pour la vérification de l'influence des ondes de choc sur le circuit principal (phase-terre) selon F.4.5 – Raccordement triphasé

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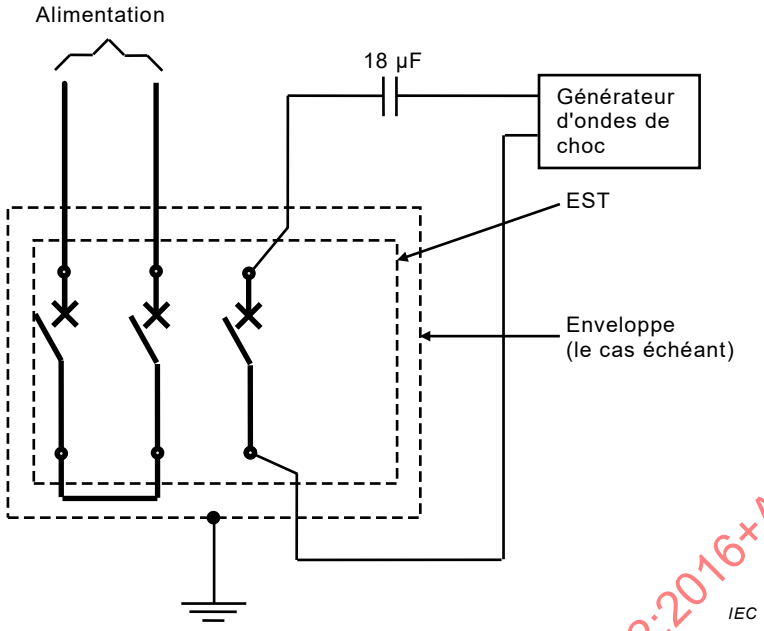


Figure F.12 – Circuit d'essai pour la vérification de l'influence des ondes de courant de choc sur le circuit principal selon F.4.5 – Deux pôles de phase en série

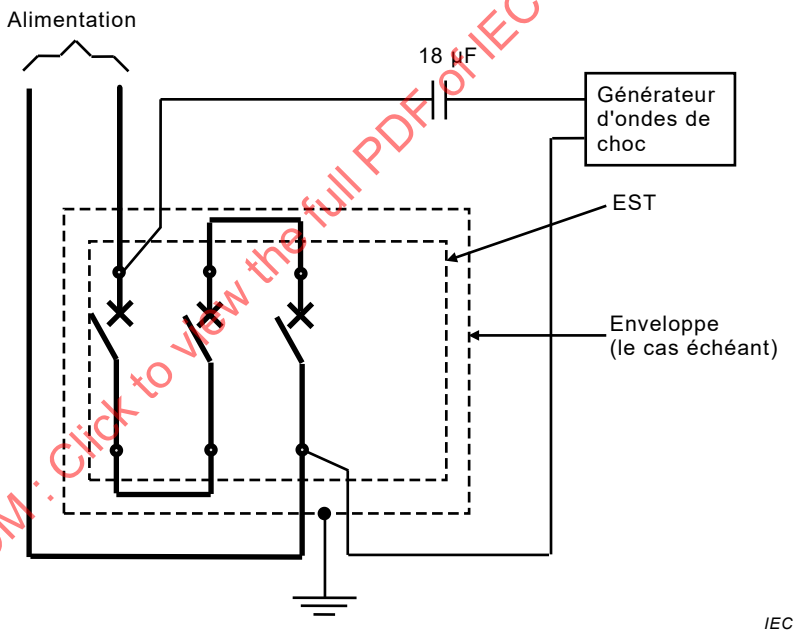
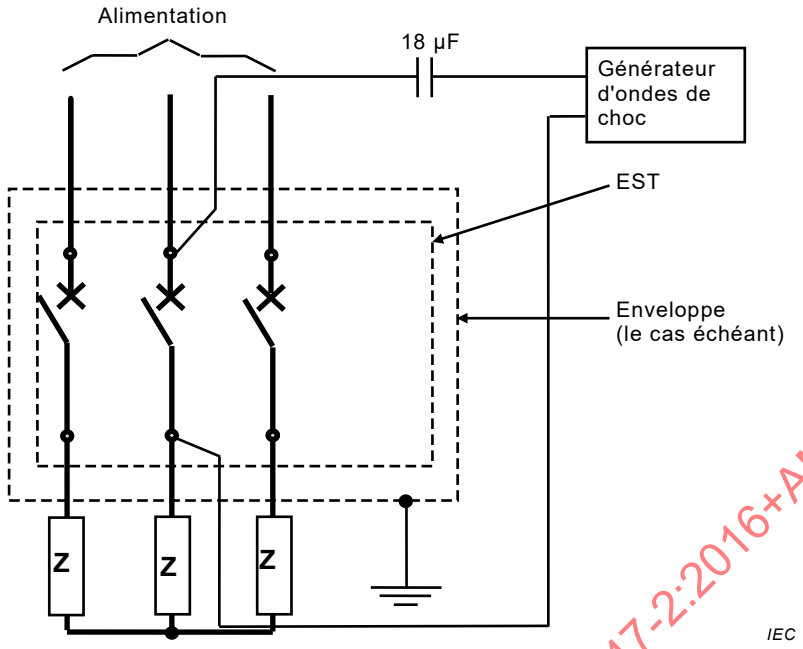


Figure F.13 – Circuit d'essai pour la vérification de l'influence des ondes de courant de choc sur le circuit principal selon F.4.5 – Trois pôles de phase en série

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Légende

Z impédance de réglage du courant (si exigé)

Figure F.14 – Circuit d'essai pour la vérification de l'influence des ondes de courant de choc sur le circuit principal selon F.4.5 – Raccordement triphasé

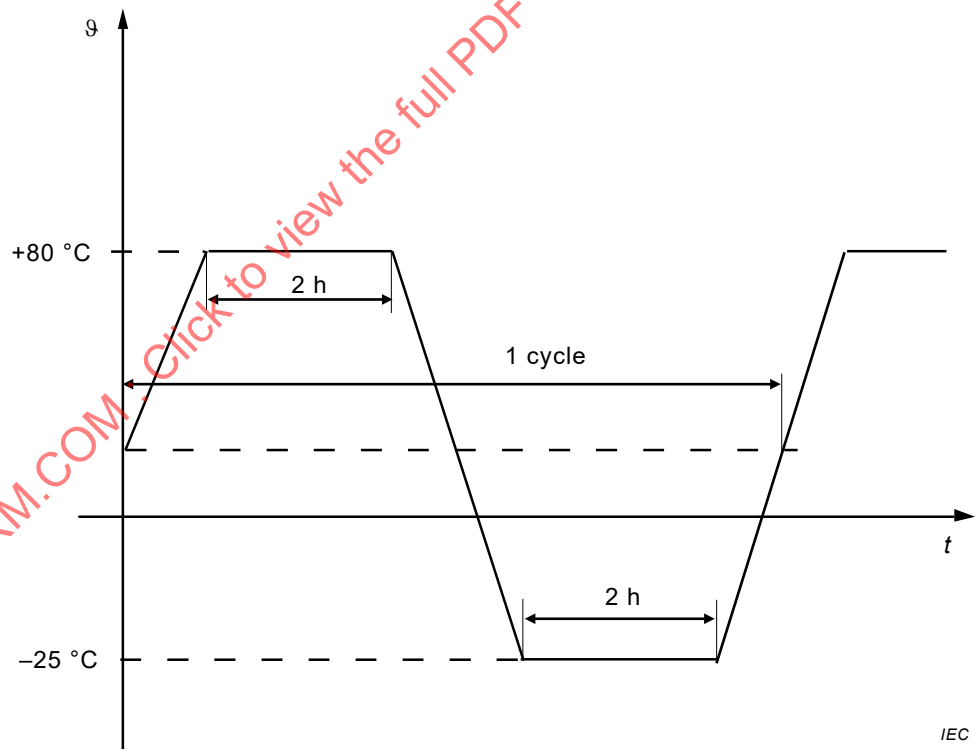
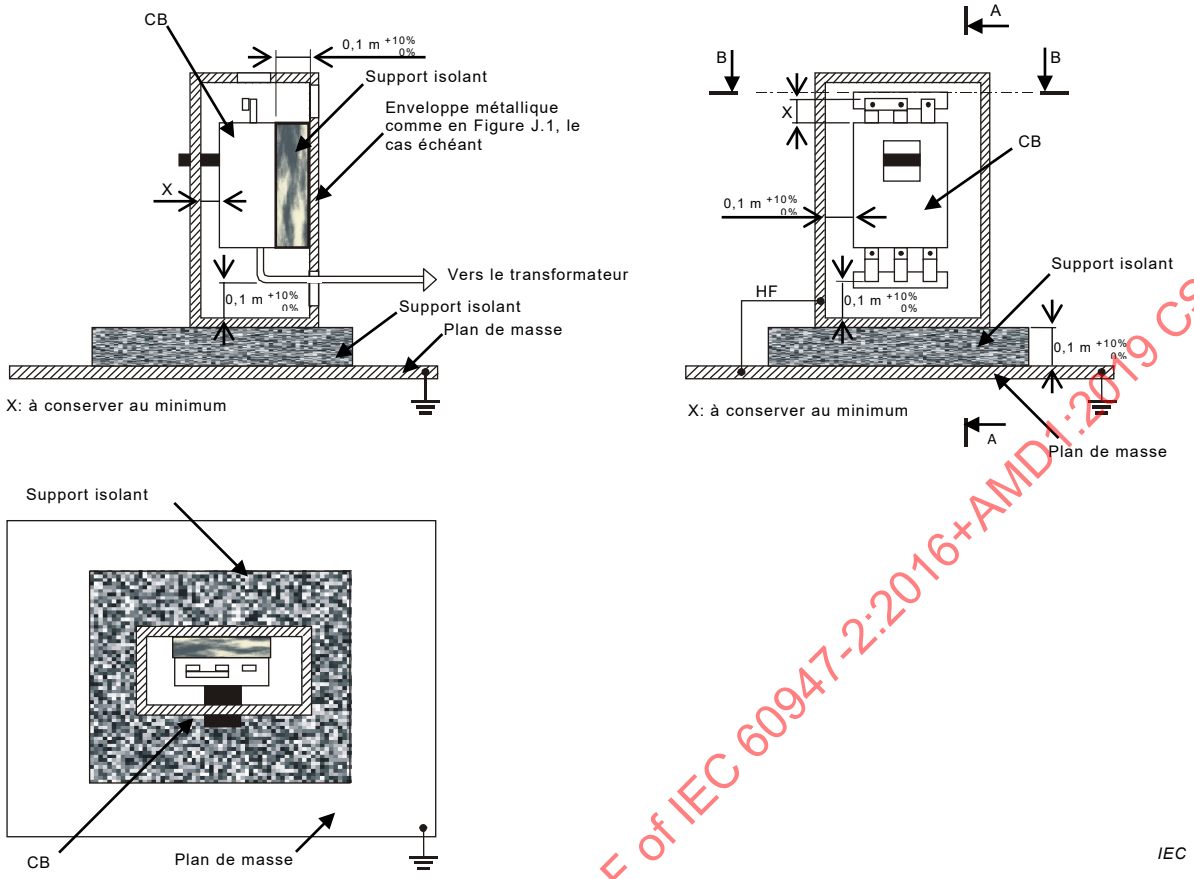


Figure F.15 – Cycles de variation de température avec un taux de variation spécifié selon F.9.1

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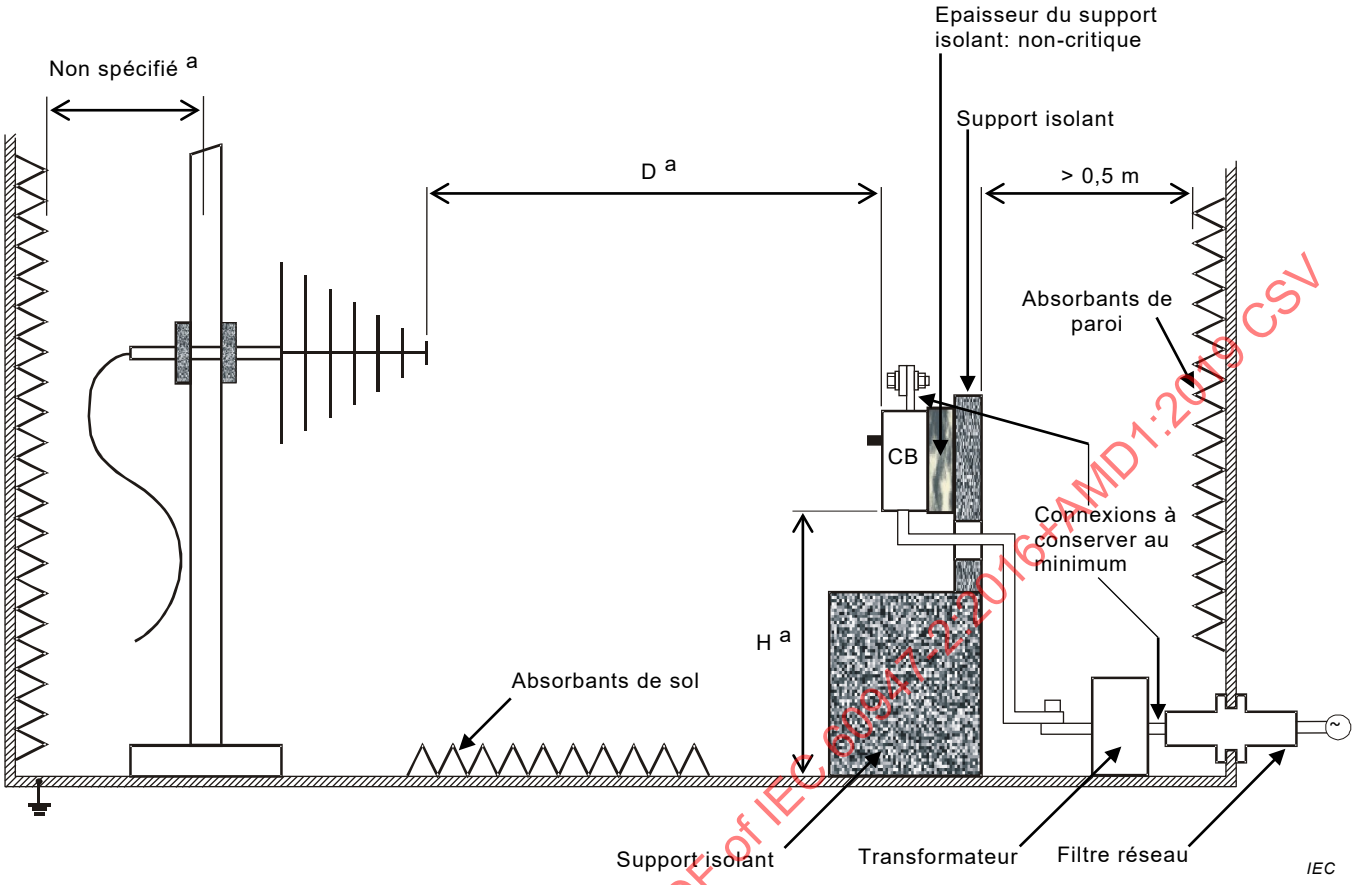
Légende

CB disjoncteur

NOTE La disposition des bornes peut varier selon le type de disjoncteur soumis à essai.

Figure F.16 – Installation générale d'essai pour les essais d'immunité

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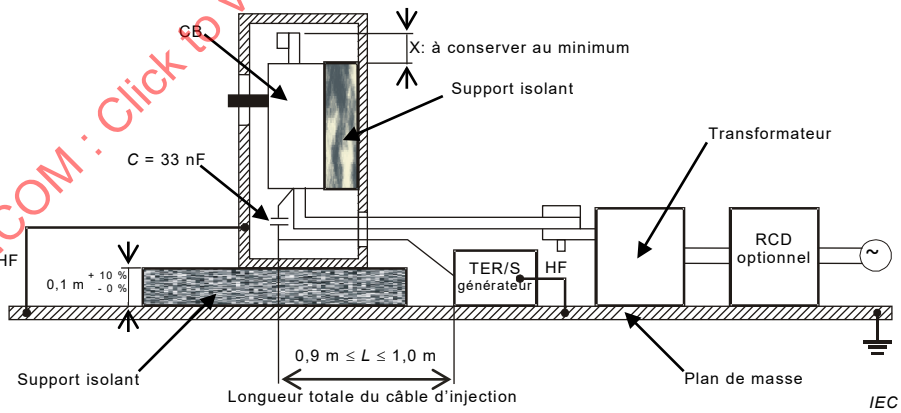


Légende

CB disjoncteur

[a] Voir l'IEC 61000-4-3

Figure F.17 – Installation d'essai pour la vérification de l'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques



Légende

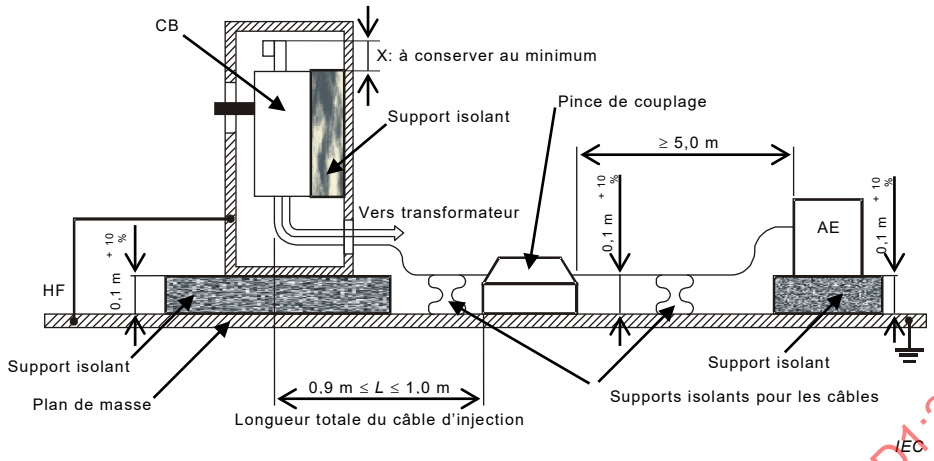
CB disjoncteur

HF connexion haute fréquence

RCD réseau de couplage-découplage

Figure F.18 – Installation d'essai pour la vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur les lignes d'alimentation

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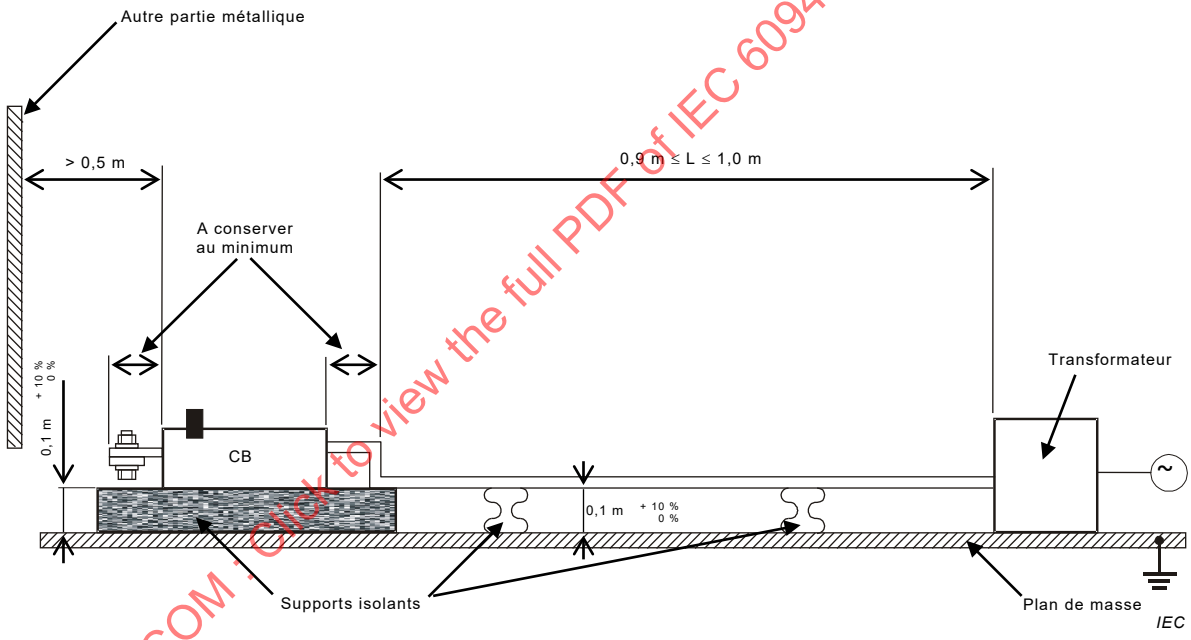
Légende

AE matériel auxiliaire

CB disjoncteur

HF connexion haute fréquence

Figure F.19 – Installation d'essai pour la vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur les lignes de signaux



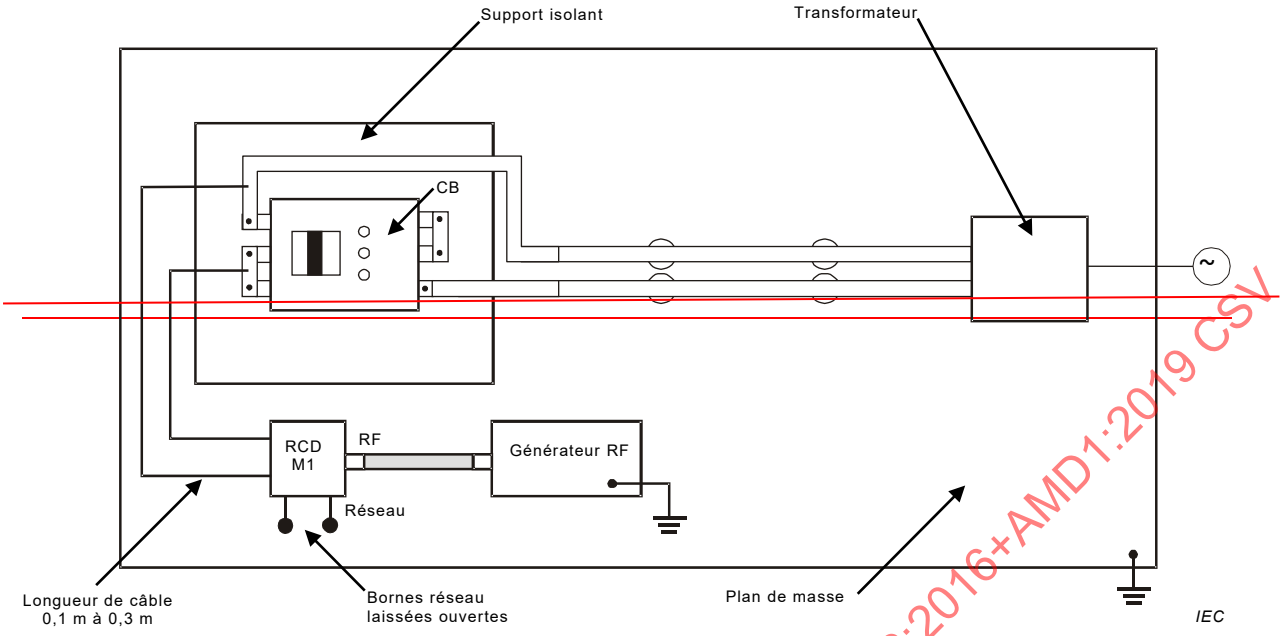
Légende

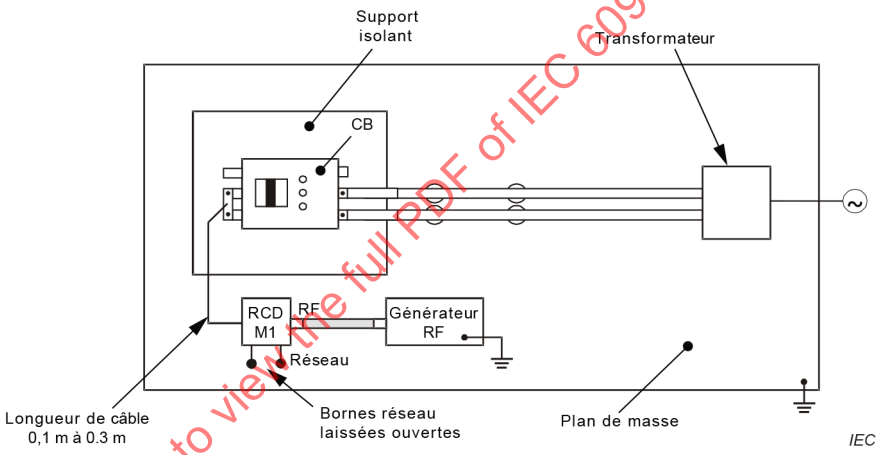
CB disjoncteur

NOTE La dimension *L* est la longueur du conducteur couplé à 0,1 m au plan de masse.

Figure F.20 – Installation générale d'essai pour la vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques (mode commun)

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Légende

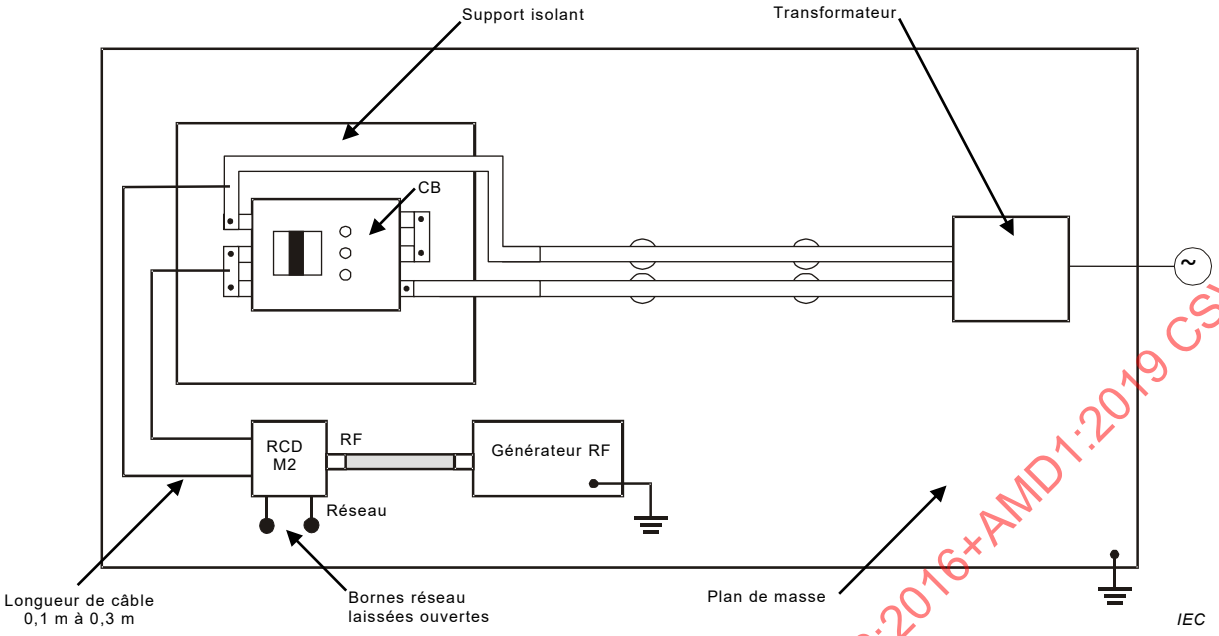
CB disjoncteur

RCD M1 réseau de couplage-découplage M1

NOTE En variante au réseau de couplage-découplage M1, les réseaux de couplage-découplage M2 ou M3 peuvent être utilisés; dans un tel cas, les deux ou trois conducteurs, suivant le cas, sont raccordés au même point de l'EUT.

Figure F.21 – Disposition des raccordements pour la vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques – Configuration de deux pôles de phase en série

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Légende

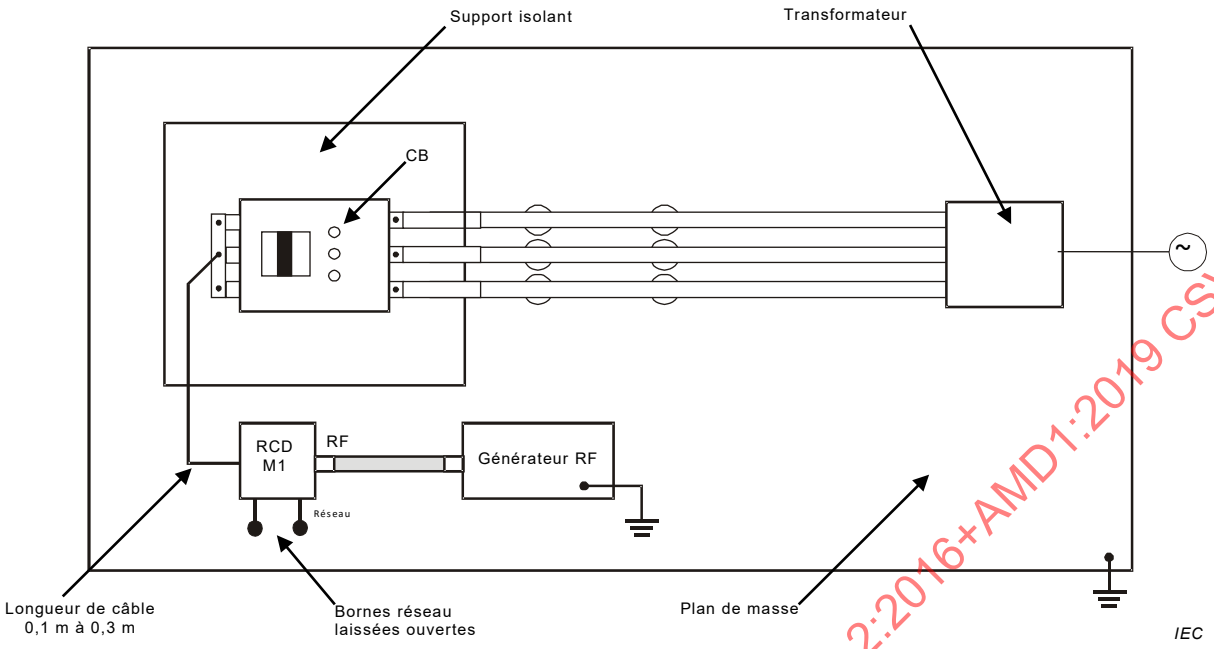
CB disjoncteur

RCD M2 réseau de couplage-découplage M2

NOTE En variante au réseau de couplage-découplage M2, le réseau de couplage-découplage M3 peut être utilisé; dans un tel cas, les deux ou trois conducteurs, suivant le cas, sont raccordés au même point de l'EUT.

Figure F.22 – Disposition des raccordements pour la vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques – Configuration de trois pôles de phase en série

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Légende

CB disjoncteur

RCD M1 réseau de couplage-découplage M1

NOTE En variante au réseau de couplage-découplage M1, les réseaux de couplage-découplage M2 ou M3 peuvent être utilisés; dans un tel cas, les deux ou trois conducteurs, suivant le cas, sont raccordés au même point de l'EUT.

Figure F.23 – Disposition des raccordements pour la vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques – Configuration triphasée

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Annexe G
(normative)

Perte de puissance

G.1 Généralités

La perte de puissance n'est pas une caractéristique fondamentale d'un disjoncteur et peut ne pas être indiquée sur le produit.

Elle donne quelques indications sur la chaleur produite dans des conditions spécifiées.

Le mesurage de la perte de puissance doit être effectué à l'air libre, sur des échantillons neufs, et doit être exprimé en watts.

G.2 Méthodes d'essai

G.2.1 Cas général

La perte de puissance est évaluée comme suit, les raccordements étant réalisés selon la Figure G.1.

$$\sum_{k=1}^{k=p} \Delta U_k \; I_k \cos \varphi_k$$

où

p est le nombre de pôles de phase;

k est le numéro du pôle;

ΔU est la chute de tension;

I est le courant d'essai qui doit être égal à I_n selon les tolérances indiquées en 8.3.2.2.2;

cos φ est le facteur de puissance.

L'usage d'un wattmètre sur chaque pôle est recommandé.

G.2.2 Disjoncteurs à courant alternatif de courant assigné ne dépassant pas 400 A

Pour les disjoncteurs à courant alternatif dont le courant assigné ne dépasse pas 400 A, il est admis d'effectuer le mesurage en courant alternatif monophasé sans mesurage du facteur de puissance.

La perte de puissance est évaluée comme suit, les raccordements étant réalisés selon la Figure G.2.

$$\sum_{k=1}^{k=p} \Delta U_k \; I_n$$

où

p est le nombre de pôles de phase;

k est le numéro du pôle;

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ΔU est la chute de tension;

I_n est le courant assigné.

G.2.3 Disjoncteurs à courant continu

Pour les disjoncteurs à courant continu, la perte de puissance doit être mesurée en courant continu.

Elle est évaluée comme en G.2.2.

G.3 Mode opératoire d'essai

L'évaluation de la perte de puissance doit être effectuée sous courant assigné dans les conditions de régime établi de température.

La chute de tension doit être mesurée entre les bornes d'entrée et de sortie sur chaque pôle.

Les fils de raccordement aux instruments de mesure (par exemple voltmètre, wattmètre) doivent être torsadés entre eux. Les boucles de mesure doivent être aussi petites que possible et doivent être positionnées de façon semblable pour chaque pôle.

Pour évaluer la perte de puissance d'un disjoncteur à courant alternatif à trois et quatre pôles selon G.2.1, l'essai est effectué avec un courant sur les trois phases (voir Figure G.1) sans courant dans le quatrième pôle dans le cas d'un disjoncteur tétrapolaire.

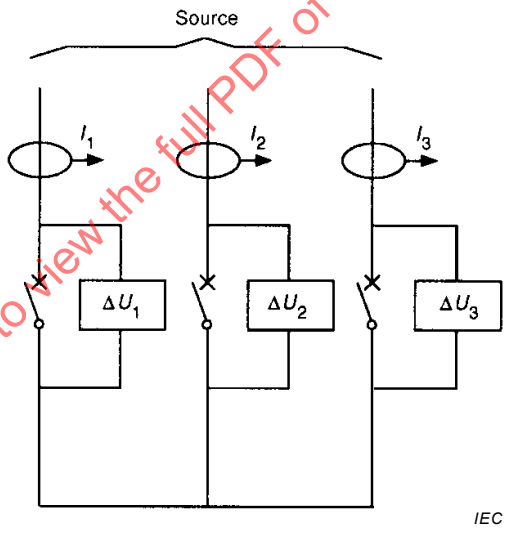


Figure G.1 – Exemple de mesurage de la perte de puissance selon G.2.1

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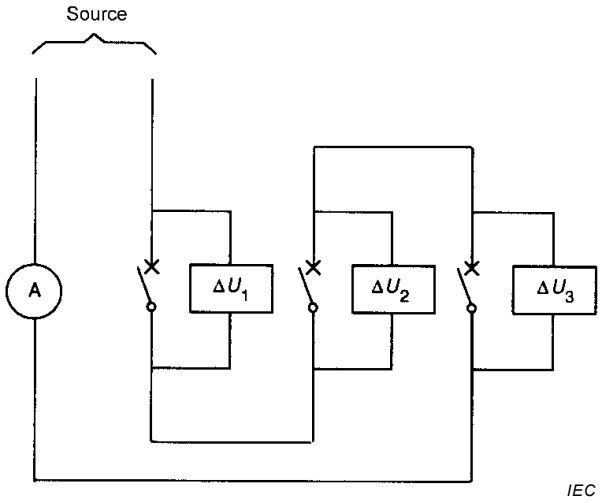


Figure G.2 – Exemple de mesurage de la perte de puissance selon G.2.2 et G.2.3

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Annexe H
(normative)

Séquence d'essai pour les disjoncteurs pour réseaux IT

NOTE Cette séquence d'essai est prévue pour couvrir le cas d'un deuxième défaut à la terre en présence d'un premier défaut sur le côté opposé d'un disjoncteur lorsqu'il est installé dans un réseau IT (voir 4.3.2.1).

H.1 Généralités

Cette séquence d'essai est applicable aux disjoncteurs multipolaires pour emploi sur des réseaux IT, selon 4.3.2.1; elle comprend les essais suivants:

Essai	Article
Court-circuit sur un pôle séparément (I_{IT})	H.2
Vérification de la tenue diélectrique	H.3
Vérification des déclencheurs de surcharge	H.4

H.2 Court-circuit sur un pôle séparément

Un essai de court-circuit est effectué sur les pôles individuels d'un disjoncteur multipolaire dans les conditions générales de 8.3.2, à une valeur du courant I_{IT} égale à

– 1,2 fois le réglage maximal du courant de déclenchement du déclencheur à retard de courte durée ou, en l'absence d'un tel déclencheur, 1,2 fois le réglage maximal du courant de déclenchement du déclencheur instantané,

ou, le cas échéant

– 1,2 fois le réglage maximal du courant de déclenchement du déclencheur à retard indépendant,

mais pas moins de 500 A et pas plus de 50 kA.

NOTE 1 Le courant présumé du circuit d'essai peut devoir être augmenté pour s'assurer que le courant d'essai excède le courant de déclenchement à retard de courte durée ou instantané réel, compte tenu de l'impédance du disjoncteur et de ses connexions.

NOTE 2 Des valeurs supérieures à I_{IT} peuvent être exigées, soumises à essai et déclarées par le fabricant.

La tension d'essai doit être la tension phase-phase correspondant à la tension assignée de fonctionnement maximale du disjoncteur adaptée pour les réseaux IT, en tenant compte des exigences pour la tension de rétablissement de 8.3.2.2.6. Le nombre d'échantillons à soumettre à essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 10. Le facteur de puissance doit être conforme au Tableau 11, adapté au courant d'essai. Lorsque I_{IT} = 50 kA, le seuil de déclenchement à retard de courte durée ou instantané doit être ajusté au réglage le plus proche inférieur à (50/1,2) kA.

Pour les disjoncteurs tétrapolaires avec un pôle neutre protégé, la tension d'essai pour ce pôle doit être la tension entre phases divisée par $\sqrt{3}$. Cet essai est applicable seulement lorsque la construction du pôle du neutre protégé est différente de celle des pôles de phase.

Le circuit d'essai doit être conforme au 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 et à la Figure 9 de l'IEC 60947-1:2007/AMD1:2010, l'alimentation S provenant de deux phases d'une alimentation triphasée, l'élément fusible F étant raccordé à la phase restante. Le ou les pôles disponibles doivent aussi être raccordés à cette phase par l'élément fusible F.

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La séquence de manœuvres doit être:

O – *t* – CO

et doit être effectuée sur chaque pôle pris séparément, à tour de rôle.

Si le disjoncteur est fourni avec un déclencheur à retard de courte durée ainsi qu'avec un déclencheur instantané, le déclencheur instantané peut fonctionner avant le déclencheur à retard de courte durée, selon le réglage et les tolérances.

H.3 Vérification de la tenue diélectrique

Après l'essai selon H.2, la tenue diélectrique doit être vérifiée conformément à 8.3.5.4.

H.4 Vérification des déclencheurs de surcharge

A la suite de l'essai selon H.3, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément à 8.3.5.5.

H.5 Marquage

~~Les disjoncteurs pour lesquels toutes les valeurs de tension assignée ont été soumises à essai selon cette annexe ou sont couvertes par de tels essais ne nécessitent aucun marquage supplémentaire.~~

~~Les disjoncteurs pour lesquels toutes les valeurs de tension assignée n'ont pas été soumises à essai selon cette annexe ou ne sont pas couvertes par de tels essais doivent être identifiés par le symbole ⊛ qui doit être marqué sur le disjoncteur juste après ces valeurs de tensions assignées, par exemple 690 V ⊛ conformément à 5.2, point b).~~

~~Lorsqu'un disjoncteur n'a pas été soumis à essai selon cette annexe, un marquage unique avec le symbole ⊛ peut être utilisé pourvu qu'il soit placé de telle façon qu'il couvre de façon non ambiguë toutes les tensions assignées.~~

Le paragraphe 5.2 est applicable avec l'ajout suivant:

Les disjoncteurs pour lesquels toutes les valeurs de tension assignée ne sont pas couvertes par les essais selon la présente annexe doivent être marqués conformément au Tableau H.1.

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Tableau H.1 – Informations sur le matériel

Elément	Information	Emplacement du marquage
H2.1	tension(s) assignée(s) inappropriée(s) pour les réseaux IT, comme suit: suivant immédiatement chaque tension assignée correspondante, par exemple 690 V  (IEC 60417-6363:2016-07) ou suivant immédiatement le groupe de tensions assignées, par exemple 415 V 500 V 690 V }  (IEC 60417-6363:2016-07)	Marqué
Légende Marqué: marqué sur le matériel		

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Annexe J
(normative)

Compatibilité électromagnétique (CEM) – Exigences et méthodes d'essai pour les disjoncteurs

J.1 Généralités

Deux classes de conditions d'environnement sont considérées et sont désignées comme suit:

– environnement A,
– environnement B.

Environnement A: désigne les réseaux/emplacements/installations à basse tension non publics ou industriels comprenant des sources fortement perturbatrices.

NOTE 1 L'environnement A correspond à des matériels de classe A dans le CISPR 11 et le CISPR ~~22~~32.

NOTE 2 Les matériels correspondant à l'environnement A peuvent créer des interférences électromagnétiques lorsqu'ils sont installés dans un environnement B.

Environnement B: désigne les réseaux publics à basse tension comme les emplacements/installations domestiques, commerciales et de l'industrie légère. Des sources fortement perturbatrices telles que des soudeuses à l'arc ne sont pas couvertes par cet environnement.

NOTE 3 L'environnement B correspond à des matériels de classe B dans le CISPR 11 et le CISPR ~~22~~32.

NOTE 4 Les matériels correspondant à l'environnement B ne créent pas d'interférences électromagnétiques lorsqu'ils sont installés dans un environnement A.

Pour les besoins de la présente annexe, le terme «EUT» (equipment under test) signifie «matériel en essai».

NOTE 5 Les exigences de CEM pour les CBI (Annexe L) et ICB (Annexe O) sont considérées comme étant couvertes par les essais appropriés sur le disjoncteur équivalent (voir L.2.1 et O.2.1).

Les essais de J.2 et J.3 sont applicables aux appareils comprenant des circuits électroniques, sauf spécification contraire dans la présente norme.

Les méthodes d'essai de J.2 et J.3 sont complétées par des modes opératoires spécifiques dans les parties appropriées de la présente norme pour vérifier le comportement sur la base des critères d'acceptation.

Des exigences complémentaires et des détails relatifs aux essais sont donnés dans les parties appropriées de la présente norme, par exemple l'Annexe B pour les disjoncteurs à protection incorporée par courant différentiel résiduel (DPR), l'Annexe F pour les disjoncteurs à protection électronique contre les surintensités, l'Annexe M pour les appareils modulaires à courant différentiel résiduel (MRCD) et l'Annexe N pour les auxiliaires de disjoncteur.

Un appareil neuf peut être utilisé pour chaque essai ou un appareil peut être utilisé pour plusieurs essais, au choix du fabricant. Les appareils de fréquences assignées 50 Hz/60 Hz doivent être soumis à essai indifféremment à l'une ou l'autre de ces fréquences assignées.

Dans le cas d'une plage d'appareils avec des commandes électroniques identiques (y compris les dimensions, les composants, les cartes de circuits imprimés et l'enveloppe, le cas échéant) et avec des capteurs de courant de même conception, il est suffisant de soumettre à essai uniquement un appareil de la plage.

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Les essais doivent être effectués avec un montage spécifique, à l'air libre ou dans une enveloppe, comme spécifié en J.2 et J.3.

J.2 Immunité

J.2.1 Généralités

Le paragraphe 7.3.2.2 de l'IEC 60947-1:2007/AMD1:2010 est applicable avec les compléments suivants.

Les essais d'immunité doivent être effectués selon le Tableau J.1. Les niveaux d'immunité spécifiés dans ce tableau peuvent être plus élevés que ceux exigés par le Tableau 23 de l'IEC 60947-1:2007/AMD1:2010, afin d'assurer une fiabilité accrue des fonctions de protection du disjoncteur.

Les données de référence pour les spécifications complémentaires d'essai sont indiquées au Tableau J.2.

Pour les besoins du présent article (J.2), le terme «accès de puissance» couvre le circuit principal, le ou les accès d'alimentation auxiliaire et tout auxiliaire raccordé au circuit principal.

Pour les essais d'immunité, les critères de comportement suivants doivent être définis:

Critère de comportement A: pendant l'essai, la résistance au fonctionnement intempestif (étape 1) et les caractéristiques fonctionnelles (étape 2) sont vérifiées. Toutes les fonctions de surveillance doivent indiquer correctement l'état.

Critère de comportement B: pendant l'essai, la résistance au fonctionnement intempestif est vérifiée. Les fonctions de surveillance peuvent indiquer un état erroné. Après l'essai, les caractéristiques fonctionnelles sont vérifiées.

Les détails de la vérification du comportement sont indiqués dans l'annexe correspondante (Annexe B, Annexe F, Annexe M ou Annexe N).

Pour tous les essais d'immunité, l'EUT doit être soumis à essai comme un matériel reposant au sol (voir série IEC 61000-4).

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Tableau J.1 – CEM – Essais d'immunité

Description	Norme de référence	Niveau d'essai [a]	Critère de comportement	Montage
Décharges électrostatiques	IEC 61000-4-2	8 kV au contact 8 kV dans l'air	B	Enveloppe Figure J.1
Champs électromagnétiques rayonnés aux fréquences radioélectriques	IEC 61000-4-3	10 V/m (jusqu'à 2 GHz) 3 V/m (de 2 GHz à 2,7 GHz)	A	Air libre [c]
Transitoires électriques rapides en salves	IEC 61000-4-4	Accès de puissance: $U_e \geq 100$ V, courant alternatif ou courant continu: 4 kV $U_e < 100$ V, courant alternatif ou courant continu: 2 kV [f] Accès par les bornes de signaux: 2 kV [g]	B	Enveloppe Figure J.1
Ondes de choc	IEC 61000-4-5	Accès de puissance, $U_e \geq 100$ V courant alternatif: 4 kV phase-terre 2 kV entre phases (Annexe F et Annexe N) 4 kV entre phases (Annexe B et Annexe M) [e] Accès de puissance, $U_e \leq 100$ V courant alternatif: 2 kV phase-terre 1 kV entre phases Accès de puissance, courant continu [f]: 0,5 kV phase-terre 0,5 kV entre phases Accès par les bornes de signaux [h]: 2 kV phase-terre 1 kV entre phases	B	Enveloppe Figure J.1
Perturbations conduites, induites par les champs radioélectriques	IEC 61000-4-6	Accès de puissance: 10 V Accès par les bornes de signaux: 10 V [g]	A	Air libre [c]
Champs magnétiques à la fréquence industrielle	Non applicable	Non applicable	Non applicable	Non applicable
Creux de tension et interruptions	IEC 61000-4-11 [d]	[d]	[d]	Air libre
Harmoniques	IEC 61000-4-13 [b]	[b]	[b]	Air libre
Creux de courant	[b]	[b]	[b]	Air libre

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[a] Les niveaux d'immunité spécifiés sont généralement plus élevés que les exigences de l'IEC 60947-1, dans le but de fournir une plus grande sécurité pour les fonctions de protection du circuit de l'appareil.

[b] Un mode opératoire d'essai spécifique est défini pour le cas des appareils électroniques de protection contre les surintensités dans l'Annexe F, en l'absence d'une norme fondamentale appropriée.

[c] A moins que le disjoncteur ne soit prévu pour être utilisé uniquement dans une enveloppe séparée spécifiée, auquel cas il doit être soumis à essai dans cette enveloppe. Les éléments détaillés, notamment les dimensions de l'enveloppe, doivent être consignés dans le rapport d'essai. L'enveloppe doit être reliée au plan de masse conformément aux instructions du fabricant.

[d] Un mode opératoire d'essai et un critère de comportement spécifiques sont définis à l'Annexe B dans le cas des DPR fonctionnellement dépendants de la tension d'alimentation et à l'Annexe M dans le cas des MRCD fonctionnellement dépendants d'une source de tension, en l'absence d'une norme fondamentale appropriée. Ces essais ne s'appliquent pas aux disjoncteurs à protection électronique contre les surintensités de l'Annexe F (voir F.1), mais sont remplacés par des essais pour les creux de courant et les interruptions (voir F.4.7).

[e] Le niveau d'immunité est plus élevé pour les appareils à courant différentiel résiduel parce qu'ils réalisent des fonctions de sécurité.

[f] Non applicable aux accès d'entrée destinés à être raccordés à des piles ou des batteries rechargeables qu'il faut retirer ou débrancher de l'appareil pour pouvoir être rechargées. Les appareils munis d'une entrée de puissance pour courant continu destinés à être utilisés avec un adaptateur d'alimentation courant alternatif – courant continu doivent être soumis à essai sur l'entrée de puissance en courant alternatif de l'adaptateur d'alimentation courant alternatif – courant continu spécifié par le fabricant ou d'un adaptateur correspondant typique, lorsque le fabricant n'en spécifie aucun. L'essai ne s'applique pas aux accès d'entrée de puissance pour courant continu prévus pour être connectés en permanence à des câbles de moins de 3 m de longueur.

[g] Applicable seulement aux accès destinés à des câbles dont la longueur totale, selon les spécifications fonctionnelles du fabricant, peut dépasser 3 m.

[h] Applicable seulement aux accès destinés à des câbles dont la longueur totale, selon les spécifications fonctionnelles du fabricant, peut dépasser 10 m. Lorsque des câbles blindés sont utilisés, cet essai s'applique seulement au blindage.

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Description	Norme de référence	Niveau d'essai	Critère de comportement	Montage
Décharges électrostatiques	IEC 61000-4-2	6 kV au contact 8 kV dans l'air	B	Enveloppe Figure J.1
Champs électromagnétiques rayonnés aux fréquences radioélectriques	IEC 61000-4-3	80 MHz à 1 GHz: 10 V/m 1,4 GHz à 6 GHz: 3 V/m	A	Air libre [c]
Transitoires électriques rapides en salves [k]	IEC 61000-4-4	Accès de puissance: $U_e \geq 100$ V courant alternatif / courant continu: 4 kV 5 kHz ou 100 kHz $U_e < 100$ V courant alternatif / courant continu [f]: 2 kV 5 kHz ou 100 kHz Accès par les bornes de signaux [g]: 2 kV 5 kHz ou 100 kHz	B	Enveloppe Figure J.1
Ondes de choc	IEC 61000-4-5	Accès de puissance, $U_e \geq 100$ V courant alternatif: 4 kV phase-terre 2 kV entre phases:(Annexe F et Annexe N) 4 kV entre phases (Annexe B et Annexe M) [e] Accès de puissance, $U_e < 100$ V courant alternatif: 2 kV phase-terre 1 kV entre phases Accès de puissance, courant continu [f]: 1 kV phase-terre 0,5 kV entre phases Accès par les bornes de signaux [h, j]: 2 kV phase-terre 1 kV entre phases	B	Enveloppe Figure J.1
Perturbations conduites, induites par les champs radioélectriques	IEC 61000-4-6	Accès de puissance, courant alternatif / courant continu: 10 V (150 kHz – 80 MHz) Accès par les bornes de signaux [g]: 10 V (150 kHz – 80 MHz)	A	Air libre [c]
Champs magnétiques à la fréquence industrielle	Non applicable	Non applicable	Non applicable	Non applicable
Creux de tension et coupures brèves	IEC 61000-4-11 [d]	[d]	[d]	Air libre
Harmoniques	IEC 61000-4-13 [b]	[b]	[b]	Air libre
Creux de courant	[b]	[b]	[b]	Air libre

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[a] Disponible.

[b] Un mode opératoire d'essai spécifique est défini pour le cas des appareils électroniques de protection contre les surintensités dans l'Annexe F, en l'absence d'une norme fondamentale appropriée.

[c] A moins que le disjoncteur ne soit destiné à être utilisé uniquement dans une enveloppe séparée spécifiée, auquel cas il doit être soumis à essai dans cette enveloppe. Les éléments détaillés, notamment les dimensions de l'enveloppe, doivent être indiqués dans le rapport d'essai. L'enveloppe doit être reliée au plan de masse conformément aux instructions du fabricant.

[d] Un mode opératoire d'essai et un critère de comportement spécifiques sont définis à l'Annexe B dans le cas des DPR fonctionnellement dépendants de la tension d'alimentation et à l'Annexe M dans le cas des MRCD fonctionnellement dépendants d'une source de tension, en l'absence d'une norme fondamentale appropriée. Ces essais ne s'appliquent pas aux disjoncteurs à protection électronique contre les surintensités de l'Annexe F (voir F.1), mais sont remplacés par des essais pour les creux de courant et les interruptions (voir F.4.7).

[e] Le niveau d'immunité est plus élevé pour les appareils à courant différentiel résiduel parce qu'ils assurent des fonctions de sécurité.

[f] Non applicable aux accès d'entrée destinés à être raccordés à des piles ou des batteries rechargeables qu'il faut retirer ou débrancher de l'appareillage pour pouvoir être rechargées. Les appareillages munis d'une entrée de puissance pour courant continu destinés à être utilisés avec un adaptateur d'alimentation courant alternatif – courant continu doivent être soumis à essai sur l'entrée de puissance en courant alternatif de l'adaptateur d'alimentation courant alternatif – courant continu spécifié par le fabricant ou d'un adaptateur correspondant typique, lorsque le fabricant n'en spécifie aucun. L'essai ne s'applique pas aux accès d'entrée de puissance pour courant continu destinés à être connectés en permanence à des câbles de moins de 3 m de longueur.

[g] Applicable uniquement aux accès destinés à des câbles dont la longueur totale, selon les spécifications fonctionnelles du fabricant, peut dépasser 3 m.

[h] Applicable uniquement aux accès destinés à des câbles dont la longueur totale, selon les spécifications fonctionnelles du fabricant, peut dépasser 10 m. Lorsque des câbles blindés sont utilisés, cet essai s'applique uniquement au blindage.

[j] Les lignes de signaux directement raccordées à des accès en courant alternatif doivent être considérées comme des accès de puissance en courant alternatif.

[k] La fréquence de répétition (5 kHz ou 100 kHz) doit faire l'objet d'un accord entre le fabricant et la station d'essai, et doit être indiquée dans le rapport d'essai.

L'installation d'essai et le schéma du circuit appropriés pour chaque essai d'immunité sont indiqués au Tableau J.2.

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Tableau J.2 – Données de référence pour les spécifications d'essai d'immunité

Essai	EUT	Paragraphe	Installation d'essai	Schéma du circuit
Décharges électrostatiques	DPR	J.2.2, ~~B.8.12.1.2~~ B.8.13.1.2	Figure J.1, Figure J.3	Figure B.1
	CB	J.2.2, F.4.2	Figure J.3, Figure F.16	Figure F.2, Figure F.3 ou Figure F.4
	MRCD	J.2.2, M.8.16.1.2	Figure J.1, Figure J.3	Figure M.3
	Autres appareils [a]	J.2.2, N.2.2	[b]	[b]
Champs électromagnétiques rayonnés aux fréquences radioélectriques	DPR	J.2.3, ~~B.8.12.1.3~~ B.8.13.1.3	Figure J.4	Figure B.1
	CB	J.2.3, F.4.3	Figure F.16, Figure F.17	Figure F.2, Figure F.3, ou Figure F.4
	MRCD	J.2.3, M.8.16.1.3	Figure J.4, Figure M.20	Figure M.3
	Autres appareils [a]	J.2.3, N.2.3	[b]	[b]
Transitoires électriques rapides en salves	DPR	J.2.4, ~~B.8.12.1.4~~ B.8.13.1.4	Figure J.5, Figure J.6	Figure B.1
	CB	J.2.4, F.4.4	Figure F.16, Figure F.18, Figure F.19	Figure F.6, Figure F.7, Figure F.8
	MRCD	J.2.4, M.8.16.1.4	Figure J.5, Figure J.6, Figure M.21	Figure M.3
	Autres appareils [a]	J.2.4, N.2.4	[b]	[b]
Ondes de choc	DPR	J.2.5, ~~B.8.12.1.5~~ B.8.13.1.5	[b]	Figure B.1
	CB	J.2.5, F.4.5	Phase-terre: Figure F.16 Entre phases: Figure F.16	Phase-terre: Figure F.9 Figure F.10 ou Figure F.11 Entre phases: Figure F.12, Figure F.13 ou Figure F.14
	MRCD	J.2.5, M.8.16.1.5	[b]	Figure M.3
	Autres appareils [a]	J.2.5, N.2.5	[b]	[b]
Perturbations conduites, induites par les champs radioélectriques	DPR	J.2.6, ~~B.8.12.1.6~~ B.8.13.1.6	[b]	Figure B.1
	CB	J.2.6, F.4.6	Figure F.16, Figure F.20, Figure F.21, Figure F.22, Figure F.23	Figure F.2, Figure F.3 ou Figure F.4
	MRCD	J.2.6, M.8.16.1.6	Figure M.22	Figure M.3
	Autres appareils [a]	J.2.6, N.2.6	[b]	[b]

[a] Appareils dans le domaine d'application de l'Annexe N.

[b] Aucune figure supplémentaire n'est nécessaire.

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J.2.2 Décharges électrostatiques

L'EUT doit être soumis à essai dans une enveloppe spécifique (voir Tableau J.1). L'installation d'essai et les exigences supplémentaires d'essai sont indiquées au Tableau J.2. Les décharges directes et indirectes doivent être appliquées conformément à l'IEC 61000-4-2.

Les essais de décharge directe doivent être effectués seulement sur les parties de l'EUT normalement accessibles à l'opérateur, telles que moyens de réglage, claviers, afficheurs, boutons-poussoirs, etc. Les points d'application doivent être consignés dans le rapport d'essai.

Les décharges directes sont appliquées 10 fois pour chaque polarité, à des intervalles ≥ 1 s.

Les décharges indirectes doivent être appliquées aux points choisis sur la surface de l'enveloppe; l'essai est effectué 10 fois à chaque point, pour chaque polarité, à des intervalles ≥ 1 s.

J.2.3 Champs électromagnétiques RF rayonnés

L'EUT doit être soumis à essai à l'air libre (voir Tableau J.1) avec les exigences supplémentaires d'essai indiquées au Tableau J.2.

L'EUT doit être soumis à essai seulement sur la face avant.

Pour permettre la répétabilité, l'installation d'essai réelle doit être détaillée dans le rapport d'essai.

Les essais doivent être effectués avec une polarisation horizontale et une polarisation verticale de l'antenne.

L'essai est effectué en deux étapes: une première étape (étape 1) où l'EUT est soumis à essai sur toute la plage de fréquences pour détecter un éventuel fonctionnement intempestif, et une deuxième étape (étape 2) où l'EUT est soumis à essai à des fréquences discrètes pour vérifier son fonctionnement correct.

Pour l'étape 1, la fréquence doit être balayée dans les plages de 80 MHz à 1 000 MHz, de 1 400 MHz à 2 000 MHz et de 2 110 MHz à 2 700 MHz, conformément à l'Article 8 de l'IEC 61000-4-3:2006. Le temps de palier de la porteuse modulée en amplitude pour chaque fréquence doit être compris entre 500 ms et 1 000 ms, et la valeur du pas de fréquence doit être de 1 % de la fréquence précédente. Le temps de palier réel doit être consigné dans le rapport d'essai.

Pour l'étape 2, destinée à vérifier les caractéristiques fonctionnelles, l'essai doit être effectué à chacune des fréquences suivantes: 80 MHz; 100 MHz; 120 MHz; 180 MHz; 240 MHz; 320 MHz; 480 MHz; 640 MHz; 960 MHz; 1 400 MHz; 1 920 MHz; 2 150 MHz et 2 450 MHz, le fonctionnement étant vérifié à chaque fréquence après stabilisation du champ.

J.2.4 Transitoires électriques rapides en salves (TER/S)

L'essai doit être effectué avec l'EUT placé dans une enveloppe spécifique (voir Tableau J.1).

L'installation d'essai est indiquée au Tableau J.2.

Pour les accès de puissance et d'alimentation auxiliaire, le réseau de couplage-découplage doit être utilisé, sauf pour l'Annexe F où la méthode d'injection directe doit être utilisée (voir Figure F.18).

Pour les accès par les bornes de signaux, le réseau de couplage-découplage ou la pince d'injection doit être utilisé(e), suivant le cas.

La perturbation doit être appliquée pendant 1 min, sauf spécification contraire.

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J.2.5 Ondes de choc

L'essai doit être effectué avec l'EUT placé dans une enveloppe spécifique (voir Tableau J.1). Les niveaux d'essai et l'installation d'essai sont indiqués au Tableau J.1 et au Tableau J.2, selon l'EUT.

Des impulsions de polarités positive et négative doivent être appliquées, avec un déphasage de 0° et de 90°.

Une série de cinq impulsions est appliquée pour chaque polarité et chaque déphasage (nombre total d'impulsions: 20), l'intervalle séparant deux impulsions étant approximativement de 1 min. Un intervalle plus court peut être utilisé en accord avec le fabricant.

J.2.6 Perturbations conduites, induites par les champs RF (mode commun)

L'EUT doit être soumis à essai à l'air libre (voir Tableau J.1) avec les exigences supplémentaires d'essai indiquées au Tableau J.2.

Les perturbations doivent être injectées, sur les lignes d'alimentation, en utilisant un réseau de couplage-découplage M1, M2 ou M3, suivant le cas.

Sur les lignes de signaux, les perturbations doivent être injectées en utilisant un réseau de couplage-découplage. Si cela n'est pas réalisable, une pince électromagnétique E.M. peut être utilisée.

L'installation d'essai particulière doit être détaillée dans le rapport d'essai.

L'essai est effectué en deux étapes: une première étape (étape 1) où l'EUT est soumis à essai sur toute la plage de fréquences pour détecter un éventuel fonctionnement intempestif, et une deuxième étape (étape 2) où l'EUT est soumis à essai à des fréquences discrètes pour vérifier son fonctionnement correct.

Pour l'étape 1, la fréquence doit être balayée dans la plage de 150 kHz à 80 MHz, conformément à l'Article 8 de l'IEC 61000-4-6:2013. Le temps de palier de la porteuse modulée en amplitude pour chaque fréquence doit être compris entre 500 ms et 1 000 ms, et la valeur du pas de fréquence doit être de 1 % de la fréquence précédente. Le temps de palier réel doit être consigné dans le rapport d'essai.

Pour l'étape 2, destinée à vérifier les caractéristiques fonctionnelles, l'essai doit être effectué à chacune des fréquences suivantes: 0,150 MHz; 0,300 MHz; 0,450 MHz; 0,600 MHz; 0,900 MHz; 1,20 MHz; 1,80 MHz; 2,40 MHz; 3,60 MHz; 4,80 MHz; 7,20 MHz; 9,60 MHz; 12,0 MHz; 19,2 MHz; 27,0 MHz; 49,4 MHz; 72,0 MHz et 80,0 MHz, le fonctionnement étant vérifié à chaque fréquence après stabilisation du niveau de la tension perturbatrice.

J.3 Emission

J.3.1 Généralités

Le paragraphe 7.3.3.2 de l'IEC 60947-1:2007/AMD2:2014 est applicable avec les compléments suivants.

Les essais d'émission sont effectués conformément au Tableau J.3.

Les données de référence pour l'application des figures relatives aux essais d'émission sont indiquées au Tableau J.4.

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Tableau J.3 – CEM – Essais d'émission

Description	Norme de référence	Limites	Montage
Harmoniques	IEC 61000-3-2	[c]	[c]
Fluctuations de tension	IEC 61000-3-3	[c]	[c]
Perturbations conduites aux fréquences radioélectriques 150 kHz à 30 MHz[e]	CISPR 11 [f] / CISPR ~~22~~32	Classe A ou classe B, groupe 1[b, e]	Air libre[d]
Perturbations rayonnées aux fréquences radioélectriques 30 MHz à 1 000 MHz[a]	CISPR 11 [f] / CISPR ~~22~~32	Classe A ou classe B, groupe 1[b]	Air libre[d]

[a] Applicable seulement aux EUT intégrant des appareils de traitement (par exemple des microprocesseurs) ou des alimentations à découpage fonctionnant à des fréquences supérieures à 9 kHz.

[b] La classe de matériel A dans le CISPR 11 et le CISPR ~~22~~32 correspond à un environnement A dans l'IEC 60947-1. Les matériels correspondant à l'environnement A peuvent créer des interférences électromagnétiques lorsqu'ils sont installés dans un environnement B. Le fabricant d'un matériel prévu pour l'environnement A doit déclarer le risque d'interférences électromagnétiques dans la documentation du produit.

La classe de matériel B dans le CISPR 11 et le CISPR ~~22~~32 correspond à un environnement B dans l'IEC 60947-1. Les matériels correspondant à l'environnement B ne créent pas d'interférences électromagnétiques lorsqu'ils sont installés dans un environnement A.

[c] Aucun essai n'est exigé puisque les circuits électroniques de commande fonctionnent à très faible puissance et créent donc des perturbations négligeables.

[d] A moins que l'EUT ne soit prévu pour être utilisé uniquement dans une enveloppe individuelle spécifiée, auquel cas il doit être soumis à essai dans cette enveloppe. Les éléments détaillés, notamment les dimensions de l'enveloppe, doivent être consignés dans le rapport d'essai.

[e] Les disjoncteurs couverts par l'Annexe F sont indépendants de la tension d'alimentation et de toute alimentation auxiliaire. Les circuits électroniques n'ont pas de couplage direct avec l'alimentation et fonctionnent à très faible puissance. Ces disjoncteurs créent des perturbations négligeables et aucun essai n'est par conséquent exigé.

[f] Une description de l'essai, de la méthode d'essai et de l'installation d'essai est donnée à l'Article 7 de la CISPR 11:2015, CISPR 11:2015/AMD1:2016.

Tableau J.4 – Données de référence pour les spécifications d'essai d'émission

Essai	EUT	Paragraphe	Installation d'essai	Schéma du circuit
Perturbations conduites aux fréquences radioélectriques	DPR	J.3.2, B.8.12.2.1	[a]	[a]
	CB	J.3.2, F.5.3	Pas d'essai	Pas d'essai
	MRCD	J.3.2, B.8.12.2.1	[a]	[a]
	Autres appareils	J.3.2, N.3.2	[a]	[a]
Perturbations rayonnées aux fréquences radioélectriques	DPR	J.3.3, B.8.12.2.1	Figure J.2	[a]
	CB	J.3.3, F.5.4	Figure J.2	Figure F.2, Figure F.3, Figure F.4
	MRCD	J.3.3, B.8.12.2.1	Figure J.2	[a]
	Autres appareils	J.3.3, N.3.3	[a]	[a]

[a] Aucune figure supplémentaire n'est nécessaire.

J.3.2 Perturbations conduites aux fréquences radioélectriques (150 kHz à 30 MHz)

La méthode d'essai et la disposition de l'essai doivent être telles qu'indiquées dans le CISPR 11 ou le CISPR ~~22~~32, suivant le cas.

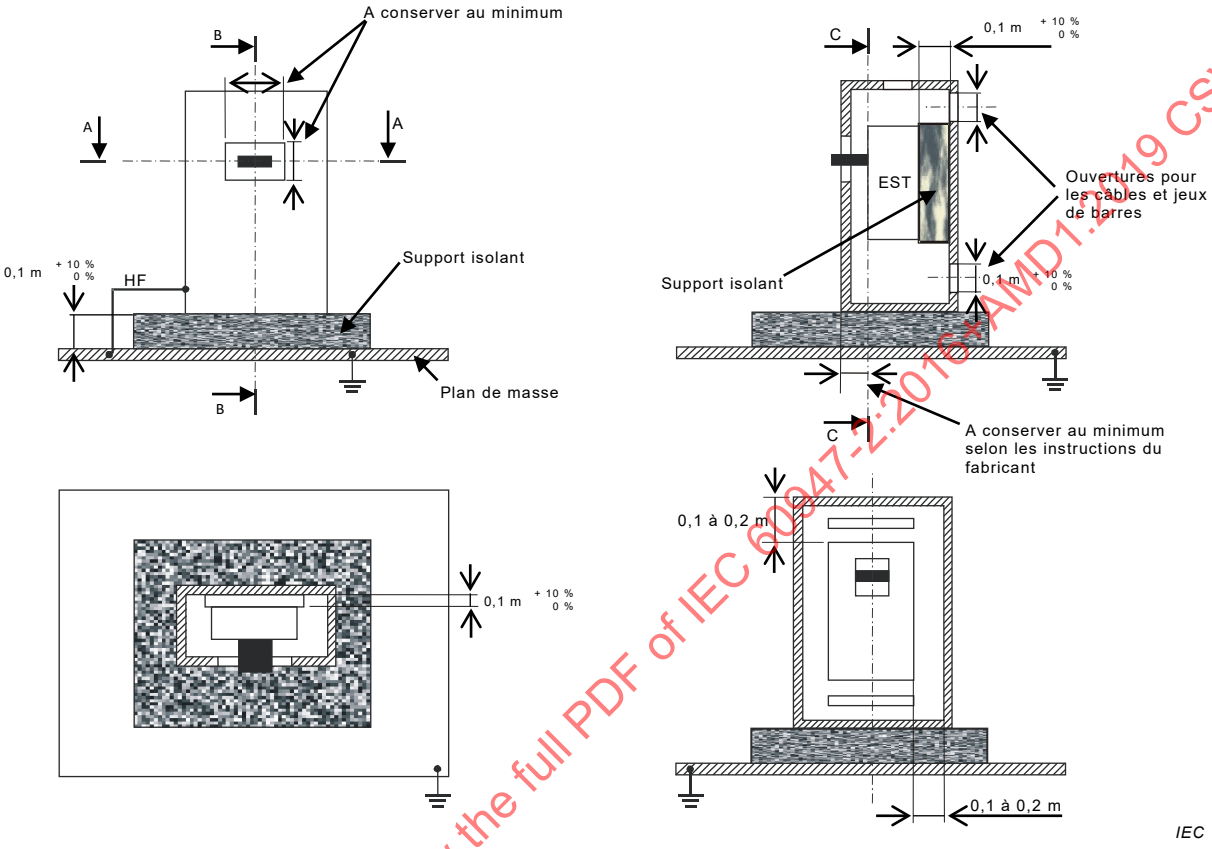
L'installation d'essai particulière, comprenant le type du câble, doit être détaillée dans le rapport d'essai.

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J.3.3 Perturbations rayonnées aux fréquences radioélectriques (30 MHz à 1 000 MHz)

L'installation d'essai est indiquée à la Figure J.2.

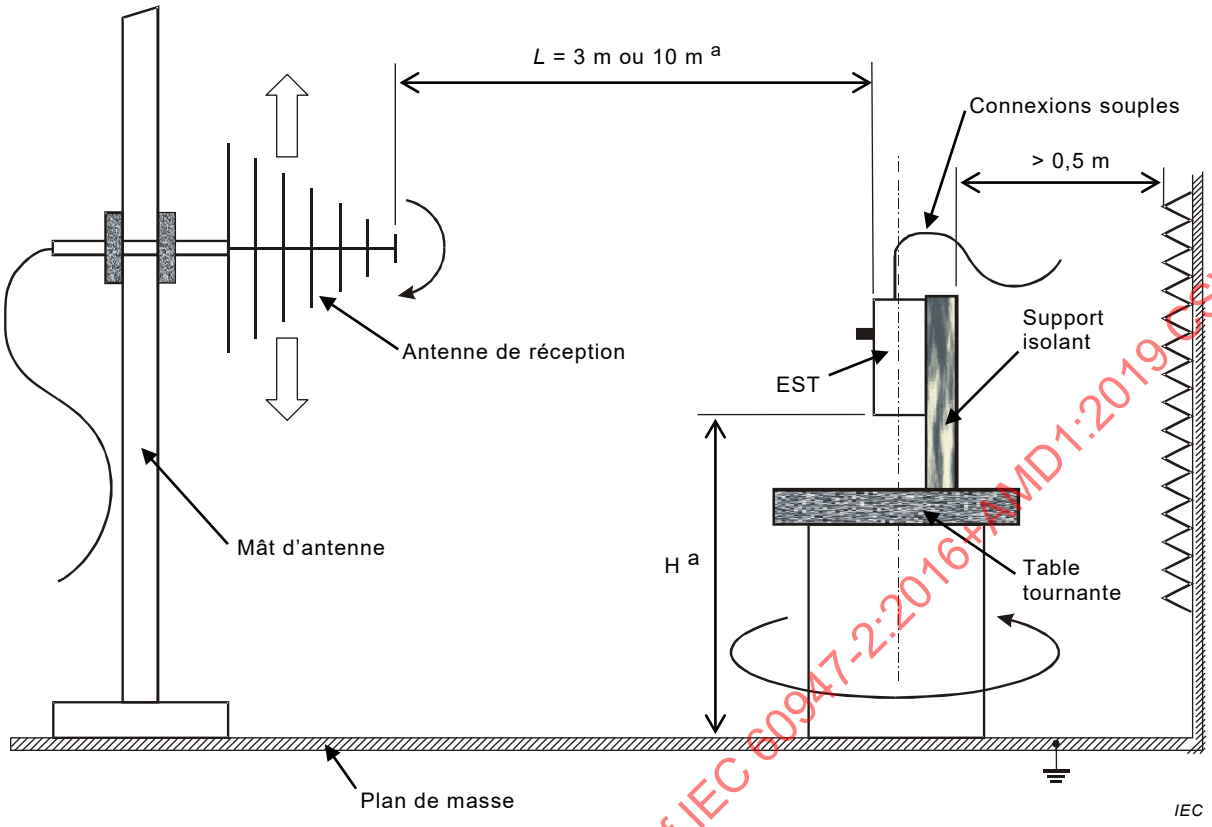
L'installation d'essai particulière, comprenant les jeux de barres d'alimentation, le transformateur, etc. doit être détaillée dans le rapport d'essai.



NOTE Dans le cas d'un disjoncteur débrochable, l'EUT comprend le châssis de débrochage.

Figure J.1 – EUT monté dans une enveloppe métallique

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[a] Voir CISPR 11/CISPR ~~22~~32.

Figure J.2 – Installation d'essai pour le mesurage des émissions rayonnées aux fréquences radioélectriques

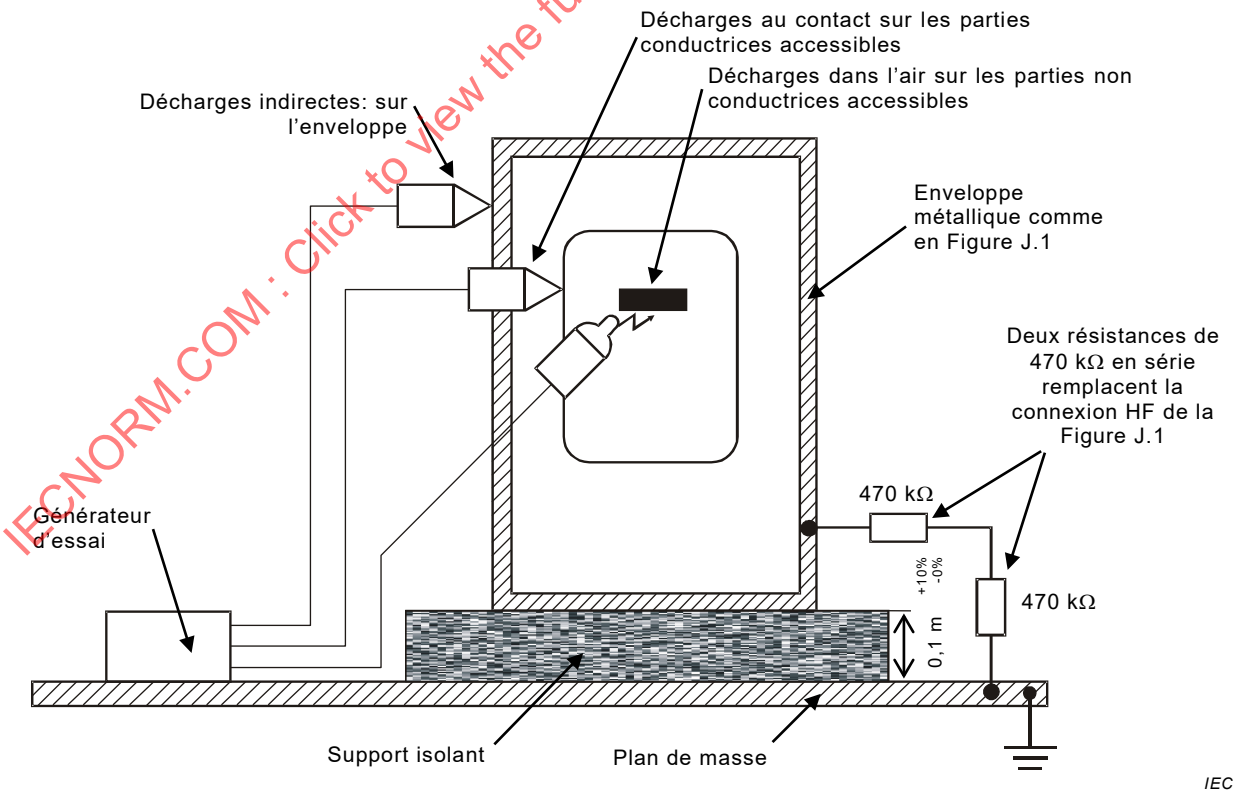
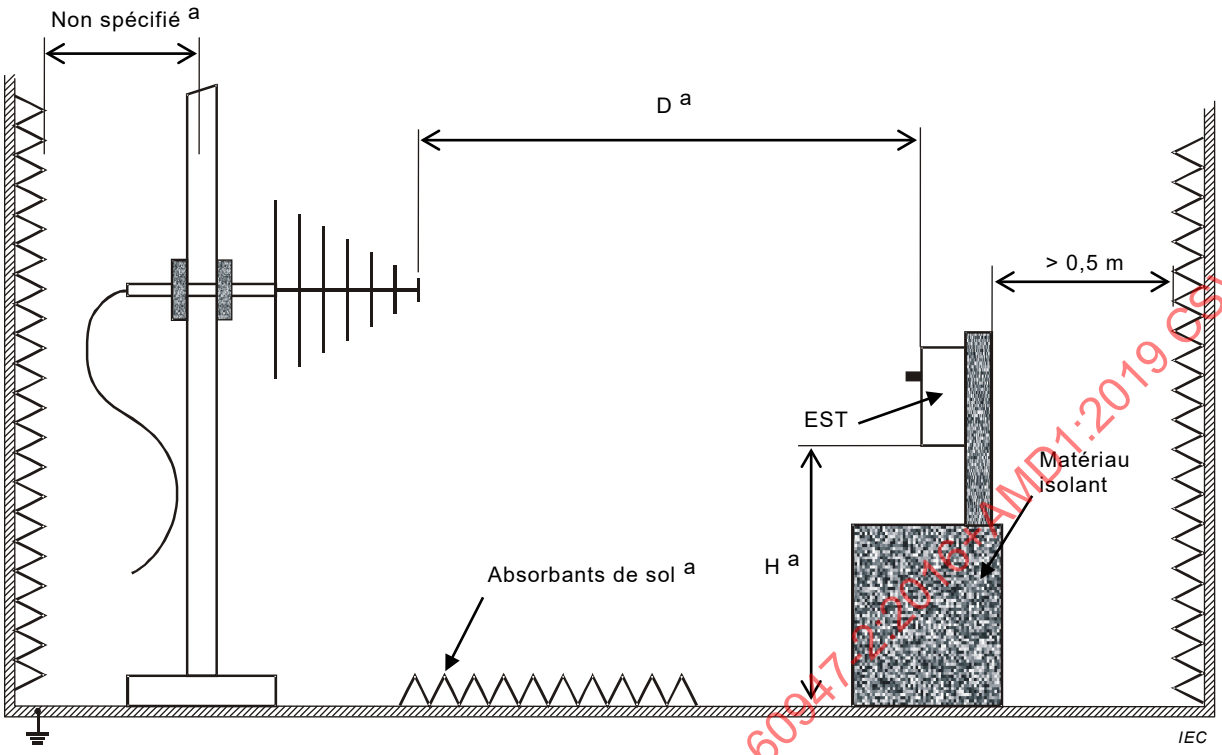


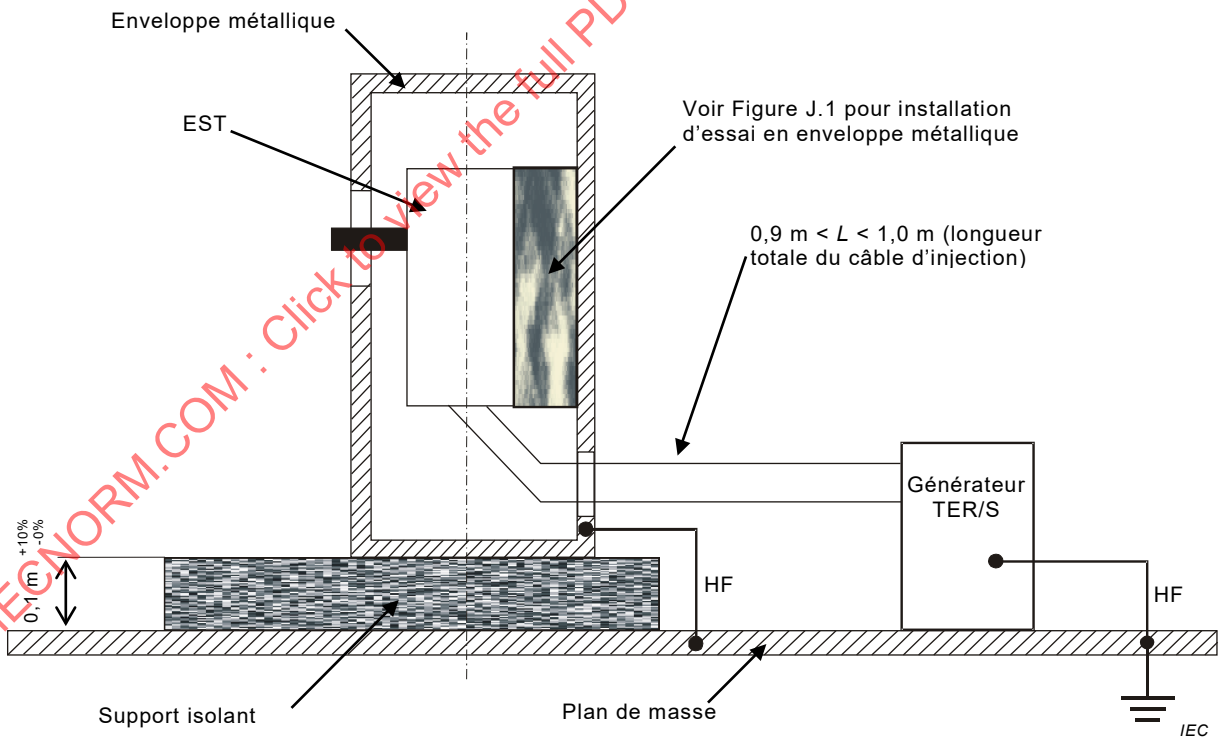
Figure J.3 – Installation d'essai pour la vérification de l'immunité aux décharges électrostatiques

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a Voir l'IEC 61000-4-3.

Figure J.4 – Installation d'essai pour la vérification de l'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques

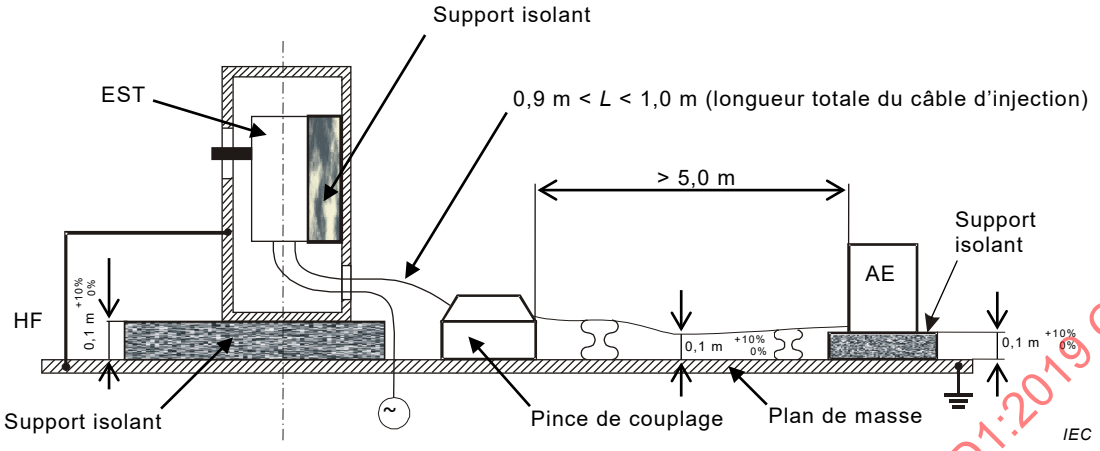


Légende

HF connexion haute fréquence

Figure J.5 – Installation d'essai pour la vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur les lignes d'alimentation

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Légende

AE matériel auxiliaire

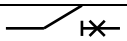
HF connexion haute fréquence

Figure J.6 – Installation d'essai pour la vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur les lignes de signaux

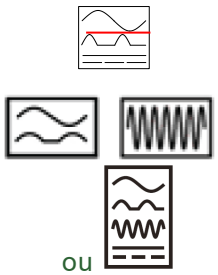
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Annexe K
(informative)

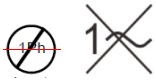
Glossaire des symboles et représentation graphique des caractéristiques

Liste des caractéristiques	Symbole	Référence IEC 60417 ou IEC 60617	Paragraphe de la présente norme
Position de fermeture du disjoncteur		IEC 60417-5007 (2002-10)	5.2
Position d'ouverture du disjoncteur		IEC 60417-5008 (2002-10)	5.2
Aptitude au sectionnement – disjoncteur et ICB		IEC 60617-S00287 combiné avec IEC 60617-S00220 (2007-01)	5.2 O.4
Aptitude au sectionnement – CBI		IEC 60617-S00288 (2007-01)	L.5
Borne du pôle neutre	N		5.2
Borne de terre de protection		IEC 60417-5019 (2006-08)	5.2
Tension assignée du circuit de commande	U_c		4.7.2
Tension assignée de la source de tension d'un MRCD	U_s		M.4.1.2.1
Tension assignée du circuit surveillé pour un MRCD	U_n		Annexe M
Courant assigné	I_n		4.3.3.3
Tension assignée de tenue aux chocs	U_{imp}		4.3.2.3
Tension assignée d'isolement	U_i		4.3.2.2
Tension assignée d'emploi	U_e		4.3.2.1
Pouvoir assigné de coupure de service en court-circuit	I_{cs}		4.3.6.2.3
Pouvoir assigné de fermeture en court-circuit	I_{cm}		4.3.6.1
Courant assigné de courte durée admissible	I_{cw}		4.3.6.4
Courant assigné différentiel résiduel de courte durée admissible d'un MRCD	$I_{\Delta w}$		M.4.3.5
Courant de court-circuit conditionnel assigné	I_{cc}		Annexe L Annexe M
Courant de court-circuit différentiel résiduel conditionnel assigné d'un MRCD	$I_{\Delta c}$		M.4.3.2
Pouvoir assigné de coupure ultime en court-circuit	I_{cu}		4.3.6.2.2
Courant limite de sélectivité	I_s		2.17.4
Courant d'intersection	I_B		2.17.5
Courant thermique conventionnel sous enveloppe	I_{the}		4.3.3.2
Courant thermique conventionnel à l'air libre	I_{th}		4.3.3.1

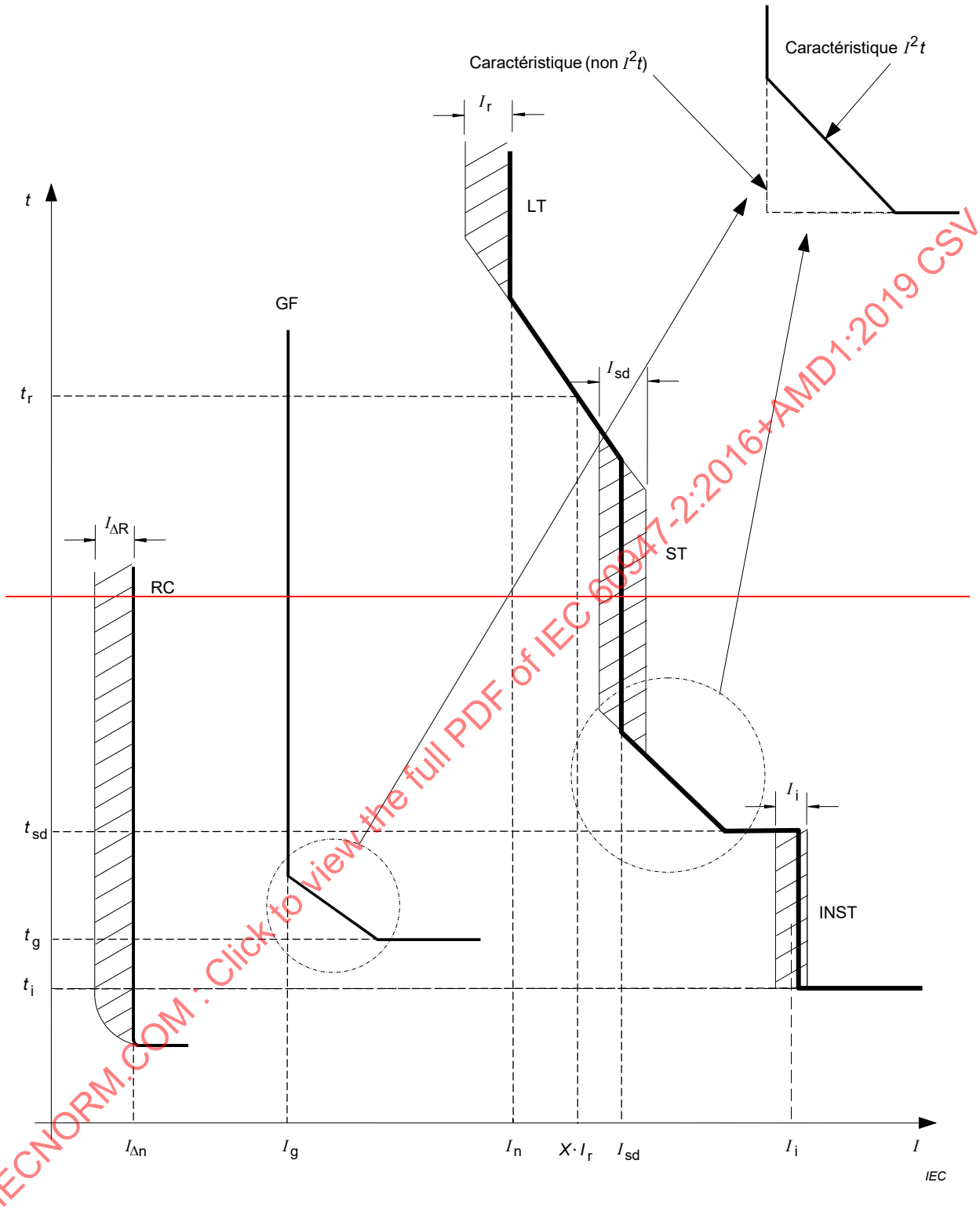
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Liste des caractéristiques	Symbole	Référence IEC 60417 ou IEC 60617	Paragraphe de la présente norme
DPR et MRCD de type AC		IEC 60417-6148 (2012-01)	B.4.4.1 M.4.2.2.1
DPR et MRCD de type A		IEC 60417-6149 (2012-01)	B.4.4.2 M.4.2.2.2
DPR et MRCD de type B	 ou	IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11 ou IEC 60417-6398:2017-12	M.4.2.2.3 B.4.4.3
Appareil d'essai DPR ou MRCD	T		B.7.2.6 M.7.2.6
Courant de réglage du déclencheur de surcharge réglable	I_r		4.7.3
Temps de déclenchement correspondant	t_r		Figure K.1
Courant de réglage de déclenchement par défaut à la terre	I_g		Figure K.1
Temps de déclenchement correspondant	t_g		Figure K.1
Pouvoir de coupure unipolaire en cas de court-circuit (réseaux mis à la terre)	I_{su}		Annexe C
Courant d'essai de court-circuit unipolaire (réseaux IT)	I_{IT}		Annexe H
Courant assigné instantané de réglage de court-circuit	I_i		2.20 Figure K.1 Annexe L Annexe O
Temps maximal de déclenchement correspondant	t_i		Figure K.1
Non adapté pour des schémas de liaison à la terre de type IT		IEC 60417-6363:2016-07	Annexe H
Pouvoir assigné de fermeture et de coupure différentiel résiduel en court-circuit	$I_{\Delta m}$		Annexe B Annexe M
Courant assigné différentiel résiduel de non-fonctionnement	$I_{\Delta no}$		Annexe B Annexe M
Courant assigné différentiel résiduel de fonctionnement	$I_{\Delta n}$		Annexe B Annexe M
~~Courant différentiel résiduel de fonctionnement~~	~~$I_{\Delta R}$~~		~~Figure K.1~~
Seuil de fonctionnement du déclencheur à retard de courte durée	I_{sd}		Figure K.1
Temps de déclenchement correspondant	t_{sd}		Figure K.1
Aptitude à fonctionner sur les réseaux ayant une phase à la terre	C		4.3.2.1
Temps limite de non-fonctionnement à 2 $I_{\Delta n}$	Δt		Annexe B
~~DPR ou MRCD temporisé au temps limite de non-réponse de 0,06 s~~	S		~~B.5 a) M.3.4~~

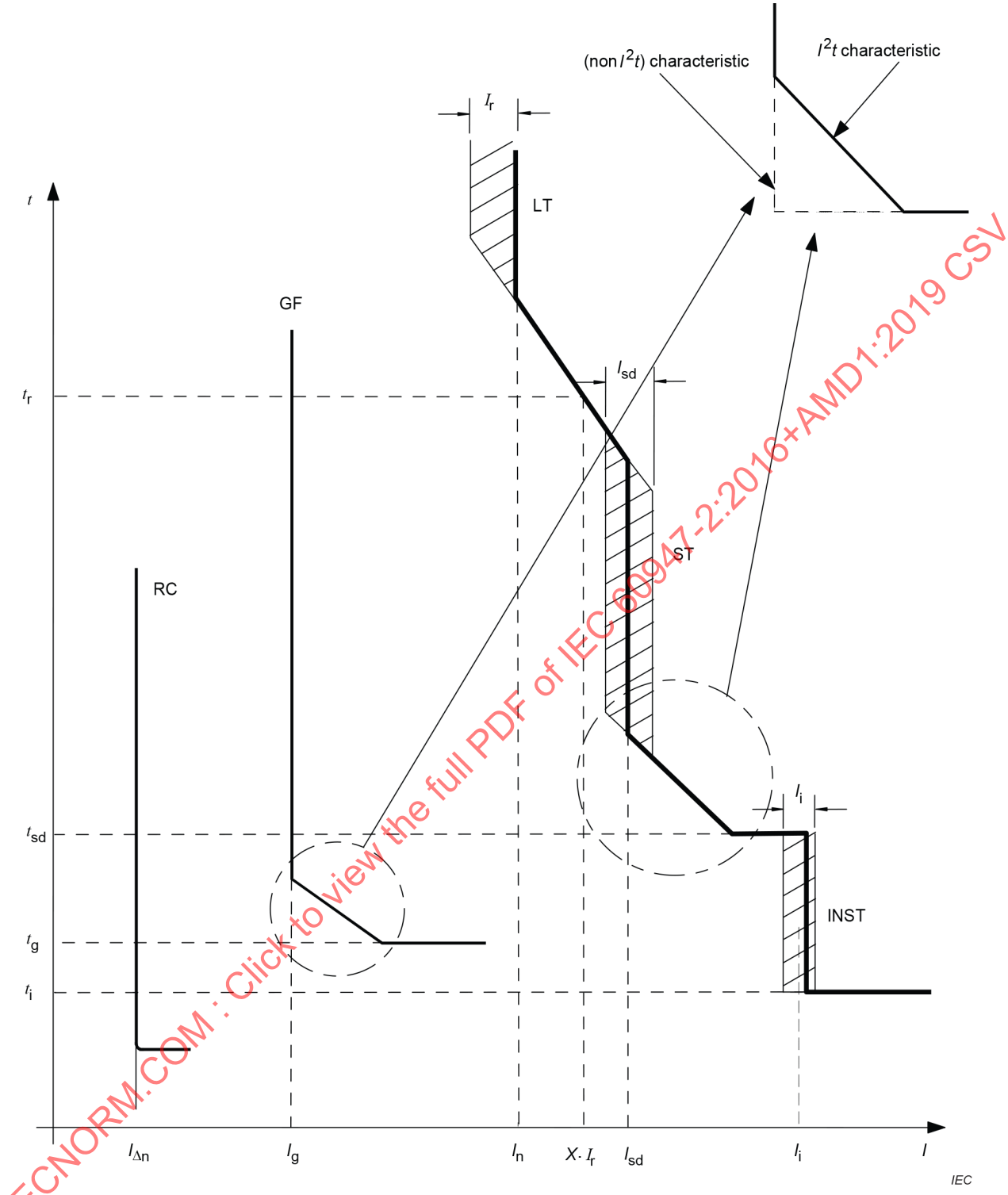
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Liste des caractéristiques	Symbole	Référence IEC 60417 ou IEC 60617	Paragraphe de la présente norme
DPR pour utilisation avec une alimentation triphasée seulement		IEC 60417-6364:2016-07	B.8.9.3
Courant assigné différentiel résiduel de refermeture automatique	$I_{\Delta ar}$		R.2.2

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Anglais	Français
(non I^2t) characteristic	Caractéristique (non I^2t)
I^2t characteristic	Caractéristique I^2t

RC courant différentiel résiduel
GF défaut à la terre
LT temps long
ST temps court
INST instantané

Figure K.1 – Relation entre les symboles et les caractéristiques de déclenchement

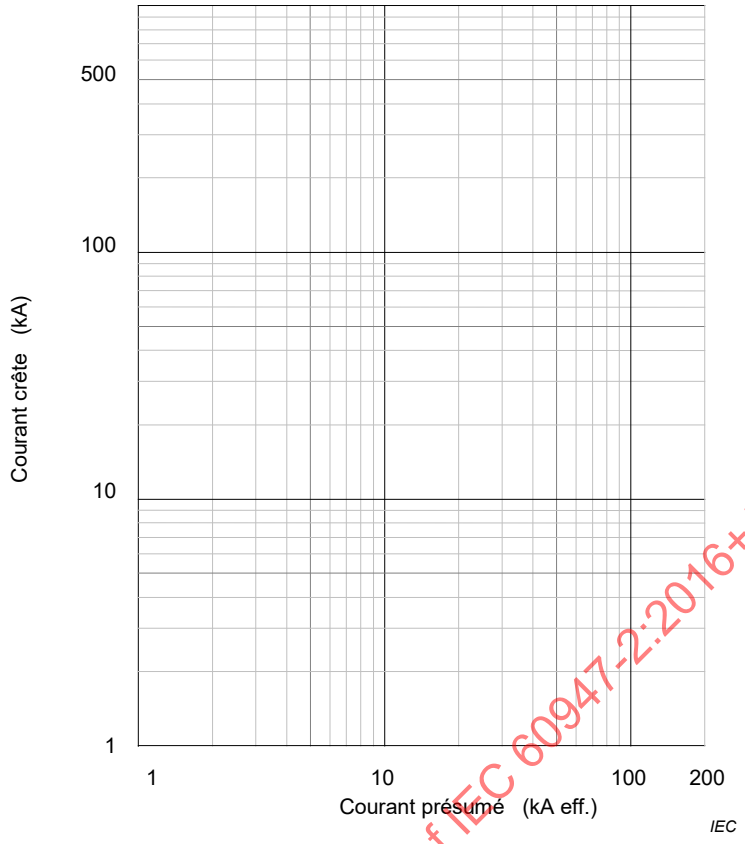


Figure K.2 – Modèle de caractéristiques du courant coupé limité par rapport au courant présumé de 1 kA à 200 kA

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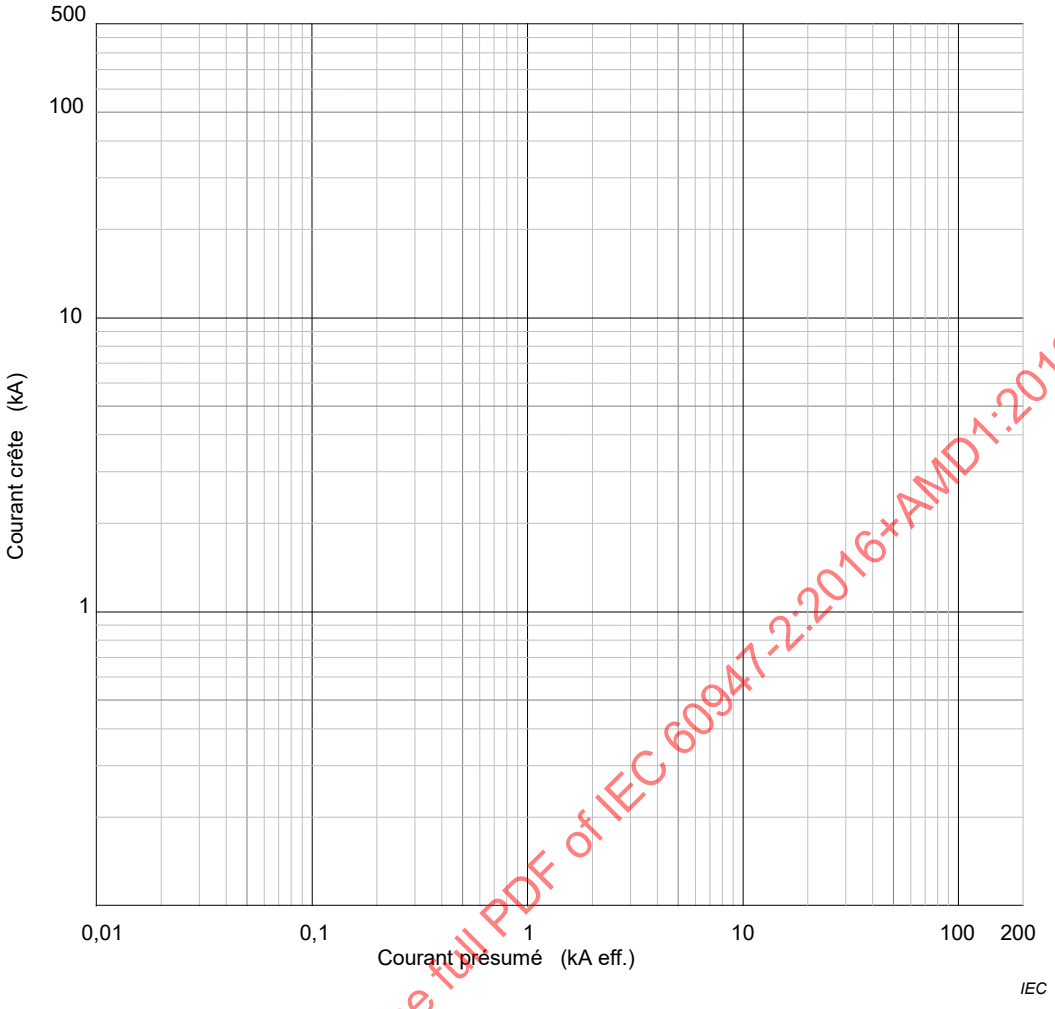


Figure K.3 – Modèle de caractéristiques du courant coupé limité par rapport au courant présumé de 0,01 kA à 200 kA

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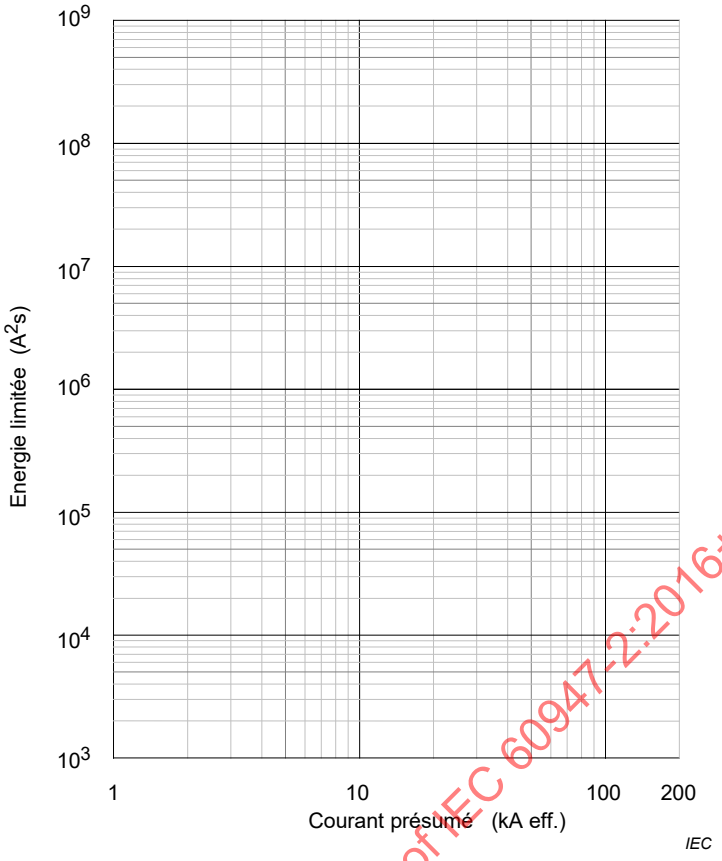


Figure K.4 – Modèle de caractéristiques de l'énergie limitée par rapport au courant présumé de 1 kA à 200 kA

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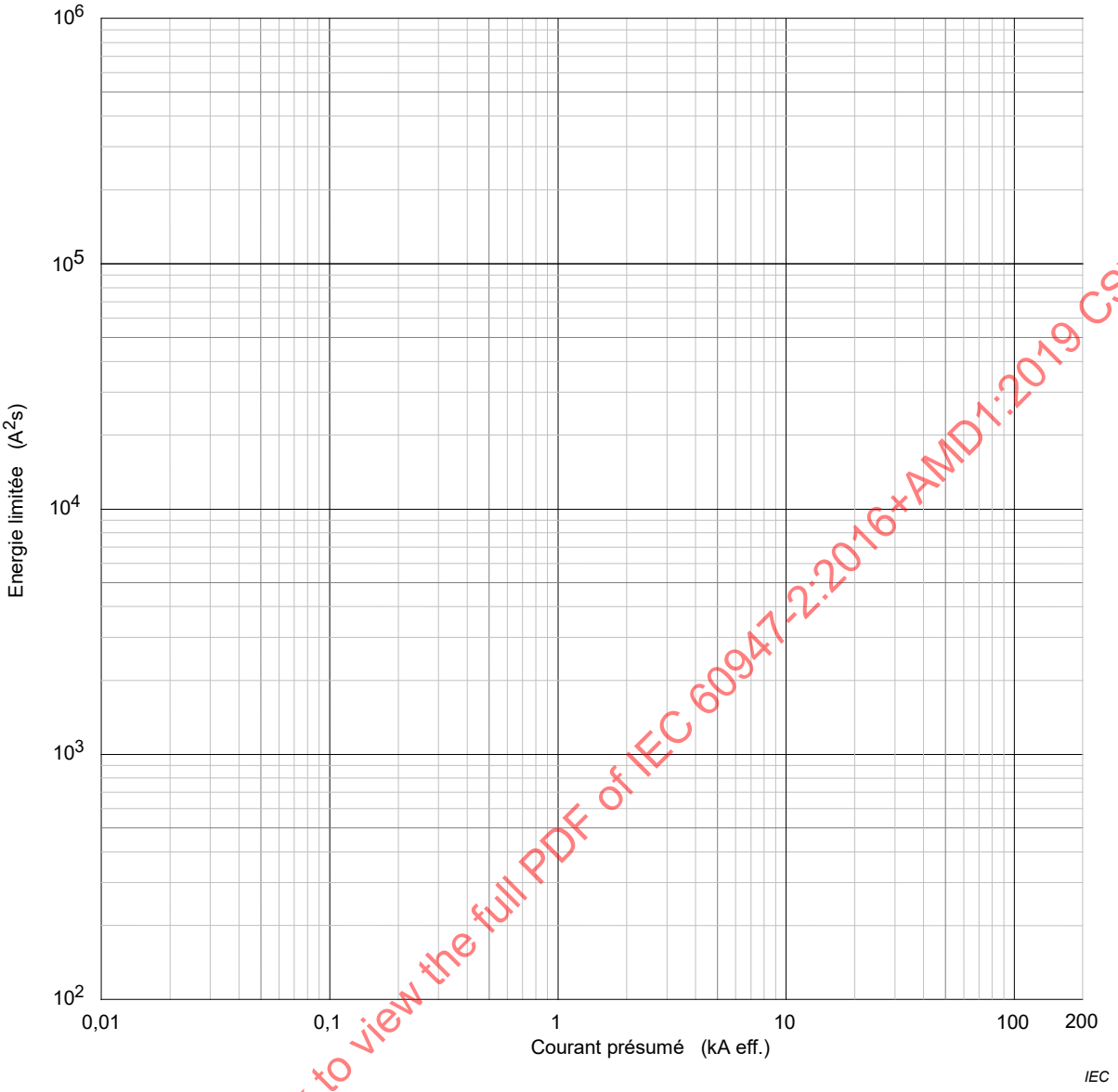
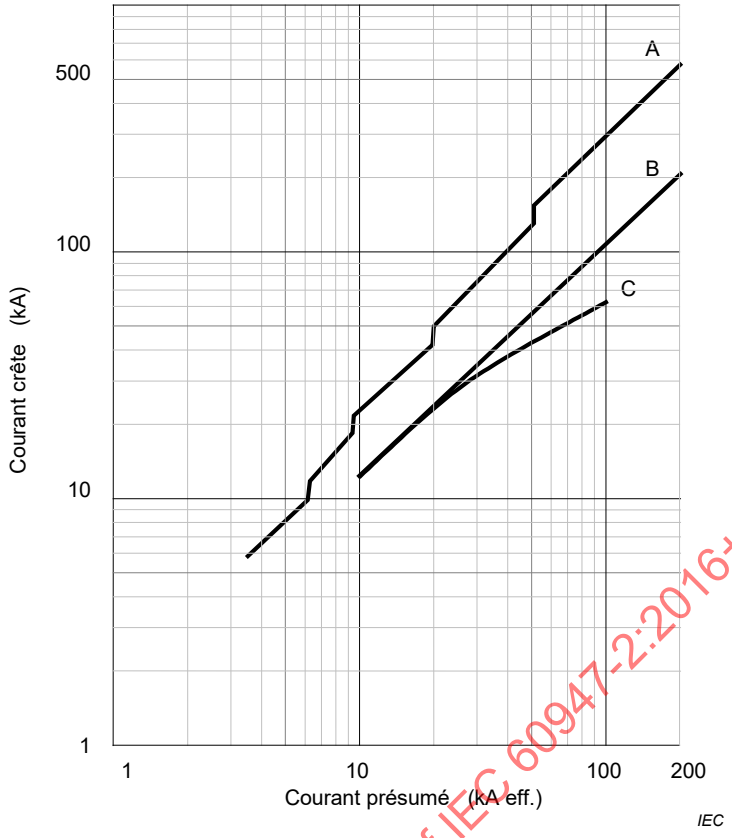


Figure K.5 – Modèle de caractéristiques de l'énergie limitée par rapport au courant présumé de 0,01 kA à 200 kA

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A Courant crête asymétrique présumé dans les conditions d'essai de la présente norme

B Courant crête symétrique présumé

C Caractéristique usuelle de courant coupé limité

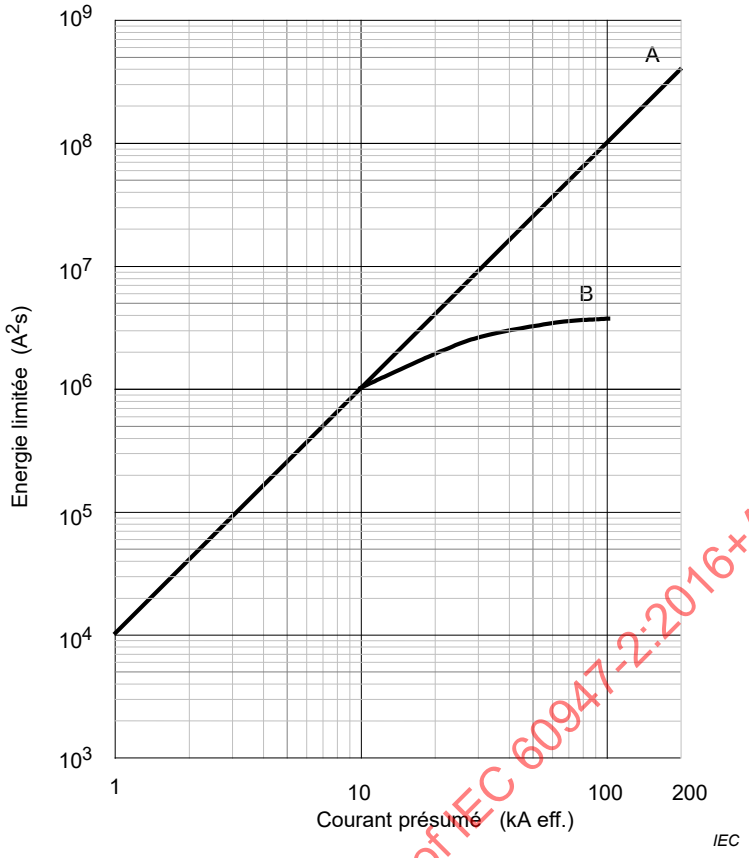
L'utilisation des modèles par les fabricants pour suivre les caractéristiques des disjoncteurs fournira une présentation commune, permettant une interprétation plus aisée par l'utilisateur.

Dans le cas de courant coupé limité, l'effet de la limitation de courant est illustré par comparaison avec le courant qui aurait circulé au travers (courant présumé) si le disjoncteur n'avait pas été présent. La comparaison est réalisée avec le courant crête asymétrique (d'appel) ou le courant crête symétrique (voir 2.3).

La courbe usuelle n'implique pas d'exigence de la norme pour une forme de courbe ou une valeur particulière, laquelle variera selon la conception du produit.

Figure K.6 – Exemple d'utilisation du modèle de la Figure K.2

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A Energie limitée d'une demi-période du courant présumé à 50 Hz

B Caractéristique d'énergie limitée usuelle d'un MCCB 250 A à 400 V 50 Hz

L'utilisation des modèles par les fabricants pour suivre les caractéristiques des disjoncteurs fournira une présentation commune, permettant une interprétation plus aisée par l'utilisateur.

Dans le cas d'énergie limitée, l'effet de la limitation de courant est illustré par comparaison avec l'énergie qui aurait circulé au cours d'une demi-période du courant symétrique présumé si le disjoncteur n'avait pas été présent (voir 2.3).

La courbe usuelle d'un MCCB 250 A n'implique pas d'exigence de la norme pour une forme de courbe ou une valeur particulière, laquelle variera selon la conception du produit.

Figure K.7 – Exemple d'utilisation du modèle de la Figure K.4

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Annexe L
(normative)

Disjoncteurs ne satisfaisant pas aux exigences concernant la protection contre les surintensités

L.1 Généralités

La présente annexe traite des disjoncteurs qui ne satisfont pas aux exigences concernant la protection contre les surintensités spécifiées dans la partie principale de la présente norme, ci-après désignés CBI. Ces appareils sont capables d'être déclenchés par un appareil auxiliaire, par exemple un déclencheur shunt ou à minimum de tension. Ils n'assurent pas la protection des circuits mais peuvent déclencher dans des conditions de court-circuit à des fins d'autoprotection. Ils possèdent une caractéristique assignée de court-circuit conditionnel et peuvent être utilisés pour le sectionnement. Ils peuvent incorporer des accessoires tels que des contacts auxiliaires et d'alarme à des fins de commande, et/ou des opérateurs à distance.

Un CBI fait partie de la plage des disjoncteurs, étant dérivé d'un disjoncteur équivalent (L.2.1) non équipé de déclencheurs à maximum de courant (classe Y) ou uniquement sans déclencheurs de surcharge (classe X), voir L.3.

L.2 Termes et définitions

En complément des termes et définitions donnés à l'Article 2, les termes et définitions suivants sont applicables.

L.2.1
disjoncteur équivalent
disjoncteur dont le CBI est dérivé, qui a été soumis à essai conformément à la présente norme et est de même taille que le CBI

L.2.2
appareil de protection contre les surintensités
DPS
appareil prévu pour la protection d'un CBI contre les surintensités par interruption, et comportant une protection contre les surcharges non moins efficace que celle du disjoncteur équivalent et un I_{cu} (pour un disjoncteur) ou un pouvoir de coupure (pour un fusible) égal ou supérieur à celui du disjoncteur équivalent

Note 1 à l'article: Le DPS peut être le disjoncteur équivalent.

L.3 Classification

Les CBI sont classés comme suit:

- classe X: avec déclencheurs instantanés intégrés et non réglables de court-circuit pour une autoprotection;
- classe Y: sans déclencheurs intégrés de court-circuit.

L.4 Valeurs assignées

L.4.1 Courant assigné (I_n)

Le courant assigné d'un CBI ne doit pas excéder le courant assigné du disjoncteur équivalent.

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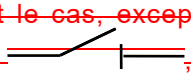
NOTE Le courant assigné d'un CBI peut être en rapport avec le courant assigné correspondant à la catégorie d'emploi AC-22 (voir l'Annexe A de l'IEC 60947-1:2007/AMD2:2014).

L.4.2 Courant conditionnel de court-circuit assigné (I_{cc})

Le paragraphe 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

Un CBI peut avoir une valeur de I_{cc} égale ou supérieure à celle du I_{cu} du disjoncteur équivalent.

L.5 Informations sur le matériel

~~Un CBI doit être marqué conformément à 5.2, suivant le cas, excepté que le symbole pour l'aptitude au sectionnement, le cas échéant, doit être  , remplaçant le symbole indiqué au deuxième tiret de 5.2 a).~~

~~De plus, il doit être marqué de la façon suivante:~~

~~– pour 5.2, point a): avec le symbole selon la classification:~~

~~CBI-X~~ ~~I_i = …~~ ~~ou~~ ~~CBI-Y~~ ~~suivant le cas.~~

~~où I_i est le courant assigné instantané de réglage de court-circuit (voir 2.20).~~

~~– pour 5.2, point c): avec les points suivants:~~

- ~~courant conditionnel de court-circuit assigné (I_{cc});~~
- ~~le DPS, s'il est spécifié.~~

~~Il convient que les instructions du fabricant attirent l'attention sur le fait que les CBI ne procurent pas de protection contre les surintensités.~~

Le paragraphe 5.2 est applicable, selon le cas, avec les modifications et les ajouts indiqués dans le Tableau L.1.

Tableau L.1 – Informations sur le matériel

Elément	Information	Emplacement du marquage
L1.1	Aptitude au sectionnement, s'il y a lieu, avec le symbole  (IEC 60617-S00288:2001-07) (ce symbole se substitue à celui utilisé dans le Tableau 13, point 1.2)	Visible
L1.2	Classification, avec le marquage CBI-X I_i = … ou CBI-Y, suivant le cas, où I_i est le courant assigné instantané de réglage de court-circuit (voir 2.20)	Visible
L3.1	Courant conditionnel de court-circuit assigné (I_{cc}) et, si spécifié, appareil de protection contre les surintensités (DPS)	Documentation
L3.2	Déclaration selon laquelle les CBI n'assurent pas de protection contre les surintensités	Documentation

Légende

Visible: visible depuis le devant lorsque le disjoncteur est installé en configuration de service et que l'organe de commande est accessible

Documentation: spécifié dans la documentation du fabricant

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L.6 Exigences relatives à la construction et au fonctionnement

Un CBI, étant dérivé du disjoncteur équivalent (voir L.2.1), satisfait à toutes les exigences relatives à la construction et au fonctionnement applicables de l'Article 7, à l'exception de 7.2.1.2.4.

NOTE Un CBI peut en outre être conforme à l'IEC 60947-3 et être marqué en conséquence.

L.7 Essais

L.7.1 Généralités

L.7.1.1 CBI de classe X

Le DPS est spécifié.

Cas 1:

$I_{cc} = I_{cu}$ du disjoncteur équivalent.

Aucun essai supplémentaire n'est exigé.

NOTE Le DPS spécifié peut être

- le disjoncteur équivalent (voir L.2.1),
- un autre disjoncteur (voir L.2.2),
- un fusible de courant conventionnel de fusion ≤ au courant de déclenchement conventionnel du disjoncteur équivalent et de pouvoir de coupure ≥ I_{cc} du CBI.

Cas 2:

$I_{cc} > I_{cu}$ du disjoncteur équivalent.

Les essais doivent être effectués conformément à L.7.2.1 et L.7.2.2, avec le DPS spécifié.

Cela s'applique lorsque

- le DPS spécifié est un disjoncteur de même taille que le disjoncteur équivalent et avec un $I_{cu} \geq I_{cc}$ du CBI,

ou

- le DPS spécifié est un fusible de courant conventionnel de fusion ≤ au courant de déclenchement conventionnel du disjoncteur équivalent et de pouvoir de coupure ≥ I_{cc} du CBI.

L.7.1.2 CBI de classe Y

Aucun essai n'est exigé pourvu qu'une des deux conditions suivantes soit remplie:

- condition 1: $I_{cc} \leq I_{cw}$ du disjoncteur équivalent,
- condition 2: I_{cc} ≤ au réglage maximal du courant assigné instantané de réglage de court-circuit du disjoncteur équivalent.

Si aucune des conditions ci-dessus n'est remplie, les essais sont exigés comme suit:

Cas 1:

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Le DPS est spécifié par le fabricant.

Les essais doivent être effectués conformément à L.7.2.1 et L.7.2.2.

Cas 2:

Le DPS n'est pas spécifié.

Les essais doivent être effectués conformément à L.7.2.1 et L.7.2.3.

L.7.2 Essais de court-circuit conventionnel assigné

L.7.2.1 Généralités

L.7.2.1.1 Applicabilité

Ces essais doivent être effectués lorsqu'ils sont exigés par L.7.1.1 cas 2, ou par L.7.1.2 cas 1 ou cas 2, suivant le cas.

Pour les CBI comportant des variantes avec différents nombres de pôles, les essais doivent être effectués sur chaque variante.

L.7.2.1.2 Conditions d'essai

Le paragraphe 8.3.2.6 est applicable.

Le circuit d'essai doit être conforme à la Figure A.4, le DPCC étant remplacé par le DPS. Si le DPS est un disjoncteur avec des réglages de surintensité ajustables, ceux-ci doivent être en position maximale.

Si le DPS consiste en un jeu de fusibles, chaque essai doit être effectué avec un jeu de fusibles neufs.

S'il y a lieu, les câbles de connexion doivent être inclus comme spécifié en 8.3.2.6.4, sauf si le DPS est un disjoncteur, auquel cas la longueur totale de câble (0,75 m) associée avec le disjoncteur peut être du côté source (voir Figure A.4).

L.7.2.1.3 Comportement pendant les essais

Le paragraphe 8.3.2.6.5 est applicable.

L.7.2.2 DPS spécifié

L.7.2.2.1 Séquence d'essai

La séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification de I_{cc}	L.7.2.2.2
Vérification de la tenue diélectrique	L.7.2.2.3

L.7.2.2.2 Vérification de I_{cc}

L'essai doit être effectué avec un courant présumé égal au I_{cc} du CBI.

Chaque essai doit consister en une séquence de manœuvres O – *t* – CO effectuée conformément à 8.3.5.3, la manœuvre CO étant effectuée par la fermeture du CBI.

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Après chaque manœuvre, le CBI doit être fermé et ouvert trois fois manuellement.

L.7.2.2.3 Vérification de la tenue diélectrique

Après l'essai de L.7.2.2.2, la tenue diélectrique doit être vérifiée conformément à 8.3.5.4.

L.7.2.3 DPS non spécifié

L.7.2.3.1 Séquence d'essai

La séquence d'essai comprend les essais suivants:

Essai	Paragraphe
Vérification de I_{cc}	L.7.2.3.2
Vérification de la tenue diélectrique	L.7.2.3.3

L.7.2.3.2 Vérification de I_{cc}

L'essai doit être effectué avec un courant présumé égal au I_{cc} du CBI.

Chaque essai doit consister en une séquence de manœuvres O – *t* – CO effectuée conformément à 8.3.5.3, la manœuvre CO étant effectuée par la fermeture du CBI.

Pendant l'essai, le courant doit être maintenu pendant trois cycles et ensuite interrompu à la source d'alimentation.

Après chaque manœuvre, le CBI doit être fermé et ouvert trois fois manuellement.

L.7.2.3.3 Vérification de la tenue diélectrique

Après l'essai de L.7.2.3.2, la tenue diélectrique doit être vérifiée conformément à 8.3.5.4.

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Annexe M
(normative)

Appareils modulaires à courant différentiel résiduel (MRCD) (non intégrés à un appareil de coupure de courant)

M.1 Généralités

M.1.1 Préambule

Les dispositions de l'Annexe B sont applicables à la présente Annexe M en adaptant, en amendant ou en complétant l'Annexe B, selon les besoins pour couvrir son application aux matériels dont le dispositif de détection de courant et/ou l'appareil de traitement sont montés séparément de l'appareil de coupure de courant.

Dans la présente annexe, le terme «DPR» utilisé dans l'Annexe B (voir B.2.3.1) est remplacé par le terme «MRCD» (voir M.2.1.1).

Lorsque cela est approprié, référence est faite au paragraphe correspondant de l'Annexe B. Dans les autres cas, référence est faite au paragraphe approprié de la partie principale de la présente norme ou, s'il y a lieu, de l'IEC 60947-1.

La présente annexe contient aussi des définitions et des caractéristiques complémentaires non contenues dans l'Annexe B, par exemple les MRCD de «type B» (dans le contexte d'un courant différentiel résiduel continu) avec les exigences et les essais correspondants.

Comme le matériel couvert par la présente annexe ne concerne pas un appareil de coupure de courant, certaines locutions conventionnelles utilisées dans l'Annexe B ont été adaptées en conséquence dans la présente annexe, par exemple «position fermée» est remplacé par «condition prête», signifiant «prêt à fonctionner».

M.1.2 Champ d'application

La présente annexe est applicable aux appareils à courant différentiel résiduel qui n'intègrent pas un appareil de coupure de courant; ceux-ci sont désignés ci-après «appareils modulaires à courant différentiel résiduel (MRCD – Modular Residual Current Device)». Ils sont principalement prévus pour être utilisés en association avec des disjoncteurs conformes à la présente norme.

NOTE Ils peuvent aussi être déclarés aptes à être utilisés en association avec d'autres appareils de coupure de courant.

Ils peuvent être ou non fonctionnellement dépendants d'une source de tension.

L'objet de la présente annexe est d'établir les exigences spécifiques auxquelles doivent satisfaire les MRCD.

M.2 Termes et définitions

Les termes et définitions de l'Annexe B sont applicables.

Les termes et définitions complémentaires suivants sont applicables à la présente annexe.

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~~**M.2.1 Termes et définitions relatifs à l'alimentation d'un MRCD**~~

~~**M.2.1.1**~~
~~**source de tension**~~
~~source prévue pour fournir l'alimentation; ce peut être:~~

~~– la tension d'alimentation~~

~~– une tension autre que la tension d'alimentation~~

~~**M.2.2 Termes et définitions relatifs au fonctionnement et aux fonctions d'un MRCD**~~

~~**M.2.2.1**~~
~~**appareil modulaire à courant différentiel résiduel**~~
~~**MRCD**~~
~~appareil ou association d'appareils comprenant un dispositif de mesure du courant et un appareil de traitement conçu pour détecter et évaluer le courant différentiel résiduel et pour commander l'ouverture des contacts d'un appareil de coupure de courant~~

~~**A.1.1.2 Temps de fonctionnement**~~

~~**M.2.2.2.1**~~
~~**temps de fonctionnement d'un MRCD**~~
~~temps qui s'écoule entre l'instant où le courant différentiel résiduel de fonctionnement est appliqué subitement et l'instant où la sortie du MRCD change d'état~~

~~**M.2.2.2.2**~~
~~**temps total de fonctionnement d'un MRCD et de l'appareil de coupure de courant associé (temps combiné)**~~
~~temps qui s'écoule entre l'instant où le courant différentiel résiduel de fonctionnement est appliqué subitement et l'instant d'extinction de l'arc de l'appareil de coupure de courant associé~~

~~**M.2.2.2.3**~~
~~**temps limite de non-fonctionnement**~~
~~temps maximal pendant lequel une valeur du courant différentiel résiduel supérieure à la valeur du courant assigné différentiel résiduel de non-fonctionnement peut être appliquée au MRCD, sans provoquer son fonctionnement~~

~~**M.2.3**~~
~~**courant différentiel résiduel de court-circuit conditionnel**~~
~~courant différentiel résiduel présumé auquel un DPR protégépar un appareil de protection contre les courts-circuits spécifié peut résister de manière satisfaisante pendant le temps total de fonctionnement de cet appareil dans des conditions spécifiées~~

~~**M.2.4**~~
~~**courant différentiel résiduel de courte durée admissible**~~
~~courant différentiel résiduel qu'un DPR en position fermée peut véhiculer pendant une courte durée spécifiée dans des conditions spécifiées~~

~~**M.3 Classification**~~

~~**M.3.1 Classification selon la configuration des conducteurs primaires**~~

~~**M.3.1.1 Type à bornes: MRCD avec des bornes d'entrée et de sortie, les conducteurs primaires étant intégrés**~~

~~**M.3.1.2 Type à conducteur traversant**~~

~~**M.3.1.2.1** MRCD avec le dispositif de détection et l'appareil de traitement combinés.~~

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M.3.1.2.2 MRCD avec le dispositif de détection et l'appareil de traitement séparés.

M.3.2 Classification selon le mode de fonctionnement

M.3.2.1 MRCD sans source de tension (voir M.2.1.1)

M.3.2.2 MRCD avec source de tension

M.3.2.2.1 Fonctionnant automatiquement en cas de défaillance de la source de tension.

M.3.2.2.2 Ne fonctionnant pas automatiquement en cas de défaillance de la source de tension mais capable de fonctionner comme prévu en cas de courant différentiel résiduel de défaut.

M.3.3 Classification selon la possibilité de réglage du courant différentiel résiduel de fonctionnement

Le paragraphe B.3.2 est applicable.

M.3.4 Classification selon la temporisation de la fonction de courant différentiel résiduel

Le paragraphe B.3.3 est applicable.

M.3.5 Classification selon le comportement en présence d'une composante continue

M.3.5.1 MRCD de type AC (voir M.4.2.2.1)

M.3.5.2 MRCD de type A (voir M.4.2.2.2)

M.3.5.3 MRCD de type B (voir M.4.2.2.3)

M.4 Caractéristiques des MRCD

M.4.1 Caractéristiques générales

M.4.1.1 Caractéristiques du circuit contrôlé

M.4.1.1.1 Plage de fréquences assignées

Plage des valeurs de fréquence du circuit contrôlé pour lesquelles le MRCD est conçu et pour lesquelles il fonctionne correctement dans des conditions spécifiées.

M.4.1.1.2 Tension assignée (U_n)

Valeur de la tension assignée par le fabricant au MRCD.

M.4.1.1.3 Courant assigné (I_n)

M.4.1.1.3.1 Type à bornes

Le paragraphe 4.3.3.3 est applicable.

M.4.1.1.3.2 Type à conducteur traversant

Valeur de courant, assignée par le fabricant au MRCD et marquée selon le Tableau M.1, point g), que le MRCD peut contrôler en service ininterrompu dans des conditions spécifiées (voir M.8.6).

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~~**M.4.1.1.4 Tension d'isolement assignée (U_i)**~~

~~Tension, assignée par le fabricant, à laquelle se réfèrent les essais diélectriques et les lignes de fuite du MRCD par rapport au circuit contrôlé.~~

~~**M.4.1.1.5 Tension assignée de tenue aux chocs (U_{imp})**~~

~~Valeur crête de la tension de choc que le MRCD peut supporter sans défaillance et à laquelle se réfèrent les valeurs des distances d'isolement par rapport au circuit contrôlé.~~

~~**M.4.1.2 Caractéristiques de la source de tension des MRCD**~~

~~**M.4.1.2.1 Valeurs assignées de la source de tension des MRCD (U_s)**~~

~~Valeurs de la source de tension auxquelles se réfèrent les fonctions d'un MRCD.~~

~~**M.4.1.2.2 Valeurs assignées des fréquences de la source de tension des MRCD**~~

~~Valeurs des fréquences de la source de tension auxquelles se réfèrent les fonctions d'un MRCD.~~

~~**M.4.1.2.3 Tension d'isolement assignée (U_i)**~~

~~Le paragraphe 4.3.1.2 de l'IEC 60947-1:2007 est applicable.~~

~~**M.4.1.2.4 Tension assignée de tenue aux chocs (U_{imp})**~~

~~Le paragraphe 4.3.1.3 de l'IEC 60947-1:2007 est applicable.~~

~~NOTE Dans le cas d'une alimentation spécifiée, l'exigence est applicable aux connexions d'entrée.~~

~~**M.4.1.3 Caractéristiques des contacts auxiliaires**~~

~~Le paragraphe 4.6 de l'IEC 60947-1:2007 est applicable.~~

~~**M.4.2 Caractéristiques des MRCD concernant leur fonction de courant différentiel résiduel**~~

~~**M.4.2.1 Généralités**~~

~~Le paragraphe B.4.2.4 est applicable en remplaçant «temps de non-réponse» par «temps de non-fonctionnement» et avec les compléments suivants.~~

~~Les valeurs maximales du temps de fonctionnement du MRCD doivent être déclarées par le fabricant pour des valeurs de courant différentiel résiduel égales à $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (ou 0,25 A pour $I_{\Delta n} \leq$ 30 mA), 10 $I_{\Delta n}$ (ou 0,5 A pour $I_{\Delta n} \leq$ 30 mA).~~

~~Le temps combiné maximal doit être conforme au Tableau B.1 pour un MRCD de type non temporisé et au Tableau B.2 pour un MRCD de type temporisé ayant une durée limite de non-fonctionnement de 0,06 s.~~

~~Les MRCD avec $I_{\Delta n} \leq$ 30 mA doivent être du type non temporisé. Ils doivent être utilisés seulement avec un appareil de coupure de courant spécifié.~~

~~**M.4.2.2 Caractéristiques de fonctionnement dans le cas d'un courant différentiel résiduel avec une composante continue**~~

~~**M.4.2.2.1 MRCD de type AC**~~

~~Le paragraphe B.4.4.1 est applicable.~~

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~~**M.4.2.2.2 MRCD de type A**~~

~~Le paragraphe B.4.4.2 est applicable.~~

~~**M.4.2.2.3 MRCD de type B**~~

~~MRCD dont le fonctionnement est assuré:~~

- ~~en cas de courants différentiels résiduels alternatifs sinusoïdaux,~~
- ~~en cas de courants différentiels résiduels continus pulsés,~~
- ~~en cas de courants différentiels résiduels continus pulsés superposés à un courant continu lissé de 6 mA,~~
- ~~en cas de courants différentiels résiduels qui peuvent être créés par des circuits redresseurs, c'est-à-dire:~~
  - ~~redresseur simple alternance avec une charge capacitive créant un courant continu lissé,~~
  - ~~redresseur double alternance,~~
  - ~~redresseur triphasé en étoile ou en pont,~~

  ~~avec ou sans commande de l'angle de phase, indépendants de la polarité, appliqués brusquement ou à montée lente.~~

~~**M.4.3 Comportement en condition de court-circuit**~~

~~**M.4.3.1 Courant conditionnel de court-circuit assigné (I_{cc})**~~

~~Le paragraphe 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.~~

~~**M.4.3.2 Courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$)**~~

~~Le paragraphe 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.~~

~~**M.4.3.3 Courant assigné de courte durée admissible (I_{cw})**~~

~~Le paragraphe 4.3.6.1 de l'IEC 60947-1:2007/AMD2:2014 s'applique.~~

~~**M.4.3.4 Valeur de crête de courant admissible**~~

~~Le paragraphe 2.5.28 de l'IEC 60947-1:2007 est applicable au circuit primaire d'un MRCD.~~

~~**M.4.3.5 Courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$)**~~

~~Le courant assigné différentiel résiduel de courte durée admissible d'un matériel est la valeur du courant différentiel résiduel de courte durée admissible, assignée au matériel par le fabricant, que le matériel peut supporter sans dommage, dans les conditions d'essai spécifiées dans la présente norme.~~

~~**M.4.4 Valeurs préférentielles et valeurs limites**~~

~~**M.4.4.1 Valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)**~~

~~Le paragraphe B.4.2.1 est applicable.~~

~~**M.4.4.2 Valeur minimale du courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)**~~

~~Le paragraphe B.4.2.3 est applicable.~~

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M.4.4.3 Valeur limite de surintensité de non-fonctionnement dans le cas d'une charge monophasée dans un circuit polyphasé

Le paragraphe B.4.2.4 est applicable.

M.4.4.4 Valeurs préférentielles de la tension assignée de la source de tension des MRCD

Le paragraphe 4.5.1 est applicable.

M.5 Informations sur le matériel

Le MRCD, l'appareil de traitement ou le dispositif de détection, suivant le cas, doit être fourni avec les informations indiquées au Tableau M.1. Les marquages doivent être indélébiles. Le marquage doit être apposé sur le MRCD lui-même ou sur une ou plusieurs plaques signalétiques. Le fabricant doit indiquer:

- pour un dispositif de détection séparé, les informations concernant le dispositif de détection, y compris les conditions de raccordement à l'appareil de traitement (type de câble, longueur, etc.),
- pour un MRCD du type conducteur traversant, les dimensions de l'ouverture de passage du conducteur et la position du conducteur traversant par rapport au dispositif de détection,
- pour un MRCD du type à bornes, la section maximale des conducteurs à raccorder,
- pour tous les types, les distances à respecter par rapport aux conducteurs environnants,
- pour tous les types, les conditions à respecter pour le raccordement entre l'appareil de traitement et l'appareil de coupure de courant,
- pour tous les types, les DPCC à associer avec le MRCD pour obtenir le courant assigné (différentiel résiduel ou non) de court-circuit conditionnel,
- pour un type non temporisé, les appareils de coupure de courant à associer avec le MRCD pour satisfaire aux temps combinés maximaux du Tableau B.1,
- pour un type temporisé ayant une durée limite de non-fonctionnement de 0,06 s, le ou les appareils de coupure de courant à associer avec le MRCD pour satisfaire aux temps combinés du Tableau B.2.

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Tableau M.1 – Informations sur le matériel

Information	Symbole	Position (voir Note 1)	Appareil unique	Appareils séparés	
				Dispositif de détection	Appareil de traitement
a) nom du fabricant ou marque de fabrique		Marqué	a	a	a
b) désignation du type ou numéro de série		Marqué	a	a	a
c) IEC 60947-2		Marqué	a		a
d) tension assignée de la source de tension	U_s	Marqué	a		a
e) tension assignée du circuit contrôlé	U_n	Marqué	a	a	
f) fréquence assignée de la source de tension		Documentation			
g) fréquence assignée du circuit contrôlé		Documentation			
h) courant maximal assigné du circuit contrôlé	I_n	Visible	a	a	a (voir Note 2)
i) courant assigné différentiel résiduel de fonctionnement (valeur(s) ou plage de valeurs, suivant le cas)	$I_{\Delta n}$	Visible	a		a)
j) courant assigné différentiel résiduel de non-fonctionnement s'il est différent de 0,5 $I_{\Delta n}$	$I_{\Delta no}$	Documentation			
k) réglage minimal du courant différentiel résiduel à 6 I_n pour les MRCD avec un dispositif de détection séparé		Documentation			
l) courant assigné de court-circuit conditionnel et/ou courant assigné de courte durée admissible, et courant assigné différentiel résiduel de court-circuit conditionnel	I_{cc} I_{cw} $I_{\Delta c}$	Documentation			
m) U_{imp} de la source de tension	U_{imp}	Documentation			
n) U_{imp} du circuit contrôlé	U_{imp}	Marqué	a	a	
o) code IP, le cas échéant (voir l'Annexe C de l'IEC 60947-1:2007)	IP--	Documentation			
p) position d'utilisation et précautions de montage		Documentation			
q) caractéristiques de sortie et/ou du ou des appareils de coupure de courant spécifiés		Documentation			
r) caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composantes continues:	Type AC  Type A  Type B 	Visible	a		a
s) temps limite de non-fonctionnement (valeur ou plage de valeurs) à 2 $I_{\Delta n}$ pour le type temporisé, suivant le cas	Δt ou S	Visible	a		a
t) appareil d'essai	T	Visible	a		a
u) schéma de câblage		Documentation			
a Information/marquage applicable.					
NOTE 1 Visible = marqué sur l'appareil et visible après l'installation. Documentation = donné dans le catalogue ou dans les notices du fabricant. Marqué = marqué sur l'appareil mais pas nécessairement visible après l'installation. NOTE 2 Seulement applicable si le courant différentiel résiduel est marqué en pourcentage de I_n.					

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M.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

M.7 Exigences relatives à la conception et au fonctionnement

M.7.1 Exigences relatives à la conception

Il ne doit pas être possible de modifier la caractéristique de fonctionnement d'un MRCD par des moyens autres que ceux spécifiquement destinés au réglage du courant assigné différentiel résiduel de fonctionnement ou de la temporisation définie.

NOTE Les MRCD peuvent être équipés de moyens indiquant l'état des sorties.

M.7.2 Exigences relatives au fonctionnement

M.7.2.1 Fonctionnement en cas de courant différentiel résiduel

Le paragraphe B.7.2.1 est applicable.

La conformité doit être vérifiée par les essais de M.8.3.

M.7.2.2 Fonctionnement dans des conditions de court-circuit

Les MRCD doivent avoir un courant assigné de court-circuit conditionnel (I_{cc}) ou un courant assigné de courte durée admissible (I_{cw}), mais peuvent avoir les deux. Ils doivent aussi avoir un courant assigné différentiel résiduel de court-circuit conditionnel ($I_{\Delta c}$) ou un courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$), mais peuvent avoir les deux.

Les MRCD doivent satisfaire aux essais pertinents de M.8.14.

M.7.2.3 Endurance mécanique et endurance électrique

Les MRCD doivent satisfaire aux essais de M.8.11.

M.7.2.4 Effets des conditions d'environnement

Les MRCD doivent satisfaire à l'essai de M.8.15.

M.7.2.5 Propriétés diélectriques

Les MRCD doivent pouvoir supporter la tension de tenue aux chocs déclarée par le fabricant conformément au 7.2.3 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Les MRCD doivent satisfaire aux essais de M.8.4.

Les distances d'isolement entre les parties sous tension du circuit contrôlé et:

- les parties sous tension du MRCD,
- les parties destinées à être mises à la terre,
- les distances d'isolement entre les conducteurs principaux, pour les MRCD du type à bornes,

doivent supporter la tension d'essai donnée au Tableau 12 de l'IEC 60947-1:2007 correspondant à la tension assignée de tenue aux chocs.

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M.7.2.6 Appareil d'essai

Les MRCD doivent être munis d'un appareil d'essai pour simuler le passage d'un courant différentiel résiduel dans le dispositif de détection, afin de permettre la vérification périodique de la capacité des MRCD à fonctionner.

L'appareil d'essai doit satisfaire aux essais de M.8.5.

Aucune tension ne doit apparaître sur le conducteur de protection, lorsqu'il existe, lors du fonctionnement du dispositif de contrôle.

L'organe de manœuvre de l'appareil d'essai doit être désigné par la lettre T, et sa couleur ne doit pas être rouge ou verte; l'emploi d'une couleur claire est recommandé.

NOTE L'appareil d'essai est seulement destiné à vérifier la fonction de déclenchement, et non la valeur à laquelle cette fonction s'accomplit, par rapport au courant assigné différentiel résiduel de fonctionnement et à la durée de la coupure.

M.7.2.7 Valeur de surintensité de non-fonctionnement dans le cas d'une charge monophasée

Les MRCD doivent satisfaire à l'essai de M.8.6.

M.7.2.8 Résistance des MRCD aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc

Les MRCD doivent satisfaire à l'essai de M.8.7.

M.7.2.9 Comportement des MRCD de types A et B en cas de courant de défaut à la terre comprenant une composante continue

Les MRCD de types A et B doivent satisfaire aux essais de M.8.8, suivant le cas.

M.7.2.10 Exigences pour les MRCD avec source de tension

Les MRCD fonctionnellement dépendants d'une source de tension doivent fonctionner correctement à toute valeur de tension comprise entre 0,85 et 1,1 fois la valeur assignée U_s (voir M.2.1.1 et M.4.1.2.1).

Selon leur classification, les MRCD fonctionnellement dépendants d'une source de tension doivent satisfaire aux exigences données au Tableau M.2.

Tableau M.2 – Exigences pour les MRCD avec source de tension

Classification de l'appareil selon M.3.2.2	Comportement en cas de défaillance de la source de tension
MRCD fonctionnant automatiquement sans retard en cas de défaillance de la source de tension (M.3.2.2.1)	Fonctionnement sans retard selon M.8.12
MRCD fonctionnant automatiquement avec retard en cas de défaillance de la source de tension (M.3.2.2.1)	Fonctionnement avec retard selon M.8.12
MRCD ne fonctionnant pas automatiquement en cas de défaillance de la source de tension mais capable de fonctionner comme prévu en cas d'apparition d'un courant différentiel résiduel de défaut (M.3.2.2.2)	Fonctionnement selon M.8.13

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~~**M.7.2.11 Echauffement des MRCD du type à bornes**~~

~~**M.7.2.11.1 Généralités**~~

~~Les échauffements des pièces des MRCD de type à bornes ne doivent pas dépasser les valeurs spécifiées au 7.2.2 de l'IEC 60947-1:2007/AMD2:2014.~~

~~**M.7.2.11.2 Température de l'air ambiant**~~

~~Les limites d'échauffement indiquées au Tableau 2 de l'IEC 60947-1:2007 et au Tableau 3 de l'IEC 60947-1:2007/AMD2:2014 ne sont valables que si la température de l'air ambiant reste comprise dans les limites indiquées en M.6.~~

~~**M.7.2.11.3 Circuit principal des MRCD du type à bornes**~~

~~Le circuit principal d'un MRCD, auquel est raccordé le circuit contrôlé, doit supporter le courant assigné tel que défini en M.4.1.2.3, sans que les échauffements ne dépassent les limites indiquées au Tableau 2 de l'IEC 60947-1:2007 et au Tableau 3 de l'IEC 60947-1:2007/AMD2:2014.~~

~~**M.7.2.12 Compatibilité électromagnétique**~~

~~Les exigences de l'Annexe J sont applicables au dispositif de détection et à l'appareil de traitement du MRCD, raccordés conformément aux instructions du fabricant.~~

~~Les essais doivent être effectués conformément à M.8.16.~~

~~L'immunité aux variations de tension est couverte par les exigences de M.7.2.10.~~

~~**M.7.2.13 Comportement des MRCD en cas de défaillance de la connexion du dispositif de détection**~~

~~Pour les MRCD à dispositif de détection séparé, en cas de déconnexion de ce dispositif de détection:~~

~~– le MRCD doit fonctionner, ou~~

~~– le MRCD doit fournir un signal pour indiquer cette déconnexion, ou~~

~~– il doit être possible de vérifier la déconnexion en manœuvrant l'appareil d'essai.~~

~~La conformité est vérifiée par les essais de M.8.9.~~

~~**M.7.2.14 Comportement des MRCD selon la fréquence assignée**~~

~~Le MRCD doit fonctionner correctement dans la plage des fréquences assignées.~~

~~La conformité est vérifiée par les essais de M.8.3.3 et M.8.5.~~

~~**M.8 Essais**~~

~~**M.8.1 Généralités**~~

~~**M.8.1.1 Essais de type**~~

~~Les essais de type sont regroupés dans plusieurs séquences, comme indiqué au Tableau M.3.~~

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Dans le cas de MRCD ayant plusieurs valeurs de réglage du courant différentiel résiduel de fonctionnement, les essais doivent être effectués au réglage minimal, sauf spécification contraire.

Dans le cas de MRCD à temporisation réglable (voir B.3.3.2.2), les essais doivent être effectués au réglage maximal, sauf spécification contraire.

Le déclencheur de l'appareil de coupure associé, le cas échéant, doit être alimenté sous sa tension assignée la plus basse.

Tableau M.3 – Séquences d'essai

Séquences		
M I	Caractéristiques de fonctionnement	M.8.3
	Propriétés diélectriques	M.8.4
	Fonctionnement de l'appareil d'essai aux limites de la tension assignée	M.8.5
	Valeur limite du courant de non-fonctionnement dans des conditions de surintensité	M.8.6
	Résistance aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc	M.8.7
	Comportement en cas de courant de défaut à la terre comprenant une composante continue	M.8.8
	Comportement en cas de défaillance de la connexion au dispositif de détection	M.8.9
	Echauffement	M.8.10
	Endurance mécanique et endurance électrique	M.8.11
	Comportement en cas de défaillance de la source de tension pour les MRCD classés selon M.3.2.2.1	M.8.12
	Comportement des MRCD classés selon M.3.2.2.2 en cas de défaillance de la source de tension	M.8.13
M II	Comportement des MRCD en conditions de court-circuit	M.8.14
M III	Effets des conditions d'environnement	M.8.15
M IV	Compatibilité électromagnétique	M.8.16

Pour les MRCD de type à bornes comportant des variantes avec différents nombres de pôles, les essais doivent être effectués sur la variante avec le plus grand nombre de pôles. Pour une variante pour laquelle il n'existe pas de différences de construction par rapport à la variante soumise à essai, aucun essai supplémentaire n'est exigé. Si la construction des variantes n'est pas identique à celle de la variante soumise à essai, ces variantes doivent alors être aussi soumises aux essais.

Un échantillon doit être soumis à essai pour chacune des séquences d'essai M I, M II et M III.

Pour la séquence d'essai M IV, un échantillon neuf peut être utilisé pour chaque essai ou un échantillon peut être utilisé pour plusieurs essais, au choix du fabricant.

Sauf spécification contraire, chacun des essais de type (ou séquence d'essai de type) est effectué sur un MRCD propre et neuf, les grandeurs d'influence ayant leur valeur normale de référence.

Le MRCD doit être installé individuellement, selon les instructions du fabricant, à l'air libre, sauf spécification contraire. La température ambiante doit être comprise entre 15 °C et 30 °C, sauf spécification contraire. Les raccordements et le montage doivent être conformes aux instructions du fabricant.

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M.8.1.2 Essais individuels de série

Le paragraphe 8.4.5 est applicable.

M.8.2 Conformité aux exigences de construction

Le paragraphe 8.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable en intégrant éventuellement les exigences de 7.1.

Séquence d'essai M I

M.8.3 Vérification des caractéristiques de fonctionnement

M.8.3.1 Généralités

Le MRCD doit être installé, monté et câblé selon les instructions du fabricant. Sauf spécification contraire, il est raccordé à un matériel d'essai, selon les spécifications du fabricant, représentant les conditions normales de service pour le circuit de sortie (par exemple connexion à un disjoncteur) afin de vérifier le changement d'état de la sortie et le temps combiné (voir M.2.2.2.2).

M.8.3.2 Conditions d'essai pour les MRCD sans source de tension

Le paragraphe B.8.2.2 est applicable.

M.8.3.3 Conditions d'essai pour les MRCD avec source de tension

Les essais doivent être effectués aux valeurs suivantes:

– 0,85 fois la valeur assignée minimale de la tension pour les essais spécifiés en M.8.3.4 et en M.8.3.5.2,

– 1,1 fois la valeur assignée maximale de la tension pour les essais spécifiés en M.8.3.5.3.

Les MRCD ayant une plage de fréquences assignées doivent être soumis à essai à la fréquence la plus élevée et à la fréquence la plus basse. Cependant, pour les MRCD de fréquences assignées égales à 50 Hz et 60 Hz, les essais à 50 Hz ou à 60 Hz sont considérés comme couvrant les deux fréquences.

M.8.3.4 Essais à vide à 20 °C ± 5 °C

M.8.3.4.1 Généralités

Le MRCD, raccordé comme indiqué à la Figure M.1, la Figure M.2 ou la Figure M.3, doit satisfaire aux essais de M.8.3.4.2, M.8.3.4.3 et M.8.3.4.4, ainsi qu'à l'essai de M.8.3.4.5 le cas échéant; tous ces essais sont effectués sur une seule voie de courant. Chacune des vérifications doit comprendre trois mesurages, suivant le cas.

Sauf spécification contraire:

– pour les MRCD à réglage du courant différentiel résiduel par variation continue ou par valeurs discrètes, les essais doivent être effectués aux réglages maximal et minimal, ainsi qu'à un réglage intermédiaire;

– pour les MRCD du type à temporisation réglable, la temporisation doit être réglée à sa valeur minimale.

M.8.3.4.2 Vérification du fonctionnement dans le cas d'une augmentation régulière du courant différentiel résiduel (Figure M.1)

Les interrupteurs d'essai S_1 et S_2, et S_a s'il y a lieu, étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est augmenté de façon régulière, à

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partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, afin d'atteindre $I_{\Delta n}$ en approximativement 30 s. Trois mesurages de courant provoquant le changement d'état de la sortie sont effectués.

Les trois valeurs mesurées doivent être comprises entre le courant assigné différentiel résiduel de non-fonctionnement $I_{\Delta no}$ et $I_{\Delta n}$.

M.8.3.4.3Vérification du fonctionnement en cas de fermeture sur le courant différentiel résiduel (Figure M.2)

Le MRCD est raccordé à un appareil de coupure, spécifié par le fabricant, et installé sur le circuit contrôlé. Les caractéristiques de cet appareil doivent être indiquées dans le rapport d'essai.

Le circuit d'essai étant étalonné à la valeur assignée du courant différentiel résiduel de fonctionnement $I_{\Delta n}$ (ou, le cas échéant, à chaque réglage spécifique du courant différentiel résiduel de fonctionnement), l'interrupteur d'essai S_2 et l'appareil de coupure étant en position fermée, les interrupteurs S_1 et S_a (s'il y a lieu) sont fermés simultanément. Le temps combiné est mesuré trois fois.

Aucun mesurage ne doit dépasser la valeur limite spécifiée pour $I_{\Delta n}$ en M.4.2.

M.8.3.4.4Vérification du fonctionnement dans le cas d'une apparition brusque d'un courant différentiel résiduel (Figure M.2 et Figure M.3)

Le MRCD est raccordé au matériel d'essai comme spécifié en M.8.3.1.

Le circuit d'essai étant étalonné à chacune des valeurs du courant différentiel résiduel de fonctionnement I_{Δ} spécifié en M.4.2, les interrupteurs d'essai S_1, et S_a s'il y a lieu, et le matériel d'essai étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est établi brusquement par la fermeture de l'interrupteur S_2.

Trois mesurages du temps de fonctionnement et du temps combiné (le cas échéant) sont effectués à chacune des valeurs de I_{Δ}:

– aucune des valeurs du temps de fonctionnement ne doit dépasser les valeurs indiquées par le fabricant,

– aucune des valeurs du temps combiné ne doit dépasser les limites indiquées en M.4.2.

M.8.3.4.5Vérification du temps limite de non-fonctionnement des MRCD de type temporisé (Figure M.3)

Le MRCD est raccordé au matériel d'essai comme spécifié en M.8.3.1.

Le circuit d'essai étant étalonné à la valeur 2 $I_{\Delta n}$, les interrupteurs d'essai S_1, et S_a s'il y a lieu, étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est établi par la fermeture de l'interrupteur S_2 durant un temps égal au temps limite de non-fonctionnement déclaré par le fabricant selon M.4.2.

L'essai est effectué trois fois. Le MRCD ne doit pas fonctionner.

Si le MRCD a un courant de réglage ajustable et/ou une temporisation réglable, l'essai est effectué, suivant le cas, au réglage minimal du courant différentiel résiduel de fonctionnement et aux réglages maximal et minimal de la temporisation.

M.8.3.5 Essais aux limites de température

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M.8.3.5.1Généralités

Le paragraphe B.8.2.5 est applicable.

M.8.3.5.2 Essai à vide à – 5 °C

Le paragraphe B.8.2.5.2 est applicable, mais selon M.8.3.4.4 et M.8.3.4.5 le cas échéant.

M.8.3.5.3 Essai en charge à + 40 °C

Le paragraphe B.8.2.5.3 est applicable.

Après avoir atteint l'équilibre thermique, le MRCD est soumis aux essais décrits en M.8.3.4.4 et en M.8.3.4.5 le cas échéant.

M.8.4Vérification des propriétés diélectriques

M.8.4.1Vérification de la tension assignée de tenue aux chocs

M.8.4.1.1Généralités

Le MRCD doit satisfaire aux exigences établies en M.7.2.5. Les essais doivent être effectués pour toutes les positions du contact auxiliaire.

Les essais sont effectués conformément au 8.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 avec les compléments suivants.

M.8.4.1.2Vérification de la tension assignée de tenue aux chocs par rapport au circuit contrôlé

M.8.4.1.2.1 Essais pour un MRCD du type à bornes

La tension d'essai, définie en M.7.2.5, est appliquée comme indiqué au 8.3.3.4.1, point 2), de l'IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Essais pour un MRCD du type à conducteur traversant

L'essai est effectué sur un dispositif de détection traversé par un jeu de barres non isolé, installé suivant les instructions du fabricant.

La tension d'essai, définie en M.7.2.5, est appliquée comme suit:

a)entre tous les conducteurs du circuit contrôlé reliés entre eux et l'embase de montage si le dispositif de détection est séparé;

b)entre tous les conducteurs du circuit contrôlé reliés entre eux et l'enveloppe de l'appareil de traitement ou son embase de montage si le dispositif de détection est incorporé;

c)entre chaque circuit auxiliaire et

– le circuit contrôlé;

– l'enveloppe ou l'embase de montage du MRCD.

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M.8.4.1.3Vérification de la tension assignée de tenue aux chocs du circuit de la source de tension (le cas échéant)

Si le circuit de la source de tension est alimenté directement par le circuit contrôlé, les essais sont effectués conformément à M.8.4.1.2.1.

Si le circuit de la source de tension n'est pas alimenté par le circuit contrôlé, la tension d'essai définie au Tableau 12 de l'IEC 60947-1:2007 est appliquée comme suit:

a)entre toutes les bornes d'alimentation du circuit de la source de tension reliées entre elles et l'enveloppe ou l'embase de montage du MRCD;

b)entre chaque borne d'alimentation du circuit de la source de tension et les autres bornes d'alimentation reliées entre elles et raccordées à l'enveloppe ou à l'embase de montage du MRCD.

M.8.4.2 Capacité des circuits raccordés au circuit contrôlé à supporter les tensions continues causées par les mesurages d'isolement

La nécessité de cette vérification pour les MRCD qui ne peuvent pas être déconnectés en service est à l'étude.

M.8.5Vérification du fonctionnement de l'appareil d'essai aux limites de la tension assignée

Le paragraphe B.8.4 est applicable, en remplaçant la tension assignée par la tension assignée de la source de tension. Le MRCD doit être soumis à essai en association avec le matériel d'essai spécifié en M.8.3.1.

M.8.6Vérification de la valeur limite du courant de non fonctionnement en conditions de surintensité, dans le cas d'une charge monophasée

Le MRCD est raccordé selon la Figure M.4 a), b) ou c), suivant le cas, en faisant particulièrement attention au positionnement des conducteurs, selon les instructions du fabricant, dans le cas d'un MRCD du type conducteur traversant, l'interrupteur S_1 étant ouvert. L'interrupteur S_a, s'il y a lieu, est alors fermé et la tension U_s est appliquée.

L'essai est effectué conformément à B.8.5 à un courant de 6 I_n. Pour les MRCD à dispositif de détection séparé, l'essai doit être effectué à la valeur de réglage de courant différentiel résiduel la plus faible déclarée par le fabricant.

Aucun changement d'état du MRCD ne doit se produire.

M.8.7Résistance aux déclenchements intempestifs dus à des courants de choc causés par des tensions de choc

M.8.7.1Généralités

Pour les MRCD à temporisation réglable, la temporisation doit être réglée au minimum.

M.8.7.2Vérification de la résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

Le paragraphe B.8.6.2 est applicable, en remplaçant la Figure B.5 par la Figure M.5.

Aucun changement d'état du MRCD ne doit se produire.

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M.8.7.3Vérification de la résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Le paragraphe B.8.6.3 est applicable, en remplaçant la Figure B.7 par la Figure M.6.

Aucun changement d'état du MRCD ne doit se produire.

M.8.8Vérification du comportement dans le cas d'un courant de défaut à la terre comprenant une composante continue

M.8.8.1Généralités

Les conditions d'essai de M.8.3.1, M.8.3.2 et M.8.3.3 sont applicables.

M.8.8.2MRCD de type A

M.8.8.2.1Généralités

Les MRCD de type A doivent satisfaire aux essais de M.8.8.2.2 à M.8.8.2.5.

Pour les MRCD dont le fonctionnement dépend d'une source de tension, les essais sont effectués à 1,1 et à 0,85 fois la tension assignée de la source de tension (U_s).

M.8.8.2.2Vérification du fonctionnement dans le cas d'une augmentation régulière d'un courant différentiel résiduel continu pulsé

Le paragraphe B.8.7.2.1 est applicable, en remplaçant la Figure B.8 par la Figure M.7.

Les interrupteurs S_1 et S_2, et S_a le cas échéant, sont fermés, le MRCD étant prêt à fonctionner.

M.8.8.2.3Vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu pulsé

Les essais de B.8.7.2.2 sont applicables avec les modifications suivantes.

Le circuit d'essai doit être conforme à la Figure M.8 ou la Figure M.9, suivant le cas.

La vérification s'effectue en deux étapes:

– pour la première étape, le MRCD est raccordé à un appareil de mesure indiquant le changement d'état de la sortie;

– pour la seconde étape, le MRCD est raccordé à un appareil de coupure, spécifié par le fabricant, et installé sur le circuit contrôlé. Les caractéristiques de cet appareil de coupure doivent être indiquées dans le rapport d'essai.

Les interrupteurs S_1, et S_a s'il y a lieu, sont en position fermée et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est soudainement établi en fermant l'interrupteur S_2.

L'essai est effectué pour chaque valeur du courant différentiel résiduel spécifié:

– pour la première étape, aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse du MRCD seul;

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– pour la seconde étape, aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.2.4 Vérification du fonctionnement en charge à la température de référence

Les essais de M.8.8.2.2 sont répétés, la voie de courant en essai et une autre voie de courant du MRCD étant parcourues par le courant assigné, le courant étant établi juste avant l'essai.

NOTE La charge avec le courant assigné n'est pas montrée à la Figure M.7c).

M.8.8.2.5 Vérification du fonctionnement dans le cas d'un courant différentiel résiduel continu pulsé auquel un courant continu lissé de 6 mA est superposé

Les essais de B.8.7.2.4 sont applicables avec les modifications suivantes.

Le circuit d'essai doit être conforme à la Figure M.10 a), b) ou c), suivant le cas.

M.8.8.3 MRCD de type B

M.8.8.3.1 Généralités

En plus des essais spécifiés en M.8.3.4 et M.8.3.5, les MRCD de type B doivent satisfaire aux essais de M.8.8.3.2 à M.8.8.3.6. Pour les MRCD avec une source de tension, ces essais sont effectués à 1,1 et 0,85 fois la tension assignée de la tension source.

M.8.8.3.2 Vérification du fonctionnement dans le cas d'une montée lente du courant différentiel résiduel continu lissé

Le circuit d'essai doit être conforme à la Figure M.11, les interrupteurs S_1 et S_2, et S_a s'il y a lieu, étant en position fermée. Chaque voie de courant est soumise à essai deux fois avec l'interrupteur S_3 en position I et deux fois avec l'interrupteur S_3 en position II.

Le courant différentiel résiduel doit être augmenté de façon régulière, à partir de zéro, afin d'atteindre 2 $I_{\Delta n}$ dans les 30 s; le fonctionnement doit se produire entre 0,5 et 2 $I_{\Delta n}$.

M.8.8.3.3 Vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu lissé

Les circuits d'essai doivent être conformes à la Figure M.12 et la Figure M.13.

La vérification s'effectue en deux étapes:

– pour la première étape, le MRCD est raccordé à un appareillage de mesure indiquant l'état de la sortie;

– pour la seconde étape, le MRCD est raccordé à un appareil de coupure de courant, spécifié par le fabricant et installé sur le circuit contrôlé. Les caractéristiques de cet appareil de coupure doivent être indiquées dans le rapport d'essai.

Le circuit étant successivement étalonné à chacune des valeurs spécifiées ci-après, l'interrupteur auxiliaire S_1 ou S_a, suivant le cas, étant en position fermée et le MRCD prêt à fonctionner, le courant différentiel résiduel est soudainement établi par fermeture de l'interrupteur S_2.

L'essai est effectué pour chaque valeur du courant différentiel résiduel spécifiée au Tableau B.1, multipliée par deux.

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Deux mesurages du temps de fonctionnement sont effectués pour chaque valeur, l'interrupteur auxiliaire S_3 étant en position I pour le premier mesurage et en position II pour le second mesurage:

– pour la première étape, aucune des valeurs obtenues ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse du MRCD seul;

– pour la seconde étape, aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.3.4 Vérification du fonctionnement dans le cas d'une application progressive d'un courant différentiel résiduel résultant d'un défaut dans un circuit alimenté par un redresseur triphasé en étoile ou en pont

Le circuit d'essai doit être conforme à la Figure M.14, les interrupteurs S_1 et S_2, et S_a s'il y a lieu, étant en position fermée. L'essai doit être effectué deux fois.

Pour chaque essai, le courant doit être augmenté de façon régulière, à partir de zéro, afin d'atteindre 2 $I_{\Delta n}$ dans les 30 s. Le fonctionnement doit se produire entre 0,5 et 2 $I_{\Delta n}$.

M.8.8.3.5 Vérification du fonctionnement dans le cas d'une application progressive d'un courant différentiel résiduel résultant d'un défaut dans un circuit alimenté par un redresseur double alternance entre phases

Le circuit d'essai doit être conforme à la Figure M.15, les interrupteurs S_1 et S_2, et S_a s'il y a lieu, étant en position fermée. L'essai doit être effectué pour toutes les combinaisons possibles de paires de voies de courant pour le dispositif de détection du MRCD.

Pour chaque essai, le courant doit être augmenté de façon régulière, à partir de zéro, afin d'atteindre 1,4 $I_{\Delta n}$ dans les 30 s. Le fonctionnement doit se produire entre 0,5 et 1,4 $I_{\Delta n}$.

NOTE 1 Pour simplifier les essais pour les courants différentiels résiduels causés par un défaut dans un circuit alimenté par un redresseur monophasé double alternance ou un redresseur triphasé en étoile ou en pont, la vérification du fonctionnement est réalisée seulement avec un courant différentiel résiduel augmentant lentement et un angle de commande de phase $\alpha = 0°$.

NOTE 2 Pour simplifier les essais pour les courants différentiels résiduels causés par un défaut dans un circuit alimenté par un redresseur triphasé, la vérification du fonctionnement est réalisée seulement pour un redresseur en étoile.

M.8.8.3.6 Vérification du fonctionnement en charge à la température de référence

Les essais de M.8.8.3.2, M.8.8.3.4 et M.8.8.3.5 sont répétés, la voie de courant en essai et une autre voie de courant du MRCD étant parcourues par le courant assigné.

M.8.9 Vérification du comportement des MRCD à dispositif de détection séparé en cas de défaillance de la connexion du dispositif de détection

M.8.9.1 Généralités

Pour les MRCD ayant une plage de valeurs assignées de la source de tension, les essais doivent être effectués pour chaque valeur assignée, selon M.8.9.2 ou M.8.9.3, suivant le cas, conformément aux instructions du fabricant.

M.8.9.2 Méthode d'essai 1

Le MRCD doit être raccordé au dispositif de détection séparé et alimenté successivement avec chacune des tensions assignées, comme indiqué à la Figure M.16. Aucun courant de défaut ne doit circuler dans le dispositif de détection et le circuit d'essai ne doit pas être actionné.

Le dispositif de détection est ensuite déconnecté et le MRCD doit fonctionner ou fournir un signal pour indiquer cette déconnexion.

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Le temps entre la déconnexion et le changement d'état de la sortie est mesuré.

Trois mesurages sont effectués; aucune valeur ne doit dépasser 5 s.

M.8.9.3 Méthode d'essai 2

Les essais doivent être effectués comme suit:

a) L'appareil d'essai est actionné. Le MRCD doit fonctionner.

b) Le dispositif de détection est déconnecté et l'appareil d'essai est actionné. Le MRCD ne doit pas fonctionner.

M.8.10 Vérification de l'échauffement des MRCD de type à bornes

M.8.10.1 Généralités

Sauf spécification contraire, le MRCD est raccordé avec des conducteurs appropriés dont les sections sont spécifiées aux Tableaux 9, 10 et 11 de l'IEC 60947-1:2007, et fixé sur une plaque de contreplaqué noire mate d'environ 20 mm d'épaisseur.

L'essai doit être réalisé dans une atmosphère protégée contre des échauffements ou des refroidissements anormaux venant de l'extérieur.

M.8.10.2 Température de l'air ambiant

Le paragraphe 8.3.3.3.1 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.8.10.3 Mode opératoire d'essai

L'essai doit être effectué conformément au 8.3.3.3.4 de l'IEC 60947-1:2007, au courant assigné I_n.

Pendant cet essai, l'échauffement ne doit pas dépasser les valeurs indiquées au Tableau 2 de l'IEC 60947-1:2007 et au Tableau 3 de l'IEC 60947-1:2007/AMD2:2014.

M.8.11 Vérification de l'endurance mécanique et électrique

La sortie du MRCD est soumise à des essais d'endurance mécanique et électrique incluant:

– 500 manœuvres à vide commandées par l'appareil d'essai,

– 500 manœuvres à vide en faisant passer le courant assigné différentiel résiduel de fonctionnement $I_{\Delta n}$ dans une seule voie de courant,

– 500 manœuvres en charge commandées par l'appareil d'essai,

– 500 manœuvres en charge en faisant passer le courant assigné différentiel résiduel de fonctionnement $I_{\Delta n}$ dans une seule voie de courant.

Les essais en charge sont effectués avec un circuit correspondant aux caractéristiques assignées de la sortie indiquées par le fabricant.

Après les essais, le MRCD ne doit montrer aucune dégradation empêchant son utilisation ultérieure. La sortie doit pouvoir supporter en position ouverte une tension égale à deux fois la valeur maximale assignée indiquée par le fabricant.

NOTE 1 Cette vérification n'est pas applicable si la sortie est conçue pour une charge spécifique et n'a pas de tension assignée de sortie.

Pour les MRCD ayant plus d'une caractéristique assignée de sortie, deux essais doivent être effectués:

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– un essai au courant assigné le plus élevé à la tension correspondante,

– un essai à la tension assignée la plus élevée au courant correspondant.

Le MRCD doit pouvoir effectuer de façon satisfaisante les essais spécifiés en B.8.10.4.2.

NOTE 2 Si la sortie du MRCD a une caractéristique assignée AC15 appropriée, selon l'IEC 60947-5-1, les essais définis dans le présent paragraphe ne sont pas nécessaires.

M.8.12 Vérification du comportement des MRCD dans le cas d'une défaillance de la source de tension pour les MRCD classés selon M.3.2.2.1

M.8.12.1 Généralités

Pour les MRCD à courant différentiel résiduel de fonctionnement réglable, l'essai doit être effectué au réglage minimal.

Pour des MRCD à temporisation réglable, l'essai est effectué à l'une quelconque des temporisations.

La tension appliquée est la tension assignée de la source de tension (U_s).

Pour les MRCD ayant une plage de tensions assignées de la source de tension, les essais doivent être effectués aux valeurs maximale et minimale de la plage de tensions.

M.8.12.2 Détermination de la valeur limite de la source de tension

Les essais doivent être effectués conformément à B.8.8.2, en remplaçant «tension d'alimentation» par «source de tension» et «bornes d'alimentation» par «bornes de la source de tension».

M.8.12.3 Vérification de l'ouverture automatique en cas de défaillance de la source de tension

Les essais doivent être effectués conformément à B.8.8.3, en remplaçant «tension d'alimentation» par «source de tension» et «bornes d'alimentation» par «bornes de la source de tension», mais dans ce cas le temps entre la mise hors tension et le changement d'état de la sortie doit être mesuré.

Trois mesurages sont effectués:

– pour les MRCD instantanés, aucune valeur ne doit dépasser 1 s;

– pour les MRCD temporisés, aucune valeur ne doit dépasser de plus de 1 s la temporisation réglée.

M.8.13 Vérification du comportement des MRCD à source de tension classés selon M.3.2.2.2, en cas de défaillance de la source de tension

Les dispositions de B.8.9 sont applicables dans le cas où la source de tension est la tension d'alimentation du circuit contrôlé. Dans le cas où la source de tension est différente de la tension d'alimentation, un essai doit être effectué comme suit.

Pour les MRCD ayant un courant différentiel résiduel réglable, l'essai doit être effectué au réglage minimal.

Pour les MRCD ayant une temporisation réglable, l'essai est effectué à l'une quelconque des temporisations.

Le MRCD est raccordé selon la Figure M.3 et alimenté à sa tension assignée, ou dans le cas d'une plage de tensions assignées, à la tension assignée la plus basse.

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L'alimentation est alors coupée par l'ouverture de S_a ou de S_1, suivant le cas; le MRCD ne doit pas fonctionner.

L'interrupteur S_a ou S_1, suivant le cas, est alors refermé et la tension est réduite à 70 % de la tension assignée la plus basse. Le courant assigné différentiel résiduel $I_{\Delta n}$ est alors appliqué en fermant S_2; le MRCD doit fonctionner.

Séquence d'essai M II

M.8.14 Vérification du comportement du MRCD dans des conditions de court-circuit

M.8.14.1 Généralités

Etant donné qu'un MRCD n'est pas un appareil de connexion, lorsqu'il a été soumis à essai avec un DPCC donné conformément à M.8.14.3 et M.8.14.5, les essais avec d'autres DPCC d'un courant de crête plus faible et de I^2t plus faibles sont également considérés comme couverts.

M.8.14.2 Conditions générales pour l'essai

M.8.14.2.1 Circuit d'essai

Le paragraphe 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 est applicable, en remplaçant les Figures 9, 10, 11 et 12 par la Figure M.17, la Figure M.18 et la Figure M.19.

Pour les essais de tenue de courte durée, le DPCC doit être omis.

M.8.14.2.2 Tolérances sur les grandeurs d'essai

Le Tableau 8 de l'IEC 60947-1:2007 est applicable.

M.8.14.2.3 Facteur de puissance du circuit d'essai

Le Tableau 11 est applicable.

M.8.14.2.4 Tension de rétablissement à fréquence industrielle

Le paragraphe 8.3.2.2.3, point a), de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.8.14.2.5 Etalonnage du circuit d'essai

Le DPCC et le MRCD, s'il est du type à bornes, sont remplacés par des connexions temporaires d'impédances négligeables comparées à celle du circuit d'essai. Pour les autres MRCD, les conducteurs traversant les dispositifs de détection font partie du circuit d'étalonnage.

Pour l'essai au courant assigné de court-circuit conditionnel I_{cc}, les résistances R et les bobines d'inductance L sont réglées de manière à obtenir, à la tension d'essai, un courant égal à I_{cc}, avec le facteur de puissance exigé. Tous les pôles du circuit d'essai sont mis sous tension simultanément.

Pour les essais au courant assigné différentiel résiduel de court-circuit conditionnel $I_{\Delta c}$, l'impédance additionnelle Z est utilisée de manière à obtenir les valeurs exigées de courant.

M.8.14.2.6 Etat du MRCD pour les essais

Le câblage et la fixation du MRCD doivent être réalisés conformément aux instructions du fabricant.

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~~Cela est particulièrement le cas pour les MRCD du type conducteur traversant pour l'installation des conducteurs traversant les dispositifs de détection.~~

~~Le MRCD doit être monté sur une plaque métallique.~~

~~M.8.14.2.7 Etat du MRCD après les essais~~

~~Après chacun des essais de M.8.14.3, M.8.14.4 et M.8.14.5, le MRCD ne doit pas présenter de dommages empêchant son utilisation ultérieure et, dans le cas d'un MRCD du type à bornes, doit pouvoir supporter une tension égale à deux fois sa tension assignée dans les conditions de 8.3.3.6.~~

~~Le MRCD doit pouvoir supporter de façon satisfaisante les essais spécifiés en B.8.10.4.2 et M.8.12.3, le cas échéant, et limités à un seul mesurage.~~

~~M.8.14.3 Vérification du courant assigné de court-circuit conditionnel (I_{cc})~~

~~M.8.14.3.1 Généralités~~

~~Cet essai n'est pas nécessaire si le courant de crête coupé limité et l'énergie limitée du DPCC associé sont plus faibles que le courant de crête et l'énergie limitée correspondant au courant assigné de courte durée admissible I_{cw}.~~

~~M.8.14.3.2 Conditions d'essai~~

~~Les connexions d'impédance négligeable sont remplacées par le DPCC et, le cas échéant, par le MRCD du type à bornes.~~

~~M.8.14.3.3 Mode opératoire d'essai~~

~~La tension assignée de la source de tension est appliquée, s'il y a lieu.~~

~~La séquence de manœuvres suivante est effectuée:~~

~~O – t – O~~

~~M.8.14.3.4 Comportement du MRCD pendant les essais~~

~~Pendant les essais, le MRCD peut fonctionner.~~

~~M.8.14.4 Vérification du courant assigné de courte durée admissible (I_{cw})~~

~~Le paragraphe 8.3.4.3 de l'IEC 60947-1:2007 est applicable au circuit primaire.~~

~~L'essai peut être effectué à toute tension appropriée. Le DPCC de la Figure M.17, de la Figure M.18 et de la Figure M.19 doit être omis pour l'essai.~~

~~M.8.14.5 Vérification du courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$)~~

~~M.8.14.5.1 Généralités~~

~~Cet essai n'est pas nécessaire si le courant de crête coupé limité et l'énergie limitée du DPCC associé sont plus faibles que le courant de crête et l'énergie limitée correspondant au courant assigné différentiel résiduel de courte durée admissible $I_{\Delta w}$.~~

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~~**M.8.14.5.2 Conditions d'essai**~~

~~Le MRCD doit être soumis à essai dans les conditions spécifiées en M.8.14.2.1 mais doit être raccordé de telle sorte que le courant de court-circuit soit un courant différentiel résiduel. Pour les essais de court-circuit différentiel résiduel, la connexion B, indiquée par la ligne en pointillé à la Figure M.17, la Figure M.18 et la Figure M.19, remplace la connexion traversant le dispositif de détection, entre X et Y.~~

~~L'essai est effectué sur une seule voie de courant.~~

~~Les connexions d'impédance négligeable sont remplacées par le DPCC et, s'il y lieu, par le MRCD.~~

~~**M.8.14.5.3 Mode opératoire d'essai**~~

~~La séquence suivante est effectuée sans synchronisation avec l'onde de tension:~~

~~O – *t* – O~~

~~**M.8.14.5.4 Comportement du MRCD pendant les essais**~~

~~Pendant les essais, le MRCD peut fonctionner.~~

~~**M.8.14.6 Vérification du courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$)**~~

~~Le paragraphe M.8.14.4 est applicable, excepté que le MRCD doit être raccordé de telle manière que le courant de court-circuit soit un courant différentiel résiduel.~~

~~***Séquence d'essai M III***~~

~~**M.8.15 Vérification des effets des conditions d'environnement**~~

~~Les conditions d'essai de B.8.11 sont applicables.~~

~~A la fin des essais, le MRCD doit supporter de façon satisfaisante les essais spécifiés en B.8.10.4.2.~~

~~***Séquence d'essai M IV***~~

~~**M.8.16 Vérification de la compatibilité électromagnétique**~~

~~**M.8.16.1 Essais d'immunité**~~

~~**M.8.16.1.1 Généralités**~~

~~Le paragraphe B.8.12.1 est applicable en remplaçant «DPR» par «MRCD» lorsque nécessaire, excepté que les vérifications après les essais doivent être un mesurage du temps de fonctionnement (voir M.2.2.2.1) à $I_{\Delta n}$, lequel ne doit pas dépasser la valeur déclarée par le fabricant (voir M.4.2). Le circuit d'essai pour la vérification doit être conforme à la Figure M.3.~~

~~**M.8.16.1.2 Décharges électrostatiques**~~

~~Le paragraphe B.8.12.1.2 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.~~

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~~**M.8.16.1.3 Champs électromagnétiques RF rayonnés**~~

~~Le paragraphe B.8.12.1.3 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.~~

~~L'installation d'essai doit être conforme à la Figure J.4 et la Figure M.20 pour les MRCD avec un dispositif de détection séparé.~~

~~**M.8.16.1.4 Transitoires électriques rapides en salves (TER/S)**~~

~~Le paragraphe B.8.12.1.4 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.~~

~~L'installation d'essai doit être conforme à la Figure J.5 et la Figure J.6, et la Figure M.21 pour les MRCD avec un dispositif de détection séparé.~~

~~**M.8.16.1.5 Ondes de choc**~~

~~Le paragraphe B.8.12.1.5 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.~~

~~**M.8.16.1.6 Perturbations conduites, induites par les champs RF (mode commun)**~~

~~Le paragraphe B.8.12.1.6 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.~~

~~L'installation d'essai doit être conforme à la Figure M.22 pour les MRCD avec un dispositif de détection séparé.~~

~~Une pince électromagnétique peut être utilisée lorsque le fonctionnement normal ne peut être obtenu à cause de l'impact du RCD sur le MRCD.~~

~~**M.8.16.2 Essais d'émission**~~

~~Le paragraphe B.8.12.2 est applicable.~~

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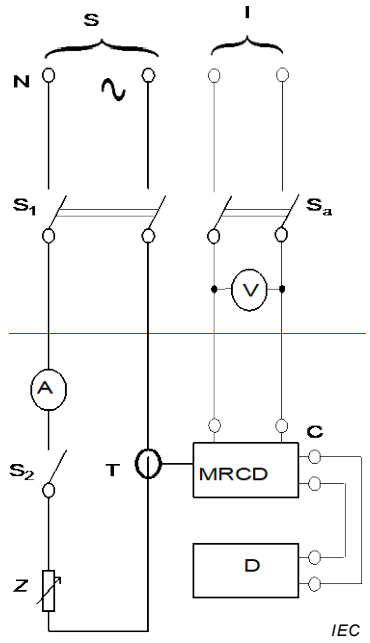


Figure M.1a) – MRCD avec un dispositif de détection séparé

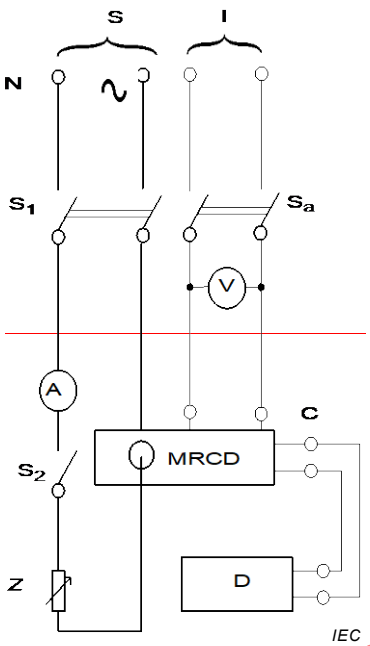


Figure M.1b) – MRCD avec un dispositif de détection intégré

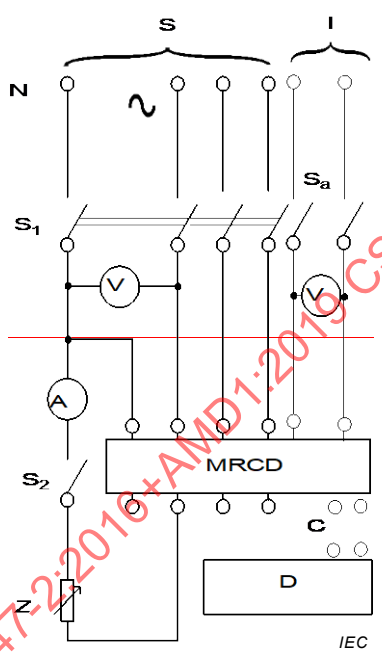


Figure M.1c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

Figure M.1 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentation régulière d'un courant différentiel résiduel

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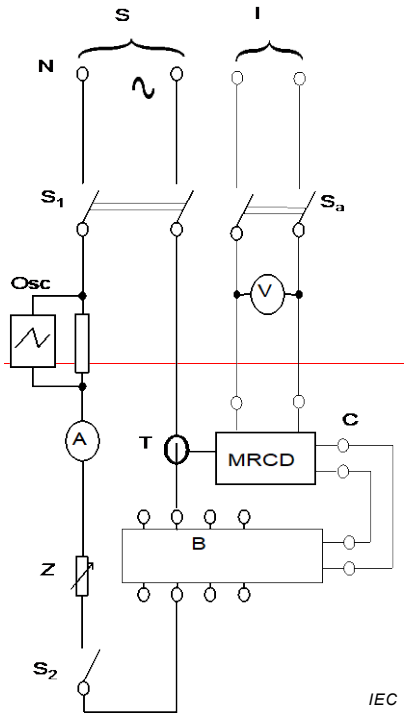


Figure M.2a) – MRCD avec un dispositif de détection séparé

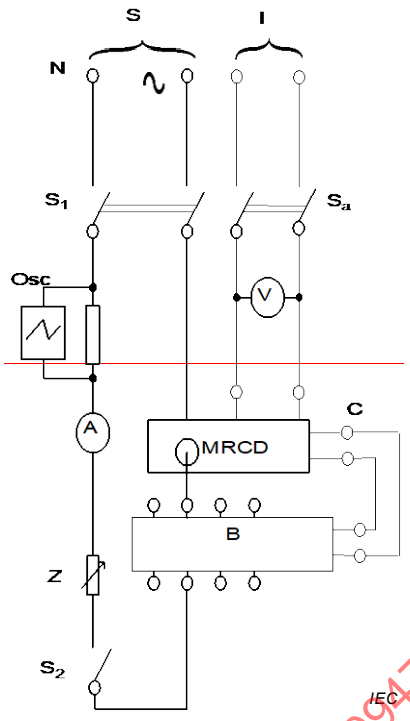


Figure M.2b) – MRCD avec un dispositif de détection intégré

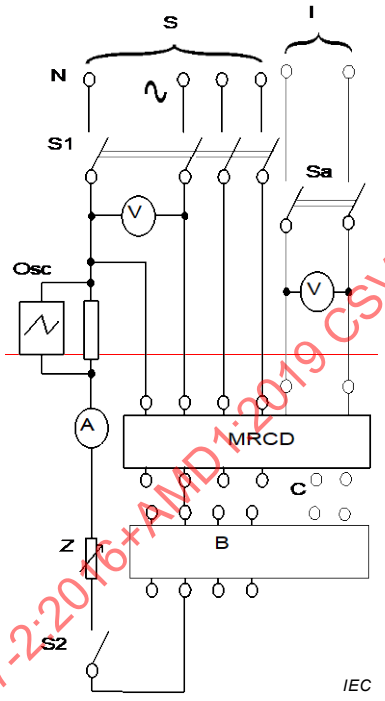


Figure M.2c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

B appareil de coupure

Osc oscilloscope

Figure M.2 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel (avec appareil de coupure)

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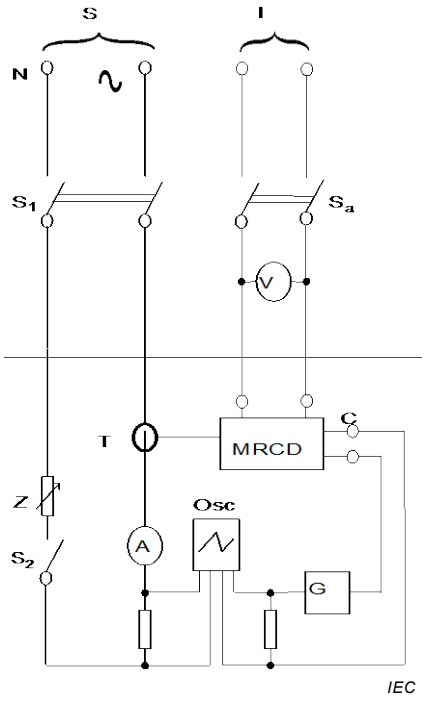


Figure M.3a) – MRCD avec un dispositif de détection séparé

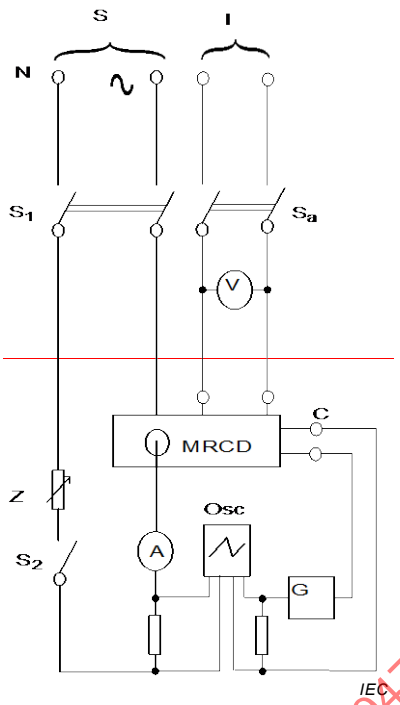


Figure M.3b) – MRCD avec un dispositif de détection intégré

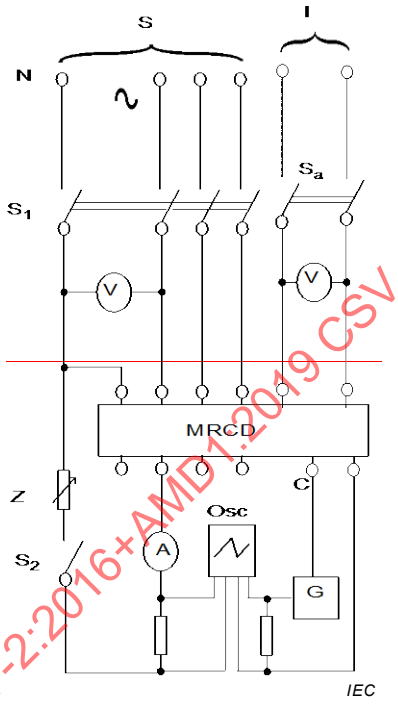


Figure M.3c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

G générateur

Osc oscilloscope

Figure M.3 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel (sans appareil de coupure)

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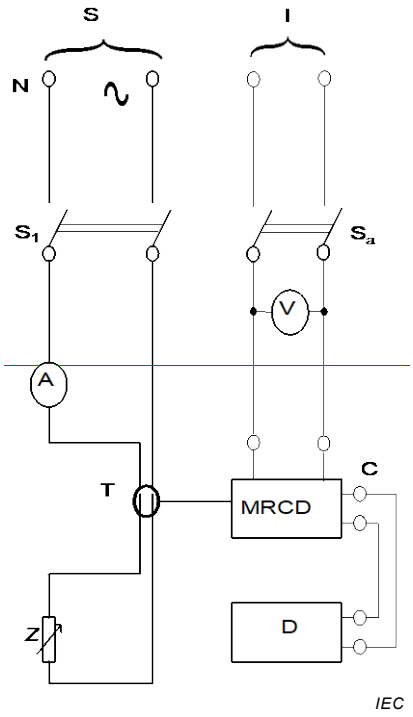


Figure M.4a) – MRCD avec un dispositif de détection séparé

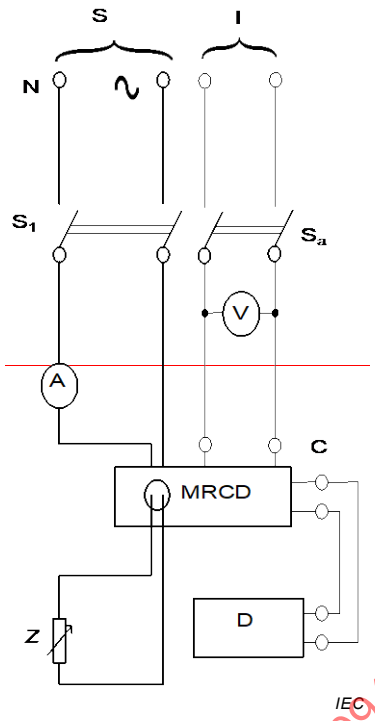


Figure M.4b) – MRCD avec un dispositif de détection intégré

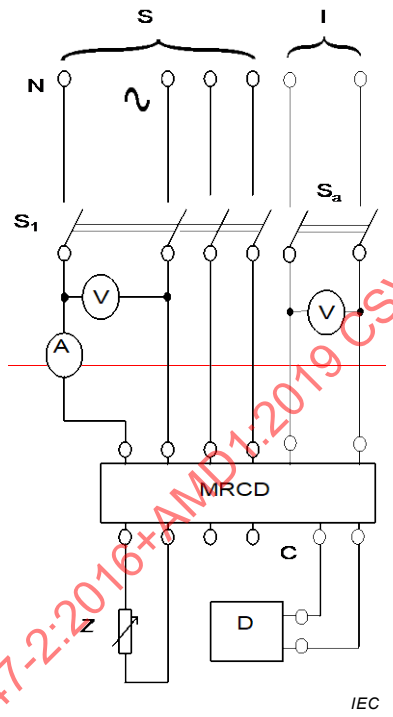


Figure M.4c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

Figure M.4 – Circuits d'essai pour la vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité

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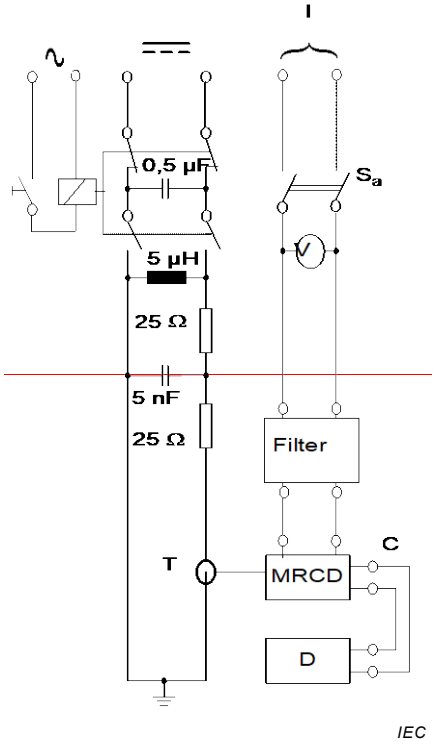


Figure M.5a) – MRCD avec un dispositif de détection séparé

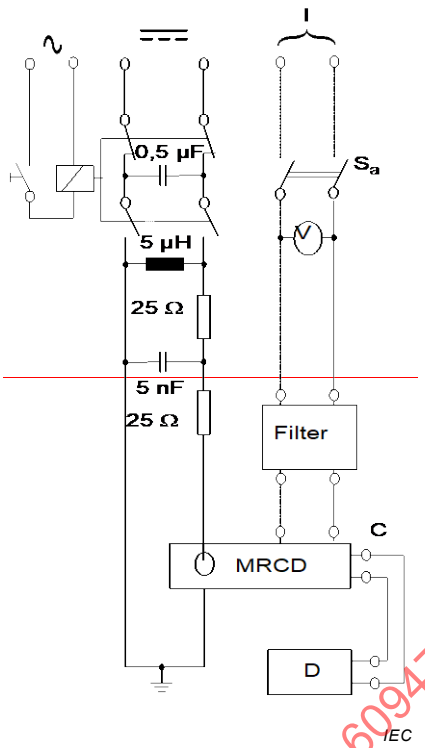


Figure M.5b) – MRCD avec un dispositif de détection intégré

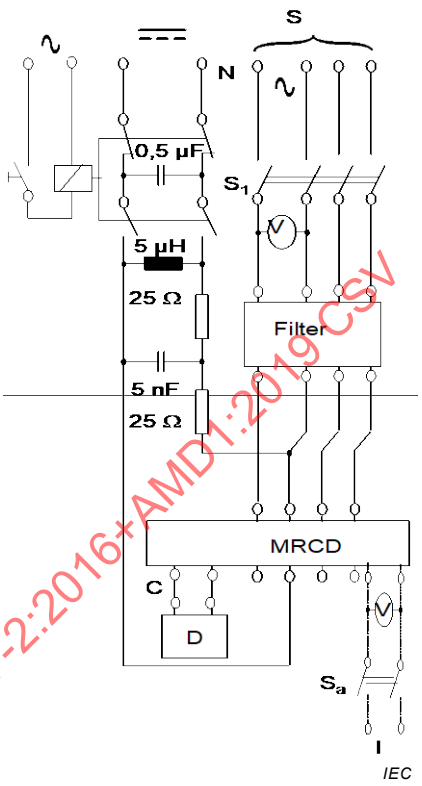


Figure M.5c) – MRCD de type à bornes

Légende

S alimentation électrique

V voltmètre

I source de tension séparée, le cas échéant

S_a interrupteur auxiliaire

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

Filter filtre

Figure M.5 – Circuits d'essai pour la vérification de la résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

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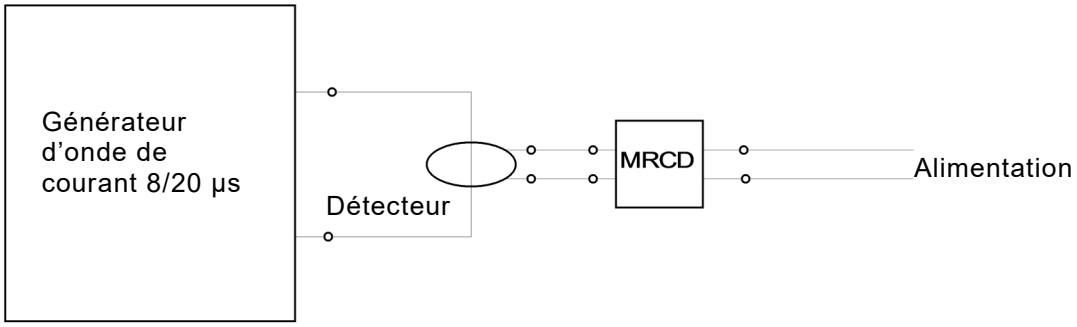


Figure M.6a) MRCD à dispositif de détection séparé

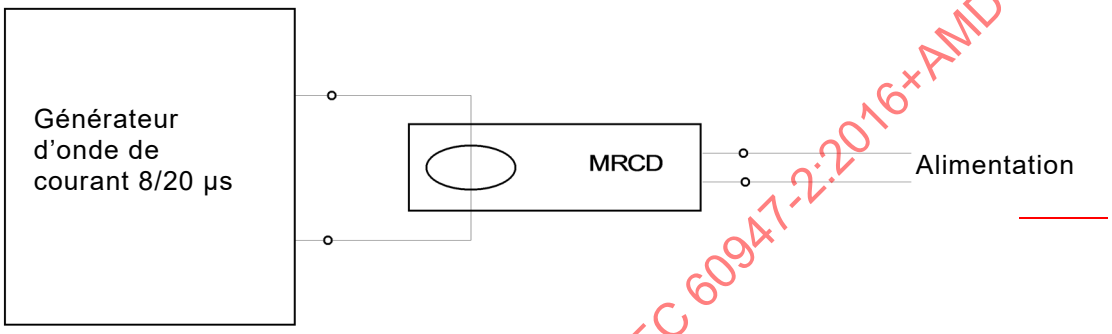


Figure M.6b) MRCD à dispositif de détection intégré

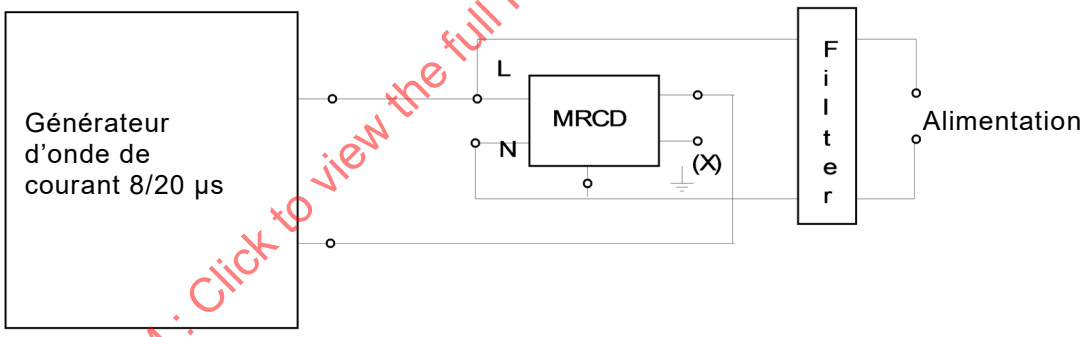


Figure M.6c) MRCD de type à bornes

IEC

~~**Figure M.6 – Circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs dans le cas d'un amorçage sans courant de suite**~~

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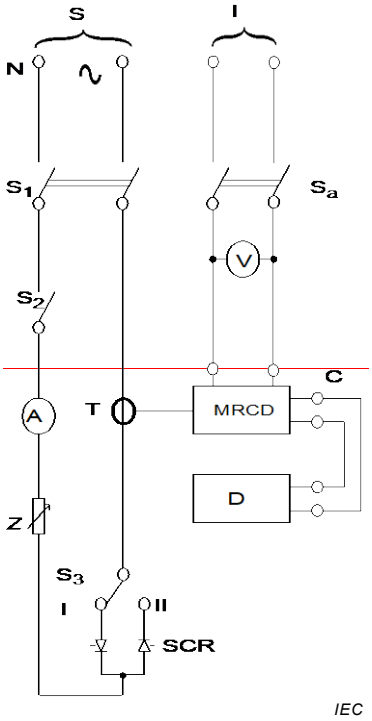


Figure M.7a) – MRCD avec un dispositif de détection séparé

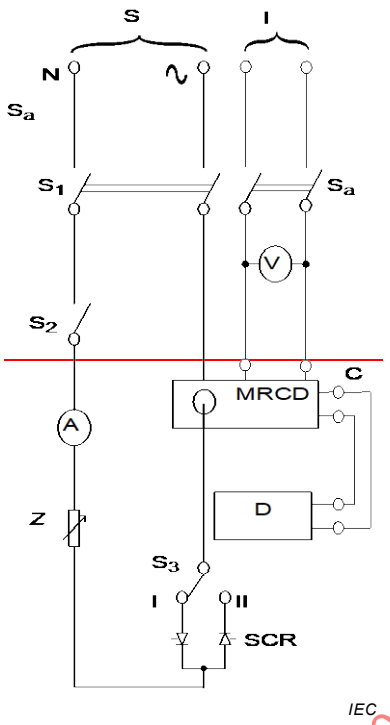


Figure M.7b) – MRCD avec un dispositif de détection intégré

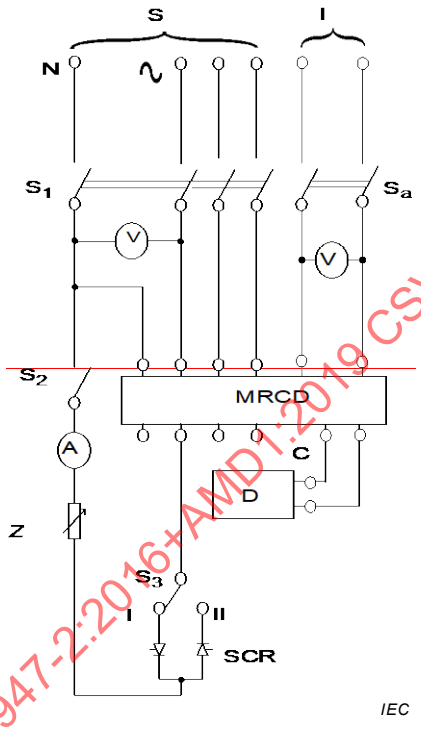


Figure M.7c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_3 inverseur

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

SCR thyristor

Figure M.7 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentation régulière d'un courant différentiel résiduel continu pulsé

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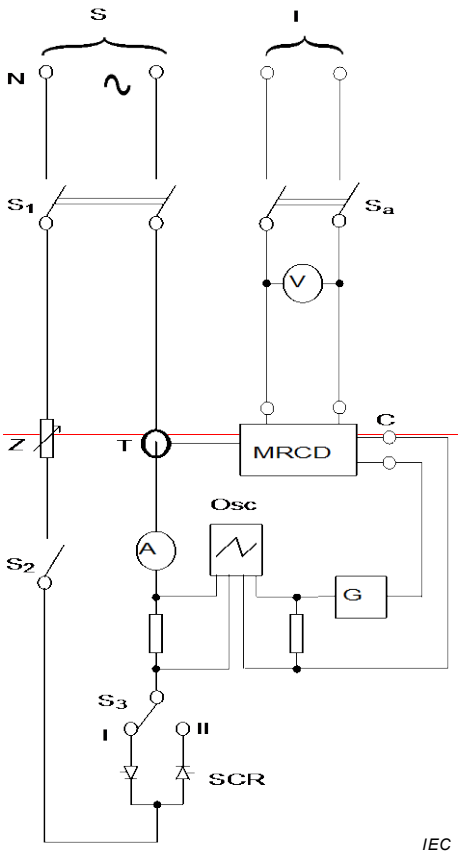


Figure M.8a) – MRCD avec un dispositif de détection séparé

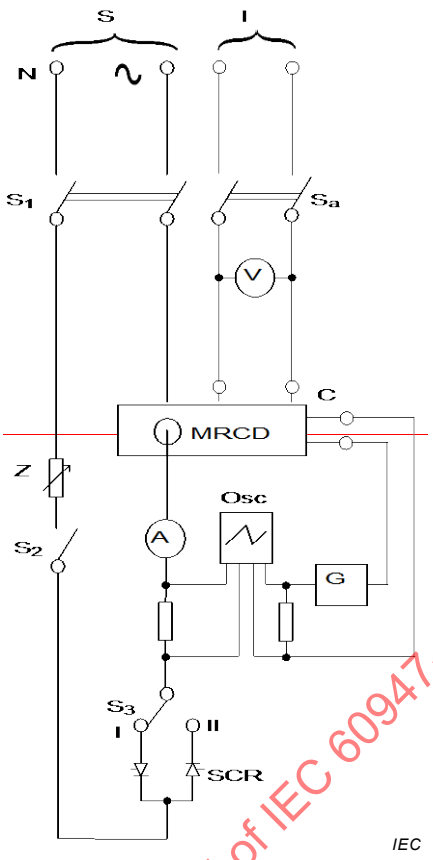


Figure M.8b) – MRCD avec un dispositif de détection intégré

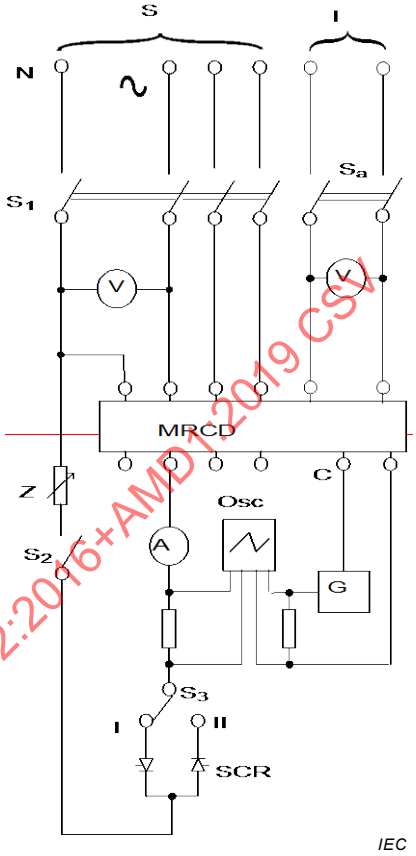


Figure M.8c) – MRCD de type à bornes

Légende

S alimentation électrique
I source de tension séparée, le cas échéant
V voltmètre
A ampèremètre
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire
S_3 inverseur
S_a interrupteur auxiliaire
Z impédance variable
T dispositif de détection
C circuit de sortie
G générateur
Osc oscilloscope
SCR thyristor

Figure M.8 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu pulsé (sans appareil de coupure)

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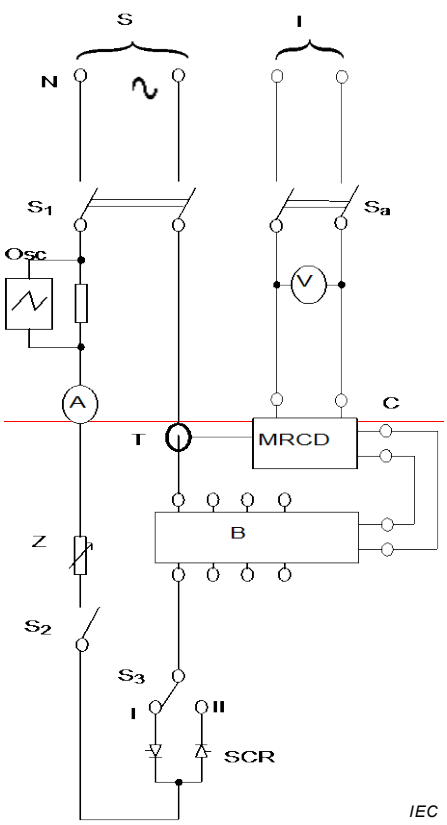


Figure M.9a) – MRCD avec un dispositif de détection séparé

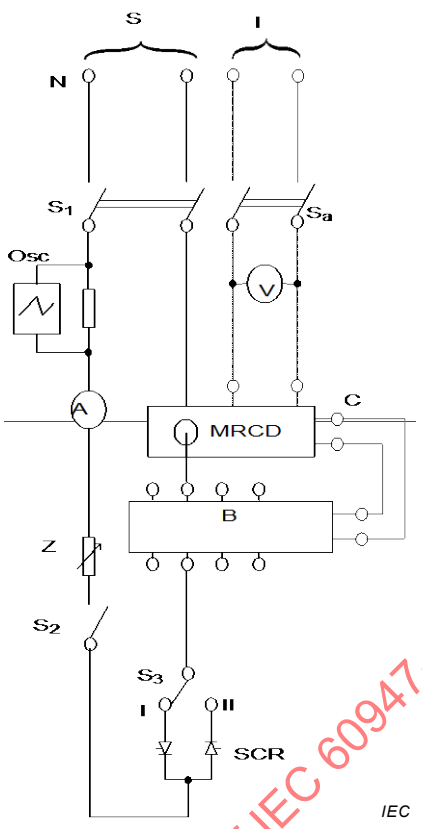


Figure M.9b) – MRCD avec un dispositif de détection intégré

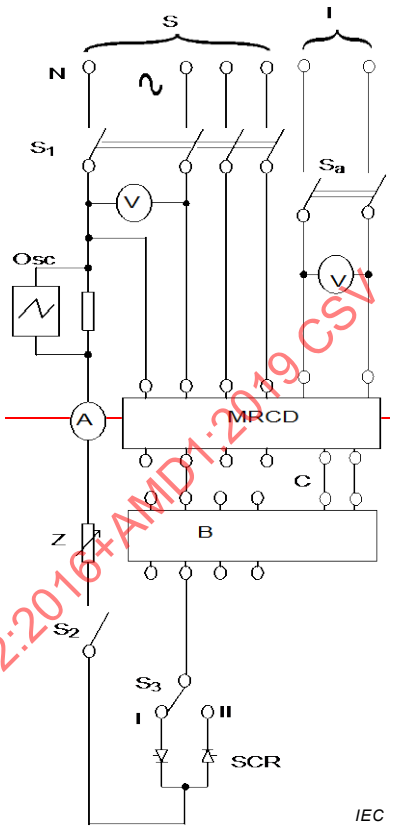


Figure M.9c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_3 inverseur

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

B appareil de coupure

Osc oscilloscope

SCR thyristor

Figure M.9 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu pulsé (avec appareil de coupure)

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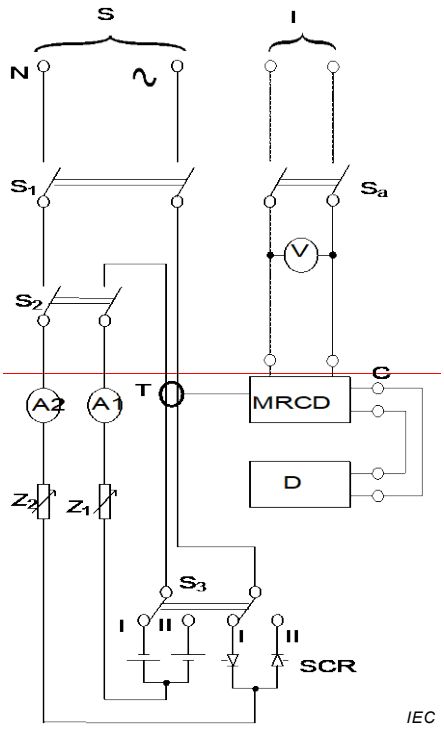


Figure M.10a) – MRCD avec un dispositif de détection séparé

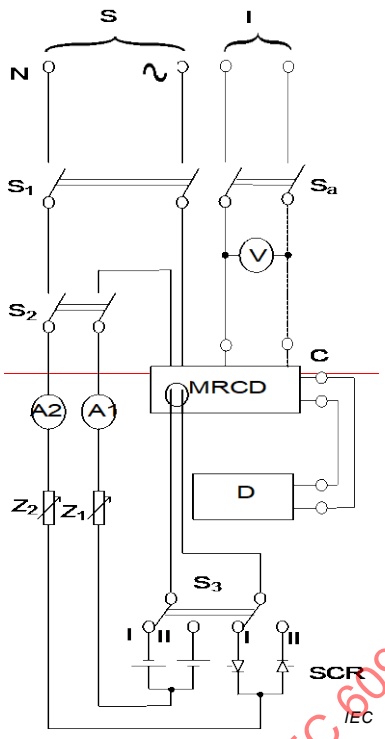


Figure M.10b) – MRCD avec un dispositif de détection intégré

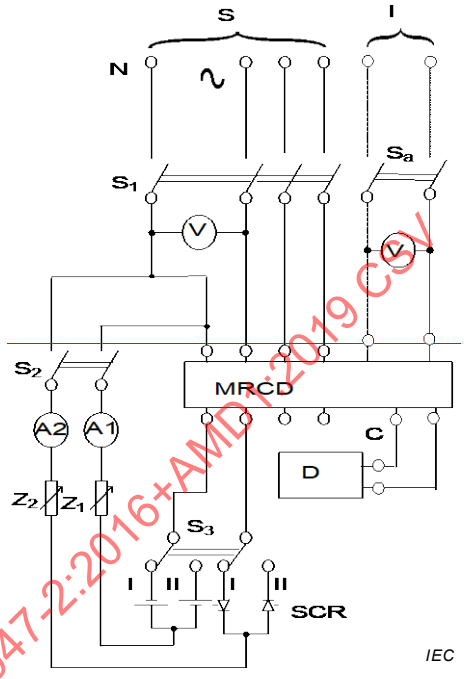


Figure M.10c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A_1 ampèremètre mesurant le courant continu

A_2 ampèremètre mesurant le courant alternatif efficace

S_1 interrupteur multipolaire

S_2 interrupteur bipolaire

S_3 double inverseur

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

SCR thyristor

Figure M.10 – Circuits d'essai pour la vérification du fonctionnement dans le cas de courants différentiels résiduels continus pulsés auxquels est superposé un courant continu lissé de 6 mA

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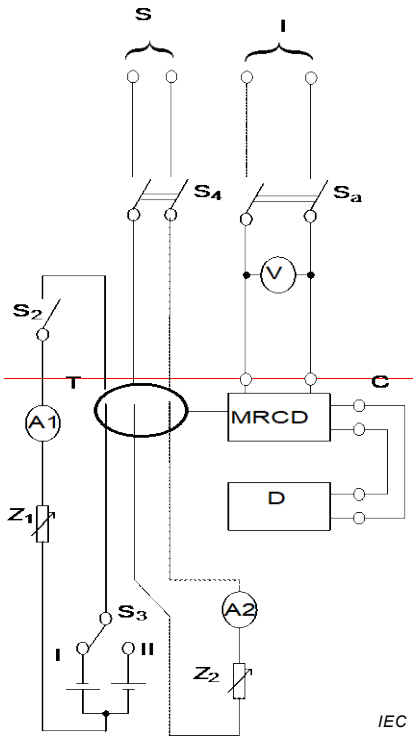


Figure M.11a) – MRCD avec un dispositif de détection séparé

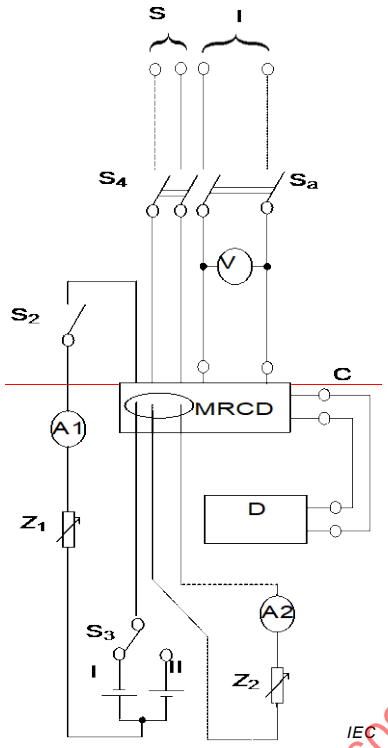


Figure M.11b) – MRCD avec un dispositif de détection intégré

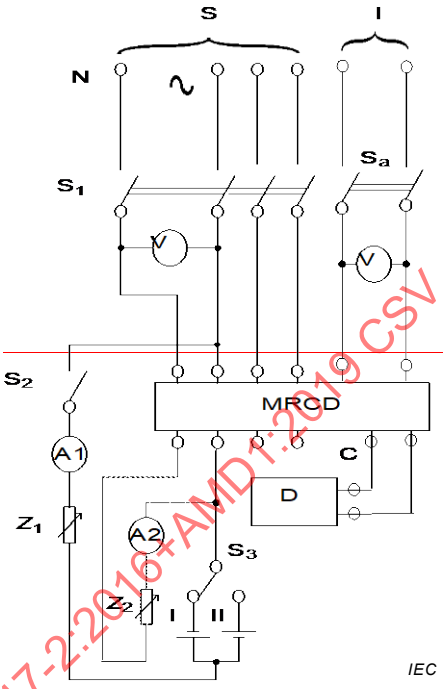


Figure M.11c) – MRCD de type à bornes

Légende

S alimentation électrique
I source de tension séparée, le cas échéant
V voltmètre
A_1 ampèremètre mesurant le courant continu
A_2 ampèremètre mesurant le courant alternatif efficace
S_1 interrupteur multipolaire
S_2 interrupteur unipolaire
S_3 double inverseur
S_4 interrupteur tétrapolaire
S_a interrupteur auxiliaire
Z_1, Z_2 impédances variables
T dispositif de détection
C circuit de sortie
D appareil indiquant le changement d'état

Figure M.11 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une montée lente du courant différentiel résiduel continu lissé

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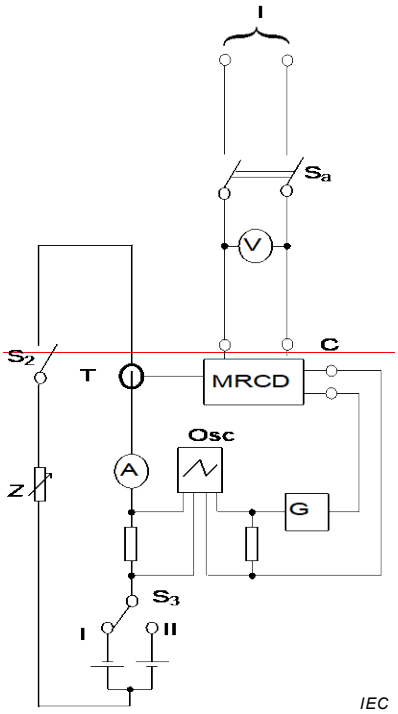


Figure M.12a) – MRCD avec un dispositif de détection séparé

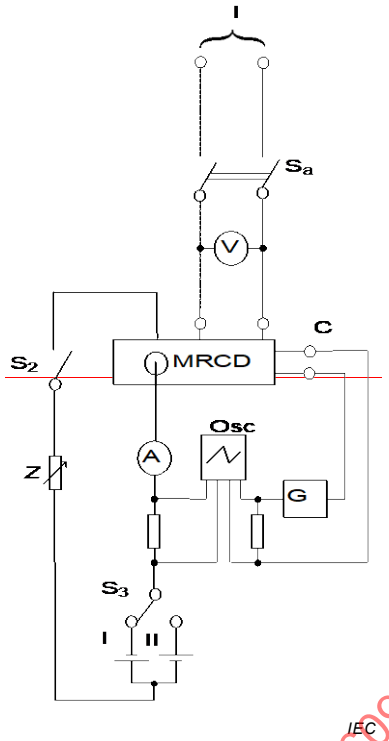


Figure M.12b) – MRCD avec un dispositif de détection intégré

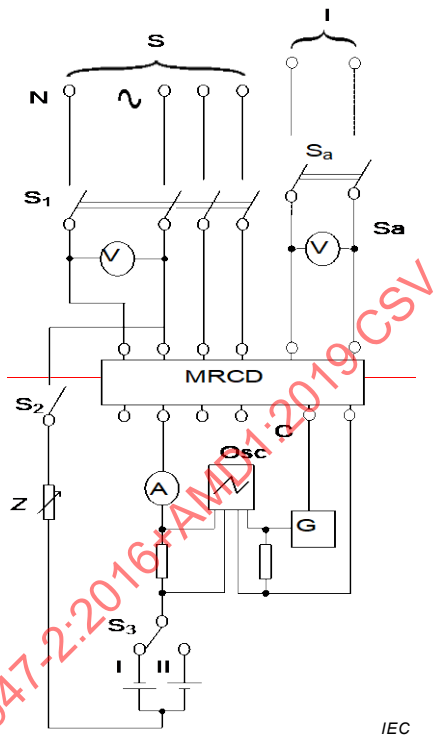


Figure M.12c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre mesurant le courant continu

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_3 inverseur

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

G générateur

Osc oscilloscope

Figure M.12 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu lissé (sans appareil de coupure)

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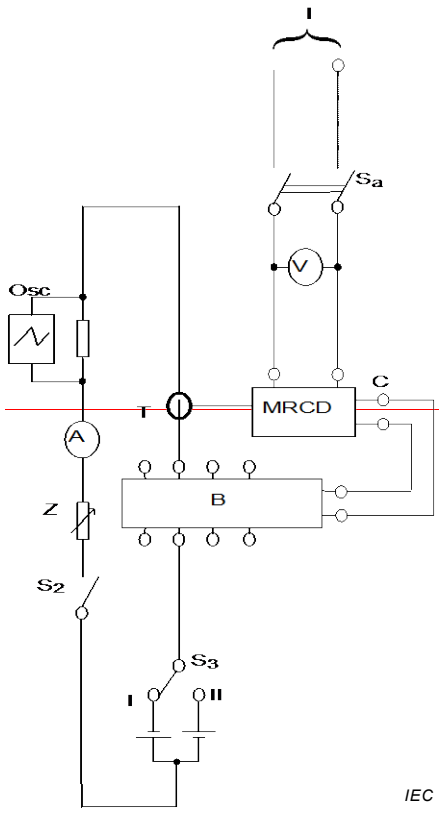


Figure M.13a) – MRCD avec un dispositif de détection séparé

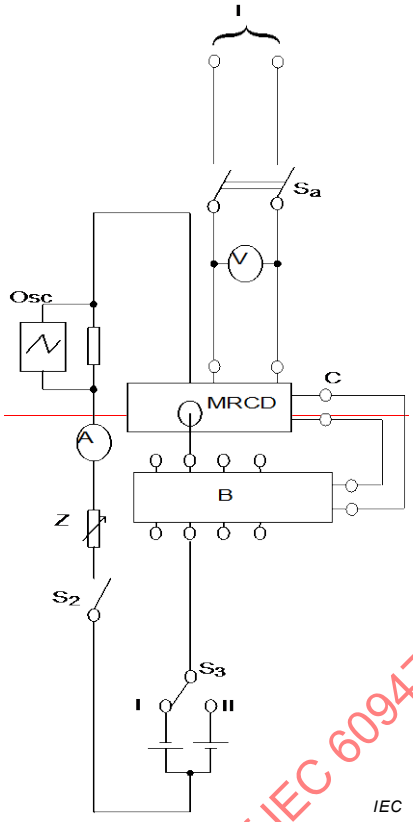


Figure M.13b) – MRCD avec un dispositif de détection intégré

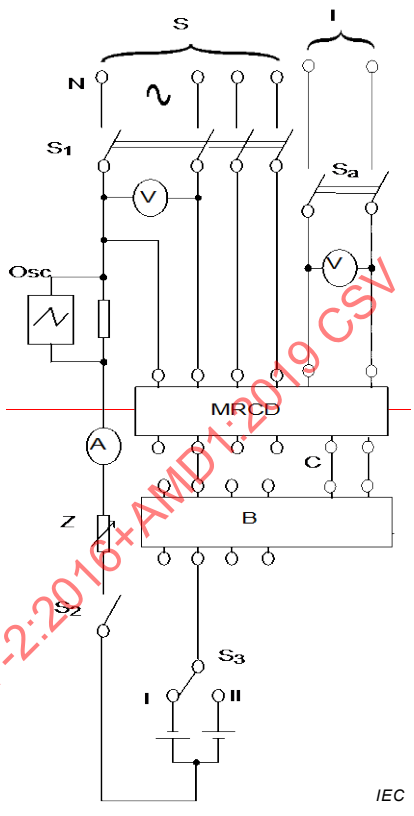


Figure M.13c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre mesurant le courant continu

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_3 inverseur

S_a interrupteur auxiliaire

Z impédance variable

T dispositif de détection

C circuit de sortie

B appareil de coupure

Osc oscilloscope

Figure M.13 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition soudaine d'un courant différentiel résiduel continu lissé (avec appareil de coupure)

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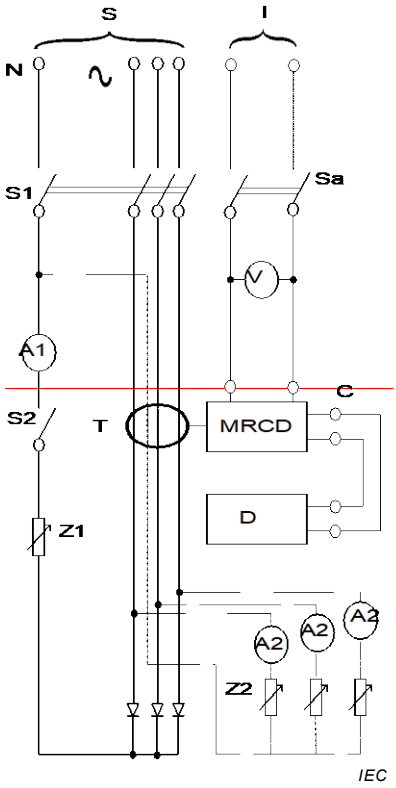


Figure M.14a) – MRCD avec un dispositif de détection séparé

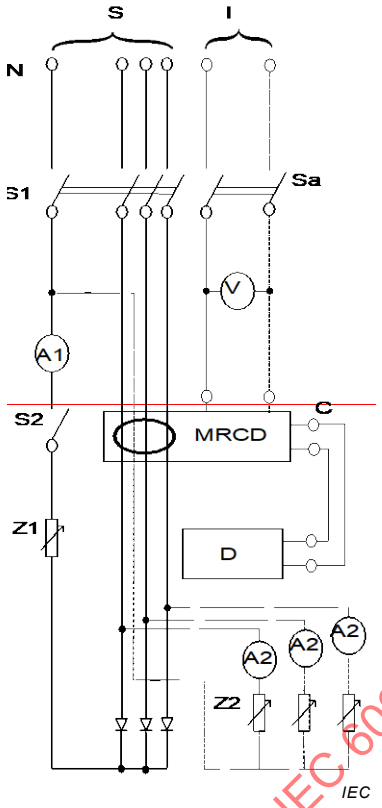


Figure M.14b) – MRCD avec un dispositif de détection intégré

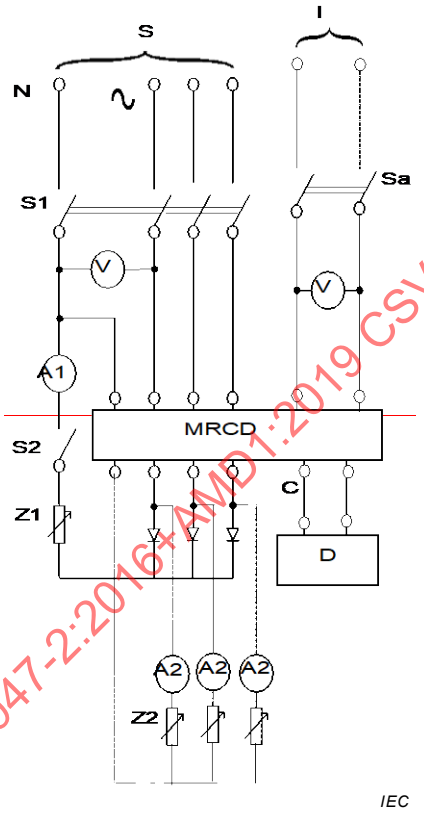


Figure M.14c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A_1 ampèremètre mesurant le courant efficace

A_2 ampèremètre mesurant le courant alternatif

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_a interrupteur auxiliaire

Z_1, Z_2 impédances variables

T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

Figure M.14 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentant progressive d'un courant différentiel résiduel résultant d'un défaut dans un circuit alimenté par un redresseur triphasé en étoile ou en pont

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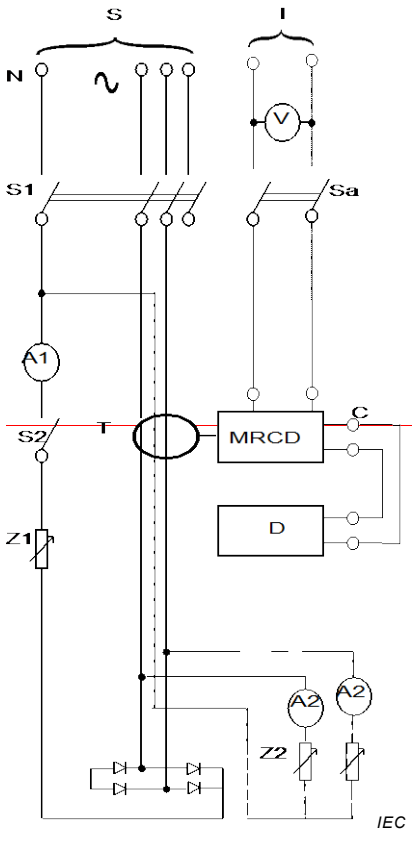


Figure M.15a) – MRCD avec un dispositif de détection séparé

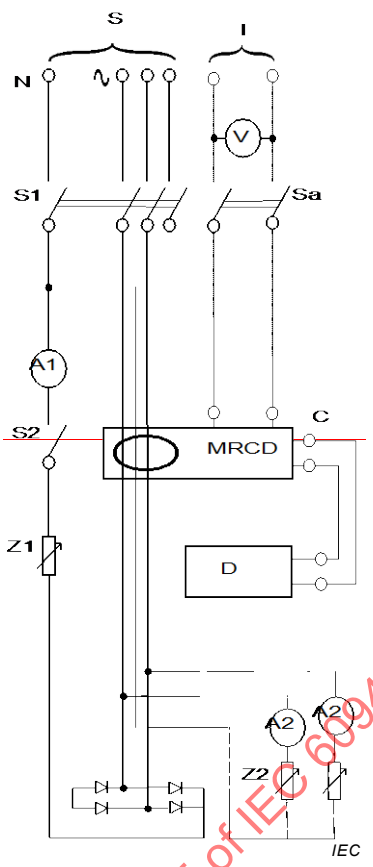


Figure M.15b) – MRCD avec un dispositif de détection intégré

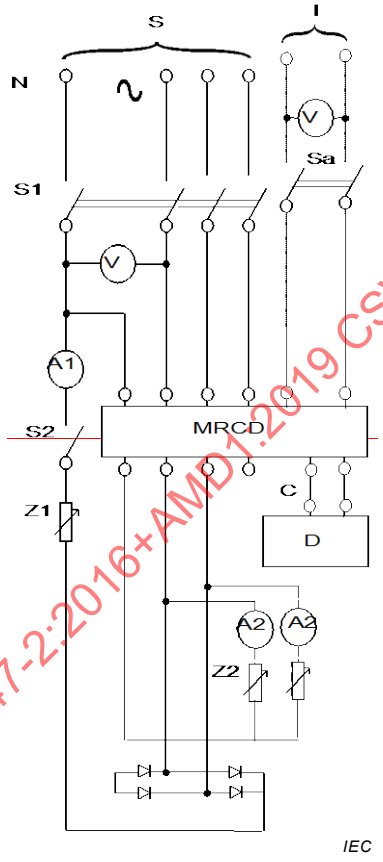


Figure M.15c) – MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A_1 ampèremètre mesurant le courant efficace

A_2 ampèremètre mesurant le courant alternatif

S_1 interrupteur multipolaire

S_2 interrupteur unipolaire

S_a interrupteur auxiliaire

Z_1, Z_2 impédances variables

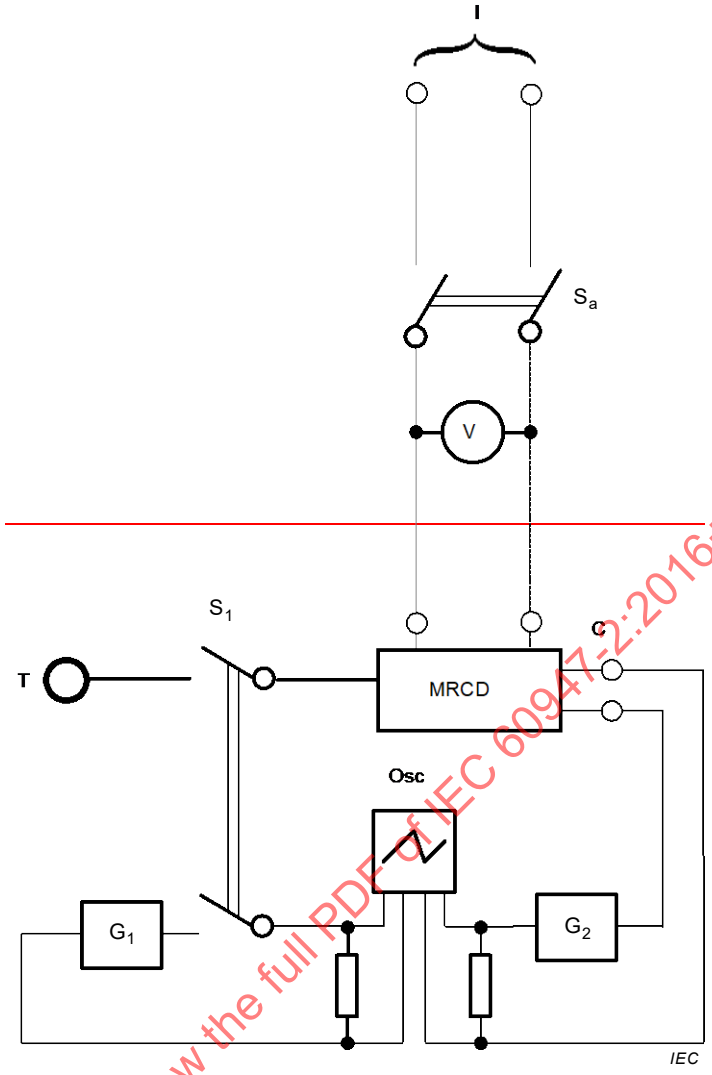
T dispositif de détection

C circuit de sortie

D appareil indiquant le changement d'état

Figure M.15 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentation progressive d'un courant différentiel résiduel résultant d'un défaut dans un circuit alimenté par un redresseur double alternance entre phases

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~~**Légende**~~

~~I source de tension séparée, le cas échéant~~

~~V voltmètre~~

~~S_1 interrupteur multipolaire~~

~~S_a interrupteur auxiliaire~~

~~T dispositif de détection~~

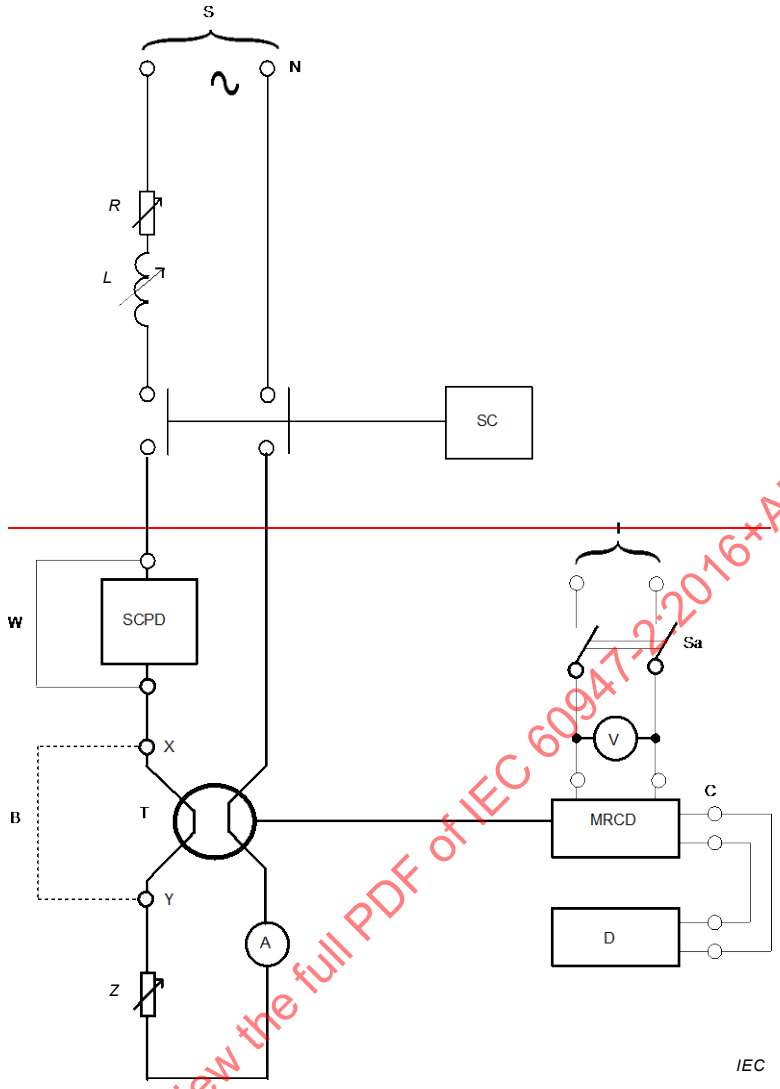
~~C circuit de sortie~~

~~G générateur~~

~~Osc oscilloscope~~

~~**Figure M.16 – Circuit d'essai pour la vérification du comportement des MRCD à dispositif de détection séparé en cas de défaillance de la connexion du dispositif de détection**~~

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Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_a interrupteur auxiliaire

SC interrupteur de court-circuit

W connexion temporaire

B connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant le dispositif de détection

L bobine d'inductance variable

R résistance variable

Z impédance variable

T dispositif de détection

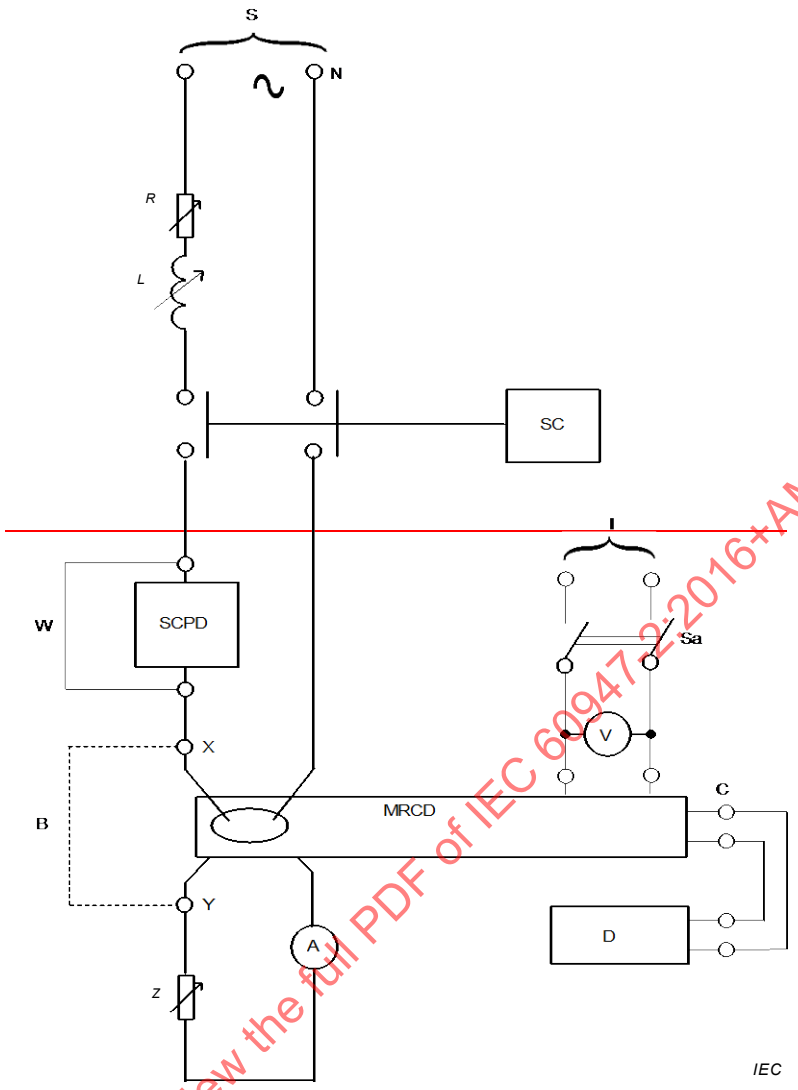
C circuit de sortie

D appareil indiquant le changement d'état

SCPD appareil de protection contre les courts-circuits

Figure M.17 – Circuit d'essai pour la vérification du comportement d'un MRCD à dispositif de détection séparé dans des conditions de court-circuit

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Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_a interrupteur auxiliaire

SC interrupteur de court-circuit

W connexion temporaire

B connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant le dispositif de détection

L bobine d'inductance variable

R résistance variable

Z impédance variable

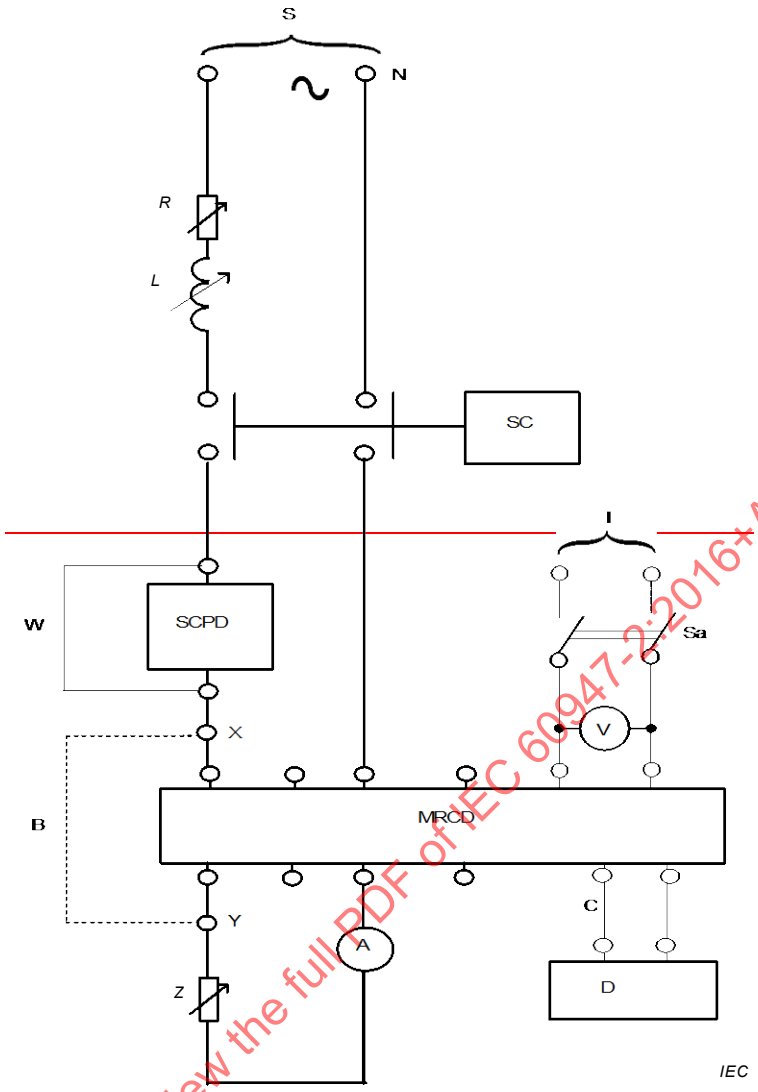
C circuit de sortie

D appareil indiquant le changement d'état

SCPD appareil de protection contre les courts-circuits

Figure M.18 – Circuit d'essai pour la vérification du comportement d'un MRCD à dispositif de détection séparé dans des conditions de court-circuit

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Légende

S alimentation électrique

A ampèremètre

SC interrupteur de court-circuit

W connexion temporaire

B connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant le dispositif de détection

L bobine d'inductance variable

R résistance variable

Z impédance variable

C circuit de sortie

D appareil indiquant le changement d'état

SCPD appareil de protection contre les courts-circuits

Figure M.19 – Circuit d'essai pour la vérification du comportement d'un MRCD de type à bornes dans des conditions de court-circuit

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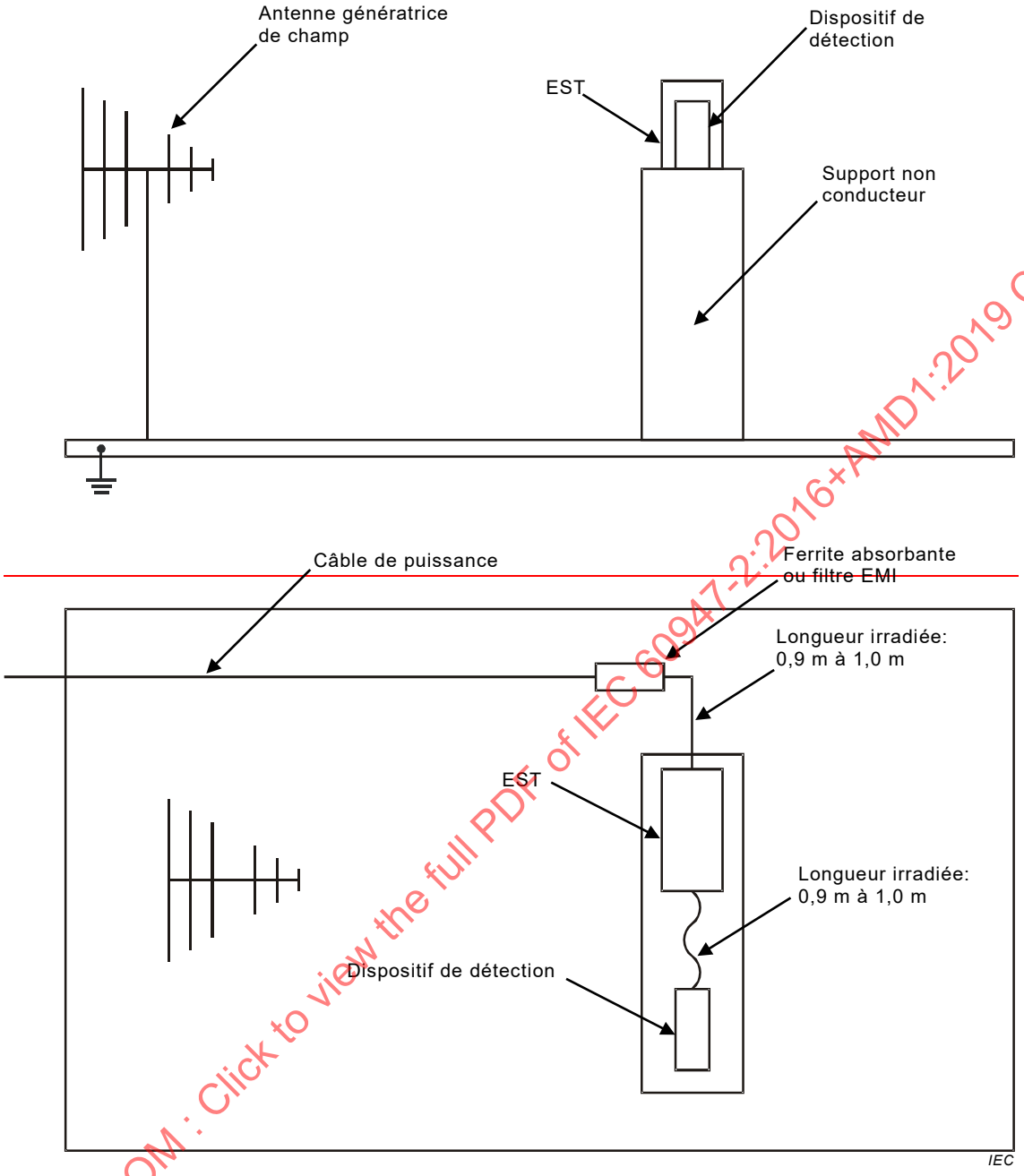
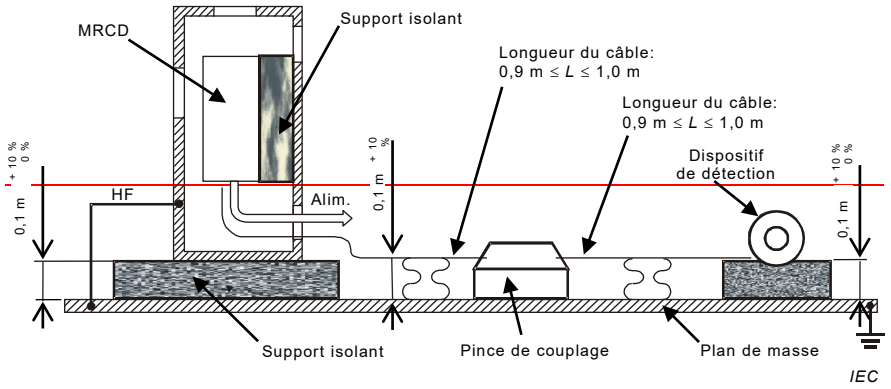
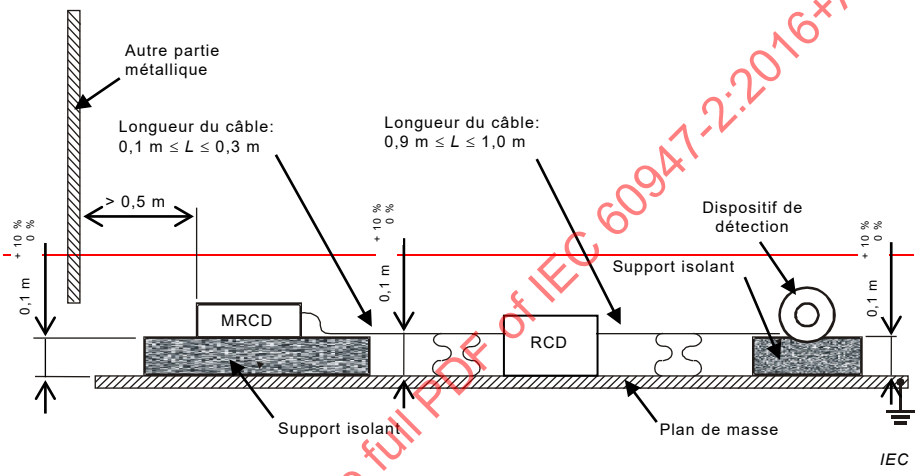


Figure M.20 – Vérification de l'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques – Installation d'essai pour les MRCD à dispositif de détection séparé (complémentaire à l'essai de l'Annexe B)

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~~Figure M.21 – Vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur le raccordement du dispositif de détection d'un MRCD à dispositif de détection séparé (complémentaire à l'essai de l'Annexe B)~~



~~Légende~~

~~RCD réseau de couplage-découplage~~

~~Figure M.22 – Vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques – Installation d'essai pour les MRCD à dispositif de détection séparé (complémentaire à l'essai de l'Annexe B)~~

M.1 Généralités

M.1.1 Préambule

Pour assurer la protection contre les dangers occasionnés par les chocs électriques, des appareils agissant sous l'effet des courants différentiels résiduels sont utilisés comme mesure de protection. Les appareils à courant différentiel résiduel, lorsque les organes de détection du courant et l'appareil de traitement sont montés ensemble avec le disjoncteur, sont couverts par l'Annexe B.

Les dispositions de l'Annexe B sont applicables à la présente annexe en adaptant, en amendant ou en complétant l'Annexe B, selon les besoins pour couvrir son application aux matériels dont l'organe de détection du courant et/ou l'appareil de traitement sont montés séparément de l'appareil de coupure de courant.

Dans la présente annexe, le terme "DPR" utilisé dans l'Annexe B (voir B.2.3.1) est remplacé par le terme "MRCD" (voir M.2.2.1).

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Lorsque cela est approprié, référence est faite au paragraphe correspondant de l'Annexe B. Dans les autres cas, référence est faite au paragraphe approprié de la partie principale du présent document ou, s'il y a lieu, de l'IEC 60947-1.

Comme le matériel couvert par la présente annexe ne concerne pas un appareil de coupure de courant, certaines locutions conventionnelles utilisées dans l'Annexe B ont été adaptées en conséquence dans la présente annexe, par exemple "position fermée" est remplacé par "condition prête", signifiant "prêt à fonctionner".

M.1.2 Domaine d'application et objet

La présente annexe est applicable aux appareils à courant différentiel résiduel qui n'intègrent pas un appareil de coupure de courant; ceux-ci sont désignés ci-après "appareils modulaires à courant différentiel résiduel (MRCD, Modular Residual Current Device)". Ils sont principalement destinés à être utilisés en association avec des disjoncteurs conformes au présent document.

Ils peuvent être ou non fonctionnellement dépendants d'une source de tension.

L'objet de la présente annexe est d'établir les exigences spécifiques auxquelles doivent satisfaire les MRCD, en association avec le ou les appareils de coupure de courant spécifiés.

M.2 Termes et définitions

Les termes et définitions de l'Annexe B sont applicables.

Les termes et définitions complémentaires suivants sont applicables à la présente annexe.

M.2.1 Termes et définitions relatifs à l'alimentation d'un MRCD

M.2.1.1
source de tension
source destinée à fournir l'alimentation qui peut être:

– la tension d'alimentation;
– une tension autre que la tension d'alimentation

M.2.2 Termes et définitions relatifs au fonctionnement et aux fonctions d'un MRCD

M.2.2.1
appareil modulaire à courant différentiel résiduel
MRCD
appareil ou association d'appareils comprenant un organe de détection du courant et un appareil de traitement, conçu pour détecter et apprécier le courant différentiel résiduel et pour commander l'ouverture des contacts d'un appareil de coupure de courant

Note 1 à l'article: L'abréviation "MRCD" est dérivée du terme anglais développé correspondant "modular residual current device".

M.2.2.2 Termes et définitions relatifs au temps

M.2.2.2.1
temps de fonctionnement d'un MRCD
temps qui s'écoule entre l'instant où le courant différentiel résiduel de fonctionnement est appliqué subitement et l'instant où la sortie du MRCD change d'état

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M.2.2.2.2
temps combiné
temps qui s'écoule entre l'instant où le courant différentiel résiduel de fonctionnement est appliqué subitement et l'instant d'extinction de l'arc de l'appareil de coupure de courant associé

M.2.2.2.3
temps limite de non-fonctionnement
temps maximal pendant lequel une valeur du courant différentiel résiduel supérieure à la valeur du courant assigné différentiel résiduel de non-fonctionnement peut être appliquée au MRCD, sans l'amener au point de fonctionnement.

M.2.3
courant différentiel résiduel de court-circuit conditionnel
courant différentiel résiduel présumé auquel un MRCD protégé par un appareil de protection contre les courts-circuits spécifié peut résister de manière satisfaisante pendant le temps total de fonctionnement de cet appareil dans des conditions spécifiées

M.2.4
courant différentiel résiduel de courte durée admissible
courant différentiel résiduel qu'un MRCD en position de fermeture peut véhiculer pendant une courte durée spécifiée dans des conditions spécifiées

M.3 Classification

M.3.1 Classification selon la configuration des conducteurs primaires

M.3.1.1 Type à bornes: MRCD avec des bornes d'entrée et de sortie, les conducteurs primaires étant intégrés

M.3.1.2 Type à conducteur traversant

M.3.1.2.1 MRCD avec l'organe de détection et l'appareil de traitement combinés

M.3.1.2.2 MRCD avec l'organe de détection et l'appareil de traitement séparés

M.3.2 Classification selon le mode de fonctionnement

M.3.2.1 MRCD sans source de tension (voir Figure M.22)

M.3.2.2 MRCD avec source de tension

M.3.2.2.1 Fonctionnant automatiquement en cas de défaillance de la source de tension

M.3.2.2.2 Ne fonctionnant pas automatiquement en cas de défaillance de la source de tension mais capable de fonctionner comme prévu en cas de courant différentiel résiduel de défaut

M.3.3 Classification selon la possibilité de réglage du courant différentiel résiduel de fonctionnement

Le paragraphe B.3.2 est applicable.

M.3.4 Classification selon la temporisation de la fonction de courant différentiel résiduel

Le paragraphe B.3.3 est applicable.

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M.3.5 Classification selon le comportement en présence d'une composante continue

M.3.5.1 MRCD de type AC (voir M.4.2.2.1)

M.3.5.2 MRCD de type A (voir M.4.2.2.2)

M.3.5.3 MRCD de type B (voir M.4.2.2.3)

M.4 Caractéristiques des MRCD

M.4.1 Caractéristiques générales

M.4.1.1 Caractéristiques du circuit contrôlé

M.4.1.1.1 Plage de fréquences assignées

Plage des valeurs de fréquence du circuit contrôlé pour lesquelles le MRCD est conçu et pour lesquelles il fonctionne correctement dans des conditions spécifiées.

M.4.1.1.2 Tension assignée (U_n)

Valeur de la tension assignée par le fabricant au MRCD.

M.4.1.1.3 Courant assigné (I_n)

M.4.1.1.3.1 Type à bornes

Le paragraphe 4.3.3.3 est applicable.

M.4.1.1.3.2 Type à conducteur traversant

Valeur de courant, assignée par le fabricant au MRCD et marquée conformément au Tableau M.1, point M.1.4), que le MRCD peut contrôler en service ininterrompu dans des conditions spécifiées (voir M.8.6).

M.4.1.1.4 Tension d'isolement assignée (U_i)

Tension, assignée par le fabricant, à laquelle se réfèrent les essais diélectriques et les lignes de fuite du MRCD par rapport au circuit contrôlé.

M.4.1.1.5 Tension assignée de tenue aux chocs (U_{imp})

Valeur crête de la tension de choc que le MRCD peut supporter sans défaillance et à laquelle se réfèrent les valeurs des distances d'isolement par rapport au circuit contrôlé.

M.4.1.2 Caractéristiques de la source de tension des MRCD

M.4.1.2.1 Valeurs assignées de la source de tension des MRCD (U_s)

Valeurs de la source de tension auxquelles se réfèrent les fonctions d'un MRCD.

M.4.1.2.2 Valeurs assignées des fréquences de la source de tension des MRCD

Valeurs des fréquences de la source de tension auxquelles se réfèrent les fonctions d'un MRCD.

M.4.1.2.3 Tension d'isolement assignée (U_i)

Le paragraphe 4.3.1.2 de l'IEC 60947-1:2007 est applicable.

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M.4.1.2.4 Tension assignée de tenue aux chocs (U_{imp})

Le paragraphe 4.3.1.3 de l'IEC 60947-1:2007 est applicable.

NOTE Dans le cas d'une alimentation spécifiée, l'exigence est applicable aux connexions d'entrée.

M.4.1.3 Caractéristiques des contacts auxiliaires

Le paragraphe 4.6 de l'IEC 60947-1:2007 est applicable.

M.4.2 Caractéristiques des MRCD concernant leur fonction de courant différentiel résiduel

M.4.2.1 Généralités

Le paragraphe B.4.2.4 est applicable en remplaçant "temps de non-réponse" par "temps de non-fonctionnement" et avec les ajouts suivants.

Les valeurs maximales du temps de fonctionnement du MRCD doivent être déclarées par le fabricant pour des valeurs de courant différentiel résiduel égales à $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (ou 0,25 A pour $I_{\Delta n} \leq$ 30 mA), 10 $I_{\Delta n}$ (ou 0,5 A pour $I_{\Delta n} \leq$ 30 mA).

Le temps combiné maximal doit être conforme au Tableau B.1 pour un MRCD de type non temporisé, et au Tableau B.2 pour un MRCD de type temporisé ayant une durée limite de non-fonctionnement de 0,06 s.

Les MRCD avec $I_{\Delta n} \leq$ 30 mA doivent être du type non temporisé.

M.4.2.2 Caractéristiques de fonctionnement dans le cas d'un courant différentiel résiduel avec une composante continue

M.4.2.2.1 MRCD de type AC

Le paragraphe B.4.4.1 est applicable.

M.4.2.2.2 MRCD de type A

Le paragraphe B.4.4.2 est applicable.

M.4.2.2.3 MRCD de type B

Le paragraphe B.4.4.3 est applicable.

M.4.3 Comportement en condition de court-circuit

M.4.3.1 Courant conditionnel de court-circuit assigné (I_{cc})

Le paragraphe 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.4.3.2 Courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$)

Le paragraphe 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.4.3.3 Courant assigné de courte durée admissible (I_{cw})

Le paragraphe 4.3.6.1 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.4.3.4 Valeur de crête de courant admissible

Le paragraphe 2.5.28 de l'IEC 60947-1:2007 est applicable au circuit primaire d'un MRCD.

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M.4.3.5 Courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$)

Le courant assigné différentiel résiduel de courte durée admissible d'un matériel est la valeur du courant différentiel résiduel de courte durée admissible, assignée au matériel par le fabricant, que le matériel peut supporter sans dommage, dans les conditions d'essai spécifiées dans le présent document.

M.4.4 Valeurs préférentielles et valeurs limites

M.4.4.1 Valeurs préférentielles du courant différentiel résiduel de fonctionnement assigné ($I_{\Delta n}$)

Le paragraphe B.4.2.1 est applicable.

M.4.4.2 Valeur minimale du courant différentiel résiduel de non-fonctionnement assigné ($I_{\Delta no}$)

Le paragraphe B.4.2.3 est applicable.

M.4.4.3 Valeur limite de surintensité de non-fonctionnement dans le cas d'une charge monophasée dans un circuit polyphasé

Le paragraphe B.4.2.4 est applicable.

M.4.4.4 Valeurs préférentielles de la tension assignée de la source de tension des MRCD

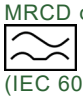
Le paragraphe 4.5.1 est applicable.

M.5 Informations sur le matériel

Le MRCD, l'appareil de traitement ou l'organe de détection, suivant le cas, doit être fourni avec les informations indiquées dans le Tableau M.1. Les marquages doivent être indélébiles. Le marquage doit être apposé sur le MRCD lui-même ou sur une ou plusieurs plaques signalétiques.

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Tableau M.1 – Informations sur le matériel

Elément	Information	Emplacement du marquage		
		Sur un appareil unique	Sur des appareils séparés	
			Organe de détection	Appareil de traitement
M1.1	caractéristique de fonctionnement en présence de courants différentiels résiduels avec ou sans composante continue: – MRCD de type AC avec le symbole  (IEC 60417-6148:2012-01) – MRCD de type A avec le symbole  (IEC 60417-6149:2012-01) – MRCD de type B avec le symbole  (IEC 60417-6398:2017-12) ou  (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	-	Visible
M1.2	courant assigné différentiel résiduel de fonctionnement (valeur(s) ou plage de valeurs, suivant le cas) ($I_{\Delta n}$)	Visible	-	Visible
M1.3	temps limite de non-fonctionnement (valeur ou plage de valeurs) à 2 $I_{\Delta n}$ pour le type temporisé, suivant le cas (Δt)	Visible	-	Visible
M1.4	courant maximal assigné du circuit contrôlé (I_n)	Visible	Marqué	Visible [a]
M1.5	appareil d'essai avec la lettre "T"	Visible	-	Visible
M2.1	nom du fabricant ou marque de fabrique	Marqué	Marqué	Marqué
M2.2	désignation du type ou référence du catalogue	Marqué	Marqué	Marqué
M2.3	IEC 60947-2	Marqué	-	Marqué
M2.4	tension assignée de la source de tension (U_s)	Marqué	-	Marqué
M2.5	tension assignée du circuit contrôlé (U_n)	Marqué	Marqué	-
M2.6	tension assignée de tenue aux chocs du circuit contrôlé (U_{imp})	Marqué	Marqué	-
M3.1	fréquence assignée de la source de tension	Documentation	-	Documentation
M3.2	tension assignée de tenue aux chocs de la source de tension (U_{imp})	Documentation	-	Documentation
M3.3	caractéristiques de sortie et/ou appareil(s) de coupure de courant spécifié(s)	Documentation	-	Documentation
M3.4	courant assigné différentiel résiduel de non-fonctionnement s'il est différent de 0,5 $I_{\Delta n}$ ($I_{\Delta no}$)	Documentation	-	Documentation
M3.5	fréquence assignée du circuit contrôlé	Documentation	Documentation	-

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Elément	Information	Emplacement du marquage		
		Sur un appareil unique	Sur des appareils séparés	
			Organe de détection	Appareil de traitement
M3.6	réglage minimal du courant différentiel résiduel à 6 I_n pour les MRCD avec un organe de détection séparé	-	Documentation	Documentation
M3.7	courant conditionnel de court-circuit assigné (I_{cc}) et/ou courant assigné de courte durée admissible (I_{cw}), et courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$)	Documentation	Documentation	Documentation
M3.8	indice IP, le cas échéant (voir l'Annexe C de l'IEC 60947-1:2007)	Documentation	Documentation	Documentation
M3.9	position d'utilisation et précautions de montage	Documentation	Documentation	Documentation
M3.10	schéma de câblage	Documentation	Documentation	Documentation
M3.11	raccordement de l'organe de détection à l'appareil de traitement (type de câble, longueur, etc.)	-	Documentation	-
M3.12	pour un MRCD du type à conducteur traversant, les dimensions de la ou des ouvertures de passage du conducteur et la position du conducteur traversant par rapport à l'organe de détection	Documentation	Documentation	-
M3.13	pour un MRCD du type à bornes, la section maximale des conducteurs à raccorder	Documentation	-	-
M3.14	distances à respecter par rapport aux conducteurs environnants	Documentation	Documentation	Documentation
M3.15	conditions à respecter pour le raccordement entre l'appareil de traitement et l'appareil de coupure de courant	Documentation	-	Documentation
M3.16	les DPCC à associer au MRCD	Documentation	-	Documentation
M3.17	pour un type non temporisé, le ou les appareils de coupure de courant à associer au MRCD pour respecter les temps combinés maximaux du Tableau B.1	Documentation	-	Documentation
M3.18	pour un type temporisé ayant une durée limite de non-fonctionnement de 0,06 s, le ou les appareils de coupure de courant à associer au MRCD pour respecter les temps combinés du Tableau B.2	Documentation	-	Documentation

Légende

Visible: visible depuis le devant lorsque le MRCD est installé en configuration de service et que l'appareil d'essai est accessible

Marqué: marqué sur le matériel

Documentation: spécifié dans la documentation du fabricant

[a] Uniquement applicable si le courant différentiel résiduel est marqué en pourcentage de I_n.

M.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

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M.7 Exigences relatives à la conception et au fonctionnement

M.7.1 Exigences relatives à la conception

Il ne doit pas être possible de modifier la caractéristique de fonctionnement d'un MRCD par des moyens autres que ceux spécifiquement destinés au réglage du courant différentiel résiduel de fonctionnement assigné ou un déclencheur à retard indépendant. Le passage d'un réglage à un autre ne doit être possible que par une action délibérée, telle que l'utilisation d'un outil, la saisie d'un mot de passe ou des moyens équivalents.

NOTE Les MRCD peuvent être équipés d'organes indiquant l'état des sorties.

M.7.2 Exigences relatives au fonctionnement

M.7.2.1 Fonctionnement en cas de courant différentiel résiduel

Le paragraphe B.7.2.1 est applicable.

La conformité doit être vérifiée par les essais décrits en M.8.3.

M.7.2.2 Fonctionnement dans des conditions de court-circuit

Les MRCD doivent avoir un courant conditionnel de court-circuit assigné (I_{cc}) ou un courant assigné de courte durée admissible (I_{cw}), mais peuvent avoir les deux. Ils doivent aussi avoir un courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$) ou un courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$), mais peuvent avoir les deux.

Les MRCD doivent satisfaire aux exigences des essais pertinents décrits en M.8.14.

M.7.2.3 Endurance mécanique et endurance électrique

Les MRCD doivent satisfaire aux exigences des essais décrits en M.8.11.

M.7.2.4 Effets des conditions d'environnement

Les MRCD doivent satisfaire aux exigences de l'essai décrit en M.8.15.

M.7.2.5 Propriétés diélectriques

Les MRCD doivent pouvoir supporter la tension de tenue aux chocs déclarée par le fabricant conformément au 7.2.3 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Les MRCD doivent satisfaire aux exigences des essais décrits en M.8.4.

Les distances d'isolement entre les parties sous tension du circuit contrôlé et:

– les parties sous tension du MRCD;
– les parties destinées à être mises à la terre;
– les distances d'isolement entre les conducteurs principaux, pour les MRCD du type à bornes;

doivent supporter la tension d'essai donnée dans le Tableau 12 de l'IEC 60947-1:2007 correspondant à la tension assignée de tenue aux chocs.

M.7.2.6 Appareil d'essai

Les MRCD doivent être équipés d'un appareil d'essai pour simuler le passage d'un courant différentiel résiduel dans l'organe de détection, afin de permettre la vérification périodique de la capacité des MRCD à fonctionner.

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L'appareil d'essai doit satisfaire aux essais décrits en M.8.5.

Aucune tension ne doit apparaître sur le conducteur de protection lors du fonctionnement de l'appareil d'essai, s'il y a lieu.

L'organe de manœuvre de l'appareil d'essai doit être désigné par la lettre T, et sa couleur ne doit pas être rouge ou verte; l'emploi d'une couleur claire est recommandé.

NOTE L'appareil d'essai est uniquement destiné à vérifier la fonction de déclenchement et non la valeur à laquelle cette fonction s'accomplit, par rapport au courant différentiel résiduel de fonctionnement assigné et à la durée de coupure.

M.7.2.7 Valeur de surintensité de non-fonctionnement dans le cas d'une charge monophasée

Les MRCD doivent satisfaire aux exigences de l'essai décrit en M.8.6.

M.7.2.8 Résistance des MRCD aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc

Les MRCD doivent satisfaire à l'essai décrit en M.8.7.

M.7.2.9 Comportement des MRCD de type A et de type B en cas de courant de défaut à la terre comprenant une composante continue

Les MRCD de type A et de type B doivent satisfaire aux exigences des essais décrits en M.8.8, suivant le cas.

M.7.2.10 Exigences pour les MRCD avec source de tension

Les MRCD fonctionnellement dépendants d'une source de tension doivent fonctionner correctement à une quelconque valeur de tension comprise entre 0,85 et 1,1 fois la valeur assignée U_s (voir Figure M.22 et M.4.12.2.1).

Selon leur classification, les MRCD fonctionnellement dépendants d'une source de tension doivent satisfaire aux exigences données dans le Tableau M.2.

Tableau M.2 – Exigences pour les MRCD avec source de tension

Classification de l'appareil selon M.3.2.2	Comportement en cas de défaillance de la source de tension
MRCD fonctionnant automatiquement sans retard en cas de défaillance de la source de tension (M.3.2.2.1)	Fonctionnement sans retard selon M.8.12
MRCD fonctionnant automatiquement avec retard en cas de défaillance de la source de tension (M.3.2.2.1)	Fonctionnement avec retard selon M.8.12
MRCD ne fonctionnant pas automatiquement en cas de défaillance de la source de tension mais capable de fonctionner comme prévu en cas d'apparition d'un courant différentiel résiduel de défaut (M.3.2.2.2)	Fonctionnement selon M.8.13

M.7.2.11 Echauffement des MRCD du type à bornes

M.7.2.11.1 Généralités

Les échauffements des pièces des MRCD de type à bornes ne doivent pas dépasser les valeurs spécifiées au paragraphe 7.2.2 de l'IEC 60947-1:2007/AMD2:2014.

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M.7.2.11.2 Température de l'air ambiant

Les limites d'échauffement données dans le Tableau 2 de l'IEC 60947-1:2007 et dans le Tableau 3 de l'IEC 60947-1:2007/AMD2:2014 ne sont applicables que si la température de l'air ambiant reste comprise dans les limites indiquées en M.6.

M.7.2.11.3 Circuit principal des MRCD du type à bornes

Le circuit principal d'un MRCD, auquel est raccordé le circuit contrôlé, doit pouvoir supporter le courant assigné tel que défini en M.4.1.2.3, sans que les échauffements ne dépassent les limites données dans le Tableau 2 de l'IEC 60947-1:2007 et dans le Tableau 3 de l'IEC 60947-1:2007/AMD2:2014.

M.7.2.12 Compatibilité électromagnétique

Les exigences de l'Annexe J sont applicables à l'organe de détection et à l'appareil de traitement du MRCD, raccordés conformément aux instructions du fabricant.

Les essais doivent être réalisés conformément à M.8.16.

L'immunité aux variations de tension est couverte par les exigences de M.7.2.10.

M.7.2.13 Comportement des MRCD en cas de défaillance de la connexion de l'organe de détection

Pour les MRCD à organe de détection séparé, en cas de déconnexion de cet organe de détection:

– le MRCD doit fonctionner; ou
– le MRCD doit fournir un signal pour indiquer cette déconnexion; ou
– il doit être possible de vérifier la déconnexion en manœuvrant l'appareil d'essai.

La conformité est vérifiée par les essais décrits en M.8.9.

M.7.2.14 Comportement des MRCD selon la fréquence assignée

Le MRCD doit fonctionner correctement dans la plage des fréquences assignées.

La conformité est vérifiée par les essais décrits en M.8.3.3 et M.8.5.

M.8 Essais

M.8.1 Généralités

M.8.1.1 Essais de type

Les essais de type sont regroupés dans plusieurs séquences, comme indiqué dans le Tableau M.3.

Dans le cas de MRCD ayant un courant différentiel résiduel de fonctionnement réglable, les essais doivent être réalisés au réglage minimal, sauf spécification contraire.

Dans le cas de MRCD à temporisations réglables (voir B.3.3.2.2), les essais doivent être réalisés au réglage maximal, sauf spécification contraire.

Le déclencheur de l'appareil de coupure de courant associé, le cas échéant, doit être alimenté sous sa tension assignée la plus basse.

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Tableau M.3 – Séquences d'essai

Séquence	Essais	Paragraphe
M I	Vérification des caractéristiques de fonctionnement	M.8.3
	Vérification des propriétés diélectriques	M.8.4
	Vérification de la manœuvre de l'appareil d'essai aux limites de la tension assignée	M.8.5
	Vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité, dans le cas d'une charge monophasée	M.8.6
	Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc	M.8.7
	Vérification du comportement dans le cas d'un courant de défaut à la terre comprenant une composante continue	M.8.8
	Vérification du comportement des MRCD à organe de détection séparé en cas de défaillance de la connexion de l'organe de détection	M.8.9
	Vérification de l'échauffement des MRCD de type à bornes	M.8.10
	Vérification de l'endurance mécanique et électrique	M.8.11
	Vérification du comportement des MRCD classés selon M.3.2.2.1 en cas de défaillance de la source de tension	M.8.12
	Vérification du comportement des MRCD classés selon M.3.2.2.2 en cas de défaillance de la source de tension	M.8.13
M II	Vérification du comportement des MRCD dans des conditions de court-circuit	M.8.14
M III	Vérification des effets des conditions d'environnement	M.8.15
M IV	Vérification de la compatibilité électromagnétique	M.8.16

Pour les MRCD de type à bornes comportant des variantes avec différents nombres de pôles, les essais doivent être réalisés sur la variante avec le plus grand nombre de pôles. Pour une variante pour laquelle il n'existe pas de différences de construction par rapport à la variante soumise à essai, aucun essai supplémentaire n'est exigé. Si la construction des variantes n'est pas identique à celle de la variante soumise à essai, ces variantes doivent alors être aussi soumises à essai.

Un échantillon doit être soumis à essai pour chacune des séquences d'essai M I, M II et M III.

Pour la séquence d'essai M IV, un échantillon neuf peut être utilisé pour chaque essai ou un échantillon peut être utilisé pour plusieurs essais, au choix du fabricant.

Sauf spécification contraire, chacun des essais de type (ou séquence d'essai de type) doit être réalisé sur un MRCD propre et neuf, les grandeurs d'influence ayant leur valeur normale de référence.

Le MRCD doit être installé individuellement, selon les instructions du fabricant, à l'air libre, sauf spécification contraire. La température ambiante de l'air doit être comprise entre 15 °C et 30 °C, sauf spécification contraire. Les raccordements et le montage doivent être conformes aux instructions du fabricant.

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M.8.1.2 Essais individuels de série

Le paragraphe 8.4.5 est applicable.

M.8.2 Conformité aux exigences de construction

Le paragraphe 8.2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable en intégrant éventuellement les exigences de 7.1.

M.8.3 Vérification des caractéristiques de fonctionnement

M.8.3.1 Généralités

Le MRCD doit être installé, monté et câblé selon les instructions du fabricant. Sauf spécification contraire, il doit être raccordé à un matériel d'essai, selon les spécifications du fabricant, représentant les conditions normales de service pour le circuit de sortie afin de vérifier le changement d'état de la sortie. Pour la mesure du temps combiné (voir M.2.2.2.2), le MRCD doit être raccordé à un appareil de coupure de courant, spécifié par le fabricant et installé dans le circuit contrôlé. Les caractéristiques de cet appareil doivent être indiquées dans le rapport d'essai.

M.8.3.2 Conditions d'essai pour les MRCD sans source de tension

Le paragraphe B.8.2.2 est applicable.

M.8.3.3 Conditions d'essai pour les MRCD avec source de tension

Les essais doivent être réalisés aux valeurs suivantes:

– 0,85 fois la valeur assignée minimale de la source de tension pour les essais spécifiés en M.8.3.4 et en M.8.3.5.2;

– 1,1 fois la valeur assignée maximale de la source de tension pour les essais spécifiés en M.8.3.5.3.

Les MRCD ayant une plage de fréquences assignées doivent être soumis à essai à la fréquence la plus élevée et à la fréquence la plus basse. Cependant, pour les MRCD de fréquences assignées égales à 50 Hz et 60 Hz, les essais à 50 Hz ou à 60 Hz sont considérés comme couvrant les deux fréquences.

M.8.3.4 Essais à vide à 20 °C ± 5 °C

M.8.3.4.1 Généralités

Le MRCD, raccordé comme représenté à la Figure M.1, la Figure M.2 ou la Figure M.3, doit satisfaire aux essais décrits en M.8.3.4.2, M.8.3.4.3 et M.8.3.4.4, ainsi qu'à l'essai décrit en M.8.3.4.5 le cas échéant; tous ces essais sont réalisés sur une seule voie de passage de courant.

Sauf spécification contraire:

– pour les MRCD à réglage du courant différentiel résiduel par variation continue ou par valeurs discrètes, les essais doivent être réalisés aux réglages maximal et minimal, ainsi qu'à un réglage intermédiaire;

– pour les MRCD du type à temporisation réglable, la temporisation doit être réglée à sa valeur minimale.

M.8.3.4.2 Vérification du fonctionnement dans le cas d'une augmentation régulière du courant différentiel résiduel (Figure M.1)

Les interrupteurs S_1 et S_2, et S_a s'il y a lieu, étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel doit être augmenté de façon régulière, à partir d'une valeur ne dépassant pas 0,2 $I_{\Delta n}$, afin d'atteindre $I_{\Delta n}$ en approximativement 30 s. La valeur de courant provoquant le changement d'état de la sortie est consignée. L'essai doit être réalisé trois fois.

Les trois valeurs mesurées doivent être comprises entre le courant différentiel résiduel de non-fonctionnement assigné $I_{\Delta no}$ et $I_{\Delta n}$.

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M.8.3.4.3 Vérification du fonctionnement en cas de fermeture sur le courant différentiel résiduel (Figure M.2)

Le circuit d'essai étant étalonné à la valeur assignée du courant différentiel résiduel de fonctionnement $I_{\Delta n}$ (ou, le cas échéant, à chaque réglage spécifique du courant différentiel résiduel de fonctionnement), l'interrupteur S_2 et l'appareil de coupure de courant étant en position fermée, les interrupteurs S_1 et S_a (s'il y a lieu) sont fermés simultanément. Le temps combiné doit être mesuré trois fois.

Aucun mesurage ne doit dépasser la valeur limite spécifiée pour $I_{\Delta n}$ en M.4.2.

M.8.3.4.4 Vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel (Figure M.2 et Figure M.3)

Le MRCD doit être raccordé au matériel d'essai comme spécifié en M.8.3.1.

Le circuit d'essai étant étalonné à chacune des valeurs du courant différentiel résiduel de fonctionnement I_{Δ} spécifié en M.4.2, l'interrupteur d'essai S_1 (et l'interrupteur S_a s'il y a lieu) et le matériel d'essai étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est établi subitement par la fermeture de l'interrupteur S_2.

Trois mesurages du temps de fonctionnement et du temps combiné (le cas échéant) sont effectués à chacune des valeurs de I_{Δ}:

– aucune des valeurs du temps de fonctionnement ne doit dépasser les valeurs indiquées par le fabricant;

– aucune des valeurs du temps combiné ne doit dépasser les limites spécifiées en M.4.2.

M.8.3.4.5 Vérification du temps limite de non-fonctionnement des MRCD de type temporisé (Figure M.3)

Le MRCD doit être raccordé au matériel d'essai comme spécifié en M.8.3.1.

Le circuit d'essai étant étalonné à la valeur 2 $I_{\Delta n}$, les interrupteurs S_1, et S_a s'il y a lieu, étant en position fermée, et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est établi par la fermeture de l'interrupteur S_2 durant un temps égal au temps limite de non-fonctionnement déclaré par le fabricant selon M.4.2.

L'essai doit être réalisé 3 fois. Le MRCD ne doit pas fonctionner.

Si le MRCD a un courant de réglage ajustable et/ou une temporisation réglable, l'essai doit être réalisé, suivant le cas, au réglage minimal du courant différentiel résiduel de fonctionnement et aux réglages maximal et minimal de la temporisation.

M.8.3.5 Essais aux limites de température

M.8.3.5.1 Généralités

Le paragraphe B.8.2.5 est applicable.

M.8.3.5.2 Essai à vide à –5 °C

Le paragraphe B.8.2.5.2 est applicable, mais selon M.8.3.4.4 et M.8.3.4.5 le cas échéant.

M.8.3.5.3 Essai en charge à +40 °C

Le paragraphe B.8.2.5.3 est applicable.

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Après avoir atteint l'équilibre thermique, le MRCD doit être soumis aux essais décrits en M.8.3.4.4 et en M.8.3.4.5 le cas échéant.

M.8.4 Vérification des propriétés diélectriques

M.8.4.1 Vérification de la tension assignée de tenue aux chocs

M.8.4.1.1 Généralités

Le MRCD doit satisfaire aux exigences établies en M.7.2.5. Les essais doivent être réalisés pour toutes les positions du contact auxiliaire.

Les essais sont réalisés conformément au paragraphe 8.3.3.4 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 avec les ajouts énumérés en M.8.4.1.2 et M.8.4.1.3.

M.8.4.1.2 Vérification de la tension assignée de tenue aux chocs par rapport au circuit contrôlé

M.8.4.1.2.1 Essais pour un MRCD du type à bornes

La tension d'essai, définie en M.7.2.5, doit être appliquée comme indiqué au paragraphe 8.3.3.4.1, point 2), de l'IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Essais pour un MRCD du type à conducteur traversant

L'essai doit être réalisé sur un organe de détection traversé par un jeu de barres non isolé, installé suivant les instructions du fabricant.

La tension d'essai, définie en M.7.2.5, doit être appliquée comme suit:

a) entre tous les conducteurs du circuit contrôlé reliés entre eux et l'embase de montage, si l'organe de détection est séparé;

b) entre tous les conducteurs du circuit contrôlé reliés entre eux et l'enveloppe de l'appareil de traitement ou son embase de montage, si l'organe de détection est incorporé;

c) entre chaque circuit auxiliaire et:

   – le circuit contrôlé;

   – l'enveloppe ou l'embase de montage du MRCD.

M.8.4.1.3 Vérification de la tension assignée de tenue aux chocs du circuit de la source de tension (le cas échéant)

Si le circuit de la source de tension est alimenté directement par le circuit contrôlé, les essais sont réalisés conformément à M.8.4.1.2.1.

Si le circuit de la source de tension n'est pas alimenté par le circuit contrôlé, la tension d'essai définie dans le Tableau 12 de l'IEC 60947-1:2007 doit être appliquée comme suit:

a) entre toutes les bornes d'alimentation du circuit de la source de tension reliées entre elles et l'enveloppe ou l'embase de montage du MRCD;

b) entre chaque borne d'alimentation du circuit de la source de tension et les autres bornes d'alimentation reliées entre elles et raccordées à l'enveloppe ou à l'embase de montage du MRCD.

M.8.4.2 Capacité des circuits raccordés au circuit contrôlé à supporter les tensions continues causées par les mesurages d'isolement

La nécessité de cette vérification pour les MRCD qui ne peuvent pas être déconnectés en service est à l'étude.

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M.8.5 Vérification du fonctionnement de l'appareil d'essai aux limites de tension assignée

Le paragraphe B.8.4 est applicable, mais en remplaçant "tension assignée" par "tension assignée de la source de tension". Le MRCD doit être soumis à essai en association avec le matériel d'essai spécifié en M.8.3.1.

M.8.6 Vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité, dans le cas d'une charge monophasée

Le MRCD doit être raccordé selon la Figure M.4, configuration a), b) ou c), suivant le cas, en faisant particulièrement attention au positionnement des conducteurs, selon les instructions du fabricant, dans le cas d'un MRCD du type à conducteur traversant, l'interrupteur S_1 étant ouvert. L'interrupteur S_a, s'il y a lieu, est alors fermé et la tension U_s est appliquée.

L'essai doit être réalisé conformément à B.8.5 à un courant de 6 I_n. Pour les MRCD à organe de détection séparé, l'essai doit être réalisé à la valeur de réglage de courant différentiel résiduel la plus faible déclarée par le fabricant.

Aucun changement d'état du MRCD ne doit se produire.

M.8.7 Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc

M.8.7.1 Généralités

Pour les MRCD à temporisations réglables, la temporisation doit être réglée au minimum.

M.8.7.2 Vérification de la résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

Le paragraphe B.8.6.2 est applicable en remplaçant la Figure M.5 par la Figure B.5.

Aucun changement d'état du MRCD ne doit se produire.

M.8.7.3 Vérification de la résistance aux déclenchements intempestifs dans le cas d'amorçage sans courant de suite

Le paragraphe B.8.6.3 est applicable en remplaçant la Figure M.6 par la Figure B.7.

Aucun changement d'état du MRCD ne doit se produire pendant l'essai à 250 A. Pendant l'essai à 3 000 A, le MRCD peut fonctionner.

M.8.7.4 Vérification après les essais

Après les essais décrits en M.8.7.2 et M.8.7.3, le fonctionnement du MRCD doit être vérifié conformément à M.8.3.4.4, avec un mesurage du temps de fonctionnement, uniquement à $I_{\Delta n}$.

M.8.8 Vérification du comportement dans le cas d'un courant de défaut à la terre comprenant une composante continue

M.8.8.1 Généralités

Les conditions d'essai décrites en M.8.3.1, M.8.3.2 et M.8.3.3 sont applicables.

Pour les MRCD dont le fonctionnement dépend d'une source de tension, les essais doivent être effectués à 1,1 et à 0,85 fois la tension assignée de la source de tension (U_s).

Sauf spécification contraire:

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– pour les MRCD à réglage du courant différentiel résiduel par variation continue ou par valeurs discrètes, les essais doivent être réalisés aux réglages maximal et minimal, ainsi qu'à un réglage intermédiaire;

– pour les MRCD du type à temporisation réglable, la temporisation doit être réglée à sa valeur minimale.

M.8.8.2 MRCD de type A

M.8.8.2.1 Vérification du fonctionnement correct dans le cas d'une augmentation régulière du courant différentiel résiduel continu pulsé

Le paragraphe B.8.7.2.1 est applicable en remplaçant la Figure M.7 par la Figure B.8.

Les interrupteurs S_1 et S_2, et S_a le cas échéant, sont fermés, le MRCD étant prêt à fonctionner.

M.8.8.2.2 Vérification du fonctionnement correct dans le cas d'une apparition subite de courants différentiels résiduels continus pulsés

Le paragraphe B.8.7.2.2 est applicable avec les modifications suivantes.

Le circuit d'essai doit être conforme à la Figure M.8 ou la Figure M.9, suivant le cas.

La vérification s'effectue en deux étapes:

– pour la première étape, le MRCD est raccordé à un appareil de mesure indiquant le changement d'état de la sortie;

– pour la deuxième étape, le MRCD est raccordé à un appareil de coupure de courant, spécifié par le fabricant et installé dans le circuit contrôlé. Les caractéristiques de cet appareil de coupure de courant doivent être indiquées dans le rapport d'essai.

L'interrupteur S_1, et l'interrupteur S_a s'il y a lieu, étant en position fermée et le MRCD étant prêt à fonctionner, le courant différentiel résiduel est subitement établi en fermant l'interrupteur S_2.

L'essai doit être réalisé pour chaque valeur du courant différentiel résiduel spécifié:

– pour la première étape, aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant;

– pour la deuxième étape, aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.2.3 Vérification du fonctionnement correct avec charge à la température de référence

Les essais décrits en M.8.8.2.2 sont répétés, la voie de passage de courant soumise à essai et une autre voie de passage de courant du MRCD étant parcourues par le courant assigné, le courant étant établi juste avant l'essai.

NOTE La charge avec le courant assigné n'est pas représentée à la Figure M.7, configuration c).

M.8.8.2.4 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu pulsé auquel est superposé un courant continu lissé de 6 mA

Le paragraphe B.8.7.2.4 est applicable avec les modifications suivantes.

Le circuit d'essai doit être conforme à la Figure M.10, configuration a), b) ou c), suivant le cas.

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M.8.8.3 MRCD de type B

M.8.8.3.1 Vérification du fonctionnement correct en cas d'augmentation régulière du courant différentiel résiduel composite

Le paragraphe B.8.8.1 est applicable, mais en remplaçant "DPR" par "MRCD" et avec les modifications suivantes:

Les essais doivent être réalisés conformément à la Figure M.16.

M.8.8.3.2 Vérification du fonctionnement correct dans le cas d'une apparition subite d'un courant différentiel résiduel composite

Le paragraphe B.8.8.2 est applicable, mais en remplaçant "DPR" par "MRCD" et avec les modifications suivantes:

Les essais doivent être réalisés conformément à la Figure M.16.

Trois mesurages du temps de fonctionnement et du temps combiné (le cas échéant) sont effectués à chacune des valeurs de I_{Δ}.

Aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse à 5 $I_{\Delta n}$ du MRCD seul; aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.3.3 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

Le paragraphe B.8.8.3 est applicable, mais en remplaçant "DPR" par "MRCD" et avec les modifications suivantes:

Les essais doivent être réalisés conformément à la Figure M.16.

La vérification de la durée de coupure est remplacée par une vérification du temps de fonctionnement, et du temps combiné le cas échéant; aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse à $I_{\Delta n}$ du MRCD seul; aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1 pour $I_{\Delta n}$.

M.8.8.3.4 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel alternatif auquel est superposé un courant différentiel résiduel continu lissé

Le paragraphe B.8.8.4 est applicable, mais en remplaçant "DPR" par "MRCD" et avec la modification suivante:

Les essais doivent être réalisés conformément à la Figure M.17.

M.8.8.3.5 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu pulsé auquel est superposé un courant différentiel résiduel continu lissé

Le paragraphe B.8.8.5 est applicable, mais en remplaçant "DPR" par "MRCD" et avec la modification suivante:

Les essais doivent être réalisés conformément à la Figure M.10.

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M.8.8.3.6 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par deux phases

Le paragraphe B.8.8.6 est applicable, mais en remplaçant "DPR" par "MRCD" et avec les modifications suivantes:

Les essais doivent être réalisés conformément à la Figure M.15.

La vérification de la durée de coupure est remplacée par une vérification du temps de fonctionnement, et du temps combiné le cas échéant; aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse du MRCD seul; aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.3.7 Vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par trois phases

Le paragraphe B.8.8.7 est applicable, mais en remplaçant "DPR" par "MRCD", avec les modifications suivantes:

Les essais doivent être réalisés conformément à la Figure M.14.

La vérification de la durée de coupure est remplacée par une vérification du temps de fonctionnement, et du temps combiné le cas échéant; aucun des temps de fonctionnement mesurés ne doit dépasser les valeurs indiquées par le fabricant pour le temps de réponse du MRCD seul; aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

M.8.8.3.8 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé

M.8.8.3.8.1 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé sans charge

La vérification s'effectue en deux étapes:

a) Le circuit d'essai doit être conforme à la Figure M.11, les interrupteurs S_1 et S_2, et S_a s'il y a lieu, étant en position fermée.

   Une voie de passage de courant choisie au hasard doit être soumise à essai deux fois avec l'interrupteur S_3 en position I et deux fois avec l'interrupteur S_3 en position II.

   Le courant différentiel résiduel doit être augmenté de façon régulière, à partir de zéro, afin d'atteindre 2 $I_{\Delta n}$ en moins de 30 s. Le MRCD doit fonctionner entre 0,5 $I_{\Delta n}$ et 2 $I_{\Delta n}$.

b) Les circuits d'essai doivent être conformes à la Figure M.12 et la Figure M.13.

   Le circuit étant successivement étalonné à chacune des valeurs spécifiées ci-après, l'interrupteur S_1 ou S_a, suivant le cas, étant en position fermée et le MRCD prêt à fonctionner, le courant différentiel résiduel est subitement établi par fermeture de l'interrupteur S_2.

   L'essai doit être réalisé pour chaque valeur du courant différentiel résiduel spécifiée dans le Tableau B.1, multipliée par deux.

   Deux mesurages du temps de fonctionnement sont effectués pour chaque valeur, l'interrupteur S_3 étant en position I pour le premier mesurage et en position II pour le deuxième mesurage.

   Aucun des temps de fonctionnement ne doit dépasser les valeurs indiquées par le fabricant et aucune valeur du temps combiné, le cas échéant, ne doit dépasser les valeurs limites spécifiées en M.4.2.1.

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M.8.8.3.8.2 Vérification du fonctionnement correct dans le cas d'un courant différentiel résiduel continu lissé avec charge

L'essai décrit en M.8.8.3.8.1 a) doit être répété, la voie de passage de courant soumise à essai et une autre voie de passage de courant du MRCD étant parcourues par le courant assigné.

M.8.8.3.9 Essais aux limites de température

Le MRCD doit être soumis aux essais spécifiés en M.8.8.3.6 et en M.8.8.3.7 (mais en procédant dans chaque cas uniquement à la vérification du temps de fonctionnement) et aux essais spécifiés en M.8.8.3.8.1 b), successivement dans les conditions suivantes:

a) température de l'air ambiant: –5 °C, sans charge;

b) température de l'air ambiant: +40 °C, et, pour les MRCD de type à bornes, le MRCD ayant été précédemment parcouru par son courant assigné, jusqu'à ce qu'il ait atteint l'équilibre thermique. Dans la pratique, cet équilibre thermique est atteint lorsque la variation de l'échauffement, mesurée sur l'une des bornes principales, n'excède pas 1 K par heure. La charge du circuit principal peut être appliquée à tension réduite mais les circuits auxiliaires doivent être alimentés à leur tension assignée de fonctionnement, notamment pour les composants dépendants de la tension d'alimentation.

Dans le cas des MRCD intégrant plusieurs réglages du courant différentiel résiduel de fonctionnement, les essais sont réalisés au réglage minimum et au réglage maximum.

M.8.9 Vérification du comportement des MRCD à organe de détection séparé en cas de défaillance de la connexion de l'organe de détection

M.8.9.1 Généralités

Pour les MRCD ayant une plage de valeurs assignées de la source de tension, les essais doivent être réalisés pour chaque valeur assignée, conformément à M.8.9.2 ou M.8.9.3, suivant le cas, et conformément aux instructions du fabricant.

M.8.9.2 Méthode d'essai 1

Le MRCD doit être raccordé à l'organe de détection séparé et doit être alimenté successivement avec chacune des tensions assignées, comme représenté à la Figure M.18. Aucun courant de défaut ne doit circuler dans l'organe de détection et le circuit d'essai ne doit pas être actionné.

L'organe de détection est ensuite déconnecté et le MRCD doit fonctionner ou fournir un signal pour indiquer cette déconnexion.

Le temps entre la déconnexion et le changement d'état de la sortie est mesuré.

Trois mesurages sont effectués; aucune valeur ne doit dépasser 5 s.

M.8.9.3 Méthode d'essai 2

Les essais doivent être réalisés comme suit:

a) l'appareil d'essai est actionné. Le MRCD doit fonctionner;

b) l'organe de détection est déconnecté et l'appareil d'essai est actionné. Le MRCD ne doit pas fonctionner.

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M.8.10 Vérification de l'échauffement des MRCD de type à bornes

M.8.10.1 Généralités

Sauf spécification contraire, le MRCD doit être raccordé avec des conducteurs appropriés dont les sections sont spécifiées aux Tableaux 9, 10 et 11 de l'IEC 60947-1:2007, et fixé sur une planche de contreplaqué peinte en noir et de finition matte, d'environ 20 mm d'épaisseur.

L'essai doit être réalisé dans une atmosphère protégée contre des échauffements ou des refroidissements anormaux venant de l'extérieur.

M.8.10.2 Température de l'air ambiant

Le paragraphe 8.3.3.3.1 de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.8.10.3 Mode opératoire d'essai

L'essai doit être réalisé conformément au paragraphe 8.3.3.3.4 de l'IEC 60947-1:2007, au courant assigné I_n.

Pendant cet essai, l'échauffement ne doit pas dépasser les valeurs énumérées dans le Tableau 2 de l'IEC 60947-1:2007 et le Tableau 3 de l'IEC 60947-1:2007/AMD2:2014.

M.8.11 Vérification de l'endurance mécanique et électrique

La sortie du MRCD doit être soumise à des essais d'endurance mécanique et électrique comprenant:

– 500 manœuvres à vide commandées par l'appareil d'essai;
– 500 manœuvres à vide en faisant passer le courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$ dans une seule voie de passage de courant;
– 500 manœuvres en charge commandées par l'appareil d'essai;
– 500 manœuvres en charge en faisant passer le courant différentiel résiduel de fonctionnement assigné $I_{\Delta n}$ dans une seule voie de passage de courant.

Les essais en charge sont réalisés sur un circuit correspondant aux caractéristiques assignées de la sortie indiquées par le fabricant.

Après les essais, le MRCD ne doit présenter aucun dommage compromettant son utilisation ultérieure. La sortie doit pouvoir supporter en position ouverte une tension égale à deux fois la valeur assignée maximale indiquée par le fabricant.

NOTE 1 Cette vérification n'est pas applicable si la sortie est conçue pour une charge spécifique et qu'elle n'a pas de tension assignée de sortie.

Pour les MRCD ayant plus d'une caractéristique assignée de sortie, deux essais doivent être réalisés:

– un essai au courant assigné le plus élevé à la tension correspondante,
– un essai à la tension assignée la plus élevée au courant correspondant.

Le MRCD doit pouvoir satisfaire aux essais spécifiés en B.8.11.4 b).

NOTE 2 Si la sortie du MRCD a une caractéristique assignée AC-15 appropriée, conformément à l'IEC 60947-5-1, les essais définis dans le présent paragraphe ne sont pas nécessaires.

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M.8.12 Vérification du comportement des MRCD classés selon M.3.2.2.1 en cas de défaillance de la source de tension

M.8.12.1 Généralités

Pour les MRCD ayant un courant différentiel résiduel de fonctionnement réglable, l'essai doit être réalisé au réglage minimal.

Pour les MRCD à temporisation réglable, l'essai doit être réalisé à l'un quelconque des réglages de la temporisation.

La tension appliquée doit être la tension assignée de la source de tension (U_s).

Pour les MRCD ayant une plage de tensions assignées de la source de tension, les essais doivent être réalisés aux valeurs maximale et minimale de la plage de tensions.

M.8.12.2 Détermination de la valeur limite de la source de tension

Les essais doivent être réalisés conformément à B.8.9.2, en remplaçant "tension d'alimentation" par "source de tension" et "bornes d'alimentation" par "bornes de la source de tension".

M.8.12.3 Vérification de l'ouverture automatique en cas de défaillance de la source de tension

Les essais sont réalisés conformément à B.8.9.3, en remplaçant "tension d'alimentation" par "source de tension" et "bornes d'alimentation" par "bornes de la source de tension". L'intervalle de temps entre l'interruption de la tension et le changement d'état de la sortie doit être mesuré.

Trois mesurages sont effectués:

– pour les MRCD à déclenchement instantané, aucune valeur ne doit dépasser 1 s;
– pour les MRCD temporisés, aucune valeur ne doit dépasser de plus de 1 s la temporisation réglée.

M.8.13 Vérification du comportement des MRCD classés selon M.3.2.2.2 en cas de défaillance de la source de tension

Les dispositions de B.8.10 sont applicables dans le cas où la source de tension est la tension d'alimentation du circuit contrôlé. Dans le cas où la source de tension est différente de la tension d'alimentation, un essai doit être réalisé comme suit.

Pour les MRCD ayant un courant différentiel résiduel de fonctionnement réglable, l'essai doit être réalisé au réglage minimal.

Pour les MRCD ayant une temporisation réglable, l'essai doit être réalisé à l'une quelconque des temporisations.

Le MRCD doit être raccordé selon la Figure M.3 et alimenté à sa tension assignée, ou dans le cas d'une plage de tensions assignées, à la tension assignée la plus basse.

L'alimentation est alors coupée par l'ouverture de S_a ou S_1, suivant le cas; le MRCD ne doit pas fonctionner.

L'interrupteur S_a ou S_1, suivant le cas, est alors refermé et la tension est réduite à 70 % de la tension assignée la plus basse. Le courant différentiel résiduel assigné $I_{\Delta n}$ est alors appliqué en fermant S_2; le MRCD doit fonctionner.

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M.8.14 Vérification du comportement des MRCD dans des conditions de court-circuit

M.8.14.1 Généralités

Etant donné qu'un MRCD n'est pas un appareil de connexion, lorsqu'il a été soumis à essai avec un DPCC donné conformément à M.8.14.3 et M.8.14.5, les essais avec d'autres DPCC présentant un courant de crête plus faible et une valeur I^2t plus faible sont également considérés comme couverts.

M.8.14.2 Conditions générales pour l'essai

M.8.14.2.1 Circuit d'essai

Le paragraphe 8.3.4.1.2 de l'IEC 60947-1:2007/AMD1:2010 est applicable, à l'exception des Figures 9, 10, 11 et 12. L'essai doit être réalisé conformément à la Figure M.19, Figure M.20 ou Figure M.21, suivant le cas.

Pour les essais de tenue de courte durée admissible, le DPCC doit être omis.

M.8.14.2.2 Tolérances sur les grandeurs d'essai

Le Tableau 8 de l'IEC 60947-1:2007 est applicable.

M.8.14.2.3 Facteur de puissance du circuit d'essai

Le Tableau 11 est applicable.

M.8.14.2.4 Tension de rétablissement à fréquence industrielle

Le paragraphe 8.3.2.2.3, point a), de l'IEC 60947-1:2007/AMD2:2014 est applicable.

M.8.14.2.5 Etalonnage du circuit d'essai

Le DPCC et le MRCD, s'il est du type à bornes, sont remplacés par des connexions temporaires d'impédances négligeables comparées à celle du circuit d'essai. Pour les autres MRCD, les conducteurs traversant les organes de détection font partie du circuit d'étalonnage.

Pour l'essai au courant conditionnel de court-circuit assigné I_{cc}, les résistances R et les bobines d'inductance L sont réglées de manière à obtenir, à la tension d'essai, un courant égal à I_{cc}, avec le facteur de puissance prescrit. Tous les pôles du circuit d'essai doivent être mis sous tension simultanément.

Pour les essais au courant différentiel résiduel conditionnel de court-circuit assigné $I_{\Delta c}$, l'impédance supplémentaire Z est utilisée de manière à obtenir les valeurs de courant exigées.

M.8.14.2.6 Etat du MRCD pour les essais

Le câblage et la fixation du MRCD doivent être réalisés conformément aux instructions du fabricant.

Cela est particulièrement le cas pour les MRCD du type à conducteur traversant pour l'installation des conducteurs traversant l'organe de détection.

Le MRCD doit être monté sur une plaque métallique.

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M.8.14.2.7 Etat du MRCD après les essais

Après chacun des essais décrits en M.8.14.3, M.8.14.4 et M.8.14.5, le MRCD ne doit pas présenter de dommages compromettant son utilisation ultérieure et, dans le cas d'un MRCD du type à bornes, il doit pouvoir supporter une tension égale à deux fois sa tension assignée dans les conditions décrites en 8.3.3.6.

Le MRCD doit être soumis de façon satisfaisante aux essais spécifiés en B.8.11.4b) et en M.8.12.3, le cas échéant, et limités à un seul mesurage.

M.8.14.3 Vérification du courant conditionnel de court-circuit assigné (I_{cc})

M.8.14.3.1 Généralités

Cet essai n'est pas nécessaire si le courant de crête coupé limité et l'énergie coupée limitée du DPCC associé sont plus faibles que le courant de crête et l'énergie coupée limitée correspondant au courant assigné de courte durée admissible I_{cw}.

M.8.14.3.2 Conditions d'essai

Les connexions d'impédance négligeable sont remplacées par le DPCC et, le cas échéant, par le MRCD du type à bornes.

M.8.14.3.3 Mode opératoire d'essai

La tension assignée de la source de tension doit être appliquée, le cas échéant.

La séquence de manœuvres suivante est effectuée:

O – *t* – O

M.8.14.3.4 Comportement du MRCD pendant les essais

Pendant les essais, le MRCD peut fonctionner.

M.8.14.4 Vérification du courant assigné de courte durée admissible (I_{cw})

Le paragraphe 8.3.4.3 de l'IEC 60947-1:2007 est applicable au circuit primaire.

L'essai peut être réalisé à une quelconque tension convenable. Le DPCC de la Figure M.17, de la Figure M.18 et de la Figure M.19 doit être omis pour l'essai.

M.8.14.5 Vérification du courant différentiel résiduel conditionnel de court-circuit assigné ($I_{\Delta c}$)

M.8.14.5.1 Généralités

Cet essai n'est pas nécessaire si le courant de crête coupé limité et l'énergie coupée limitée du DPCC associé sont plus faibles que le courant de crête et l'énergie coupée limitée correspondant au courant assigné différentiel résiduel de courte durée admissible $I_{\Delta w}$.

M.8.14.5.2 Conditions d'essai

Le MRCD doit être soumis à essai dans les conditions spécifiées en M.8.14.2.1 mais il doit être raccordé de telle sorte que le courant de court-circuit soit un courant différentiel résiduel. Pour les essais de court-circuit différentiel résiduel, la connexion B, indiquée par la ligne en pointillé à la Figure M.19, la Figure M.20 et la Figure M.21, remplace la connexion traversant l'organe de détection, entre X et Y.

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L'essai doit être réalisé sur une seule voie de passage de courant.

Les connexions d'impédance négligeable sont remplacées par le DPCC et, s'il y a lieu, par le MRCD.

M.8.14.5.3 Mode opératoire d'essai

La séquence suivante doit être effectuée sans synchronisation avec l'onde de tension:

O – *t* – O

M.8.14.5.4 Comportement du MRCD pendant les essais

Pendant les essais, le MRCD peut fonctionner.

M.8.14.6 Vérification du courant assigné différentiel résiduel de courte durée admissible ($I_{\Delta w}$)

Le paragraphe M.8.14.4 est applicable, excepté que le MRCD doit être raccordé de telle manière que le courant de court-circuit soit un courant différentiel résiduel.

M.8.15 Vérification des effets des conditions d'environnement

Les conditions d'essai décrites en B.8.12 sont applicables.

A la fin des essais, le MRCD doit pouvoir supporter de façon satisfaisante les essais spécifiés en B.8.11.4 b).

M.8.16 Vérification de la compatibilité électromagnétique

M.8.16.1 Essais d'immunité

M.8.16.1.1 Généralités

Le paragraphe B.8.13.1 est applicable, mais en remplaçant "DPR" par "MRCD" lorsque cela est nécessaire, excepté que les vérifications après les essais doivent consister en un mesurage du temps de fonctionnement (voir M.2.2.2.1) à $I_{\Delta n}$, lequel ne doit pas dépasser la valeur déclarée par le fabricant (voir M.4.2). Le circuit d'essai pour la vérification doit être conforme à la Figure M.3.

M.8.16.1.2 Décharges électrostatiques

Le paragraphe B.8.13.1.2 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.

M.8.16.1.3 Champs électromagnétiques RF rayonnés

Le paragraphe B.8.13.1.3 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.

L'installation d'essai doit être conforme à la Figure J.4 et la Figure M.22 pour les MRCD avec un organe de détection séparé.

M.8.16.1.4 Transitoires électriques rapides en salves (TER/S)

Le paragraphe B.8.13.1.4 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.

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L'installation d'essai doit être conforme à la Figure J.5, la Figure J.6 et la Figure M.23 pour les MRCD avec un organe de détection séparé.

M.8.16.1.5 Ondes de choc

Le paragraphe B.8.13.1.5 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.

M.8.16.1.6 Perturbations conduites, induites par les champs RF (mode commun)

Le paragraphe B.8.13.1.6 est applicable avec les spécifications supplémentaires indiquées en M.8.16.1.1.

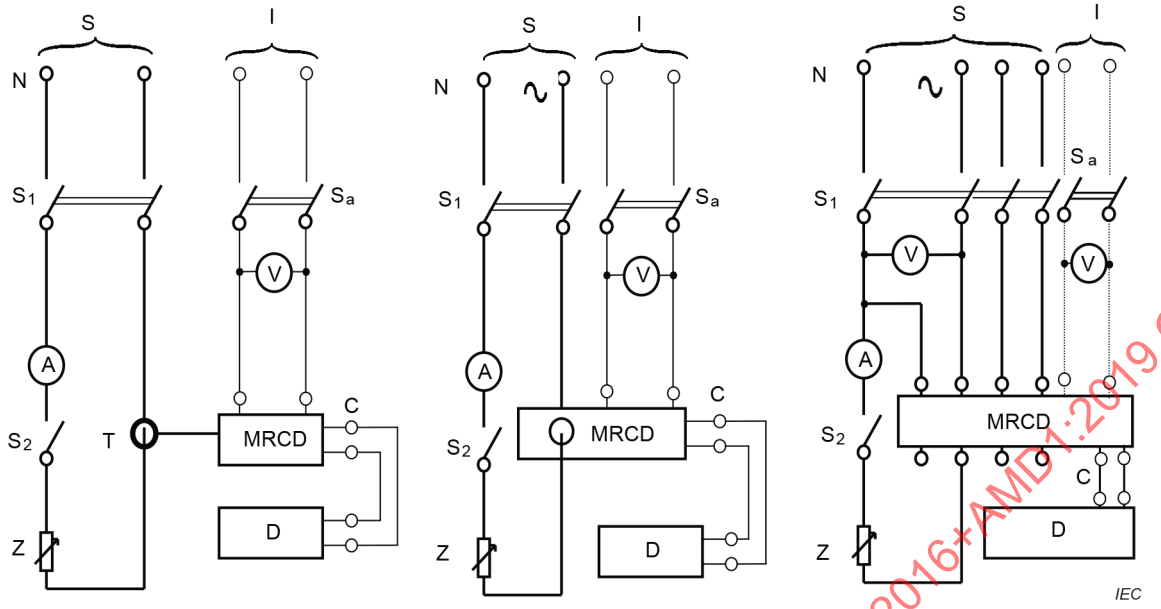
L'installation d'essai doit être conforme à la Figure M.24 pour les MRCD avec un organe de détection séparé.

Une pince électromagnétique peut être utilisée lorsque le fonctionnement normal ne peut être obtenu à cause de l'impact du RCD sur le MRCD.

M.8.16.2 Essais d'émission

Le paragraphe B.8.13.2 est applicable.

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

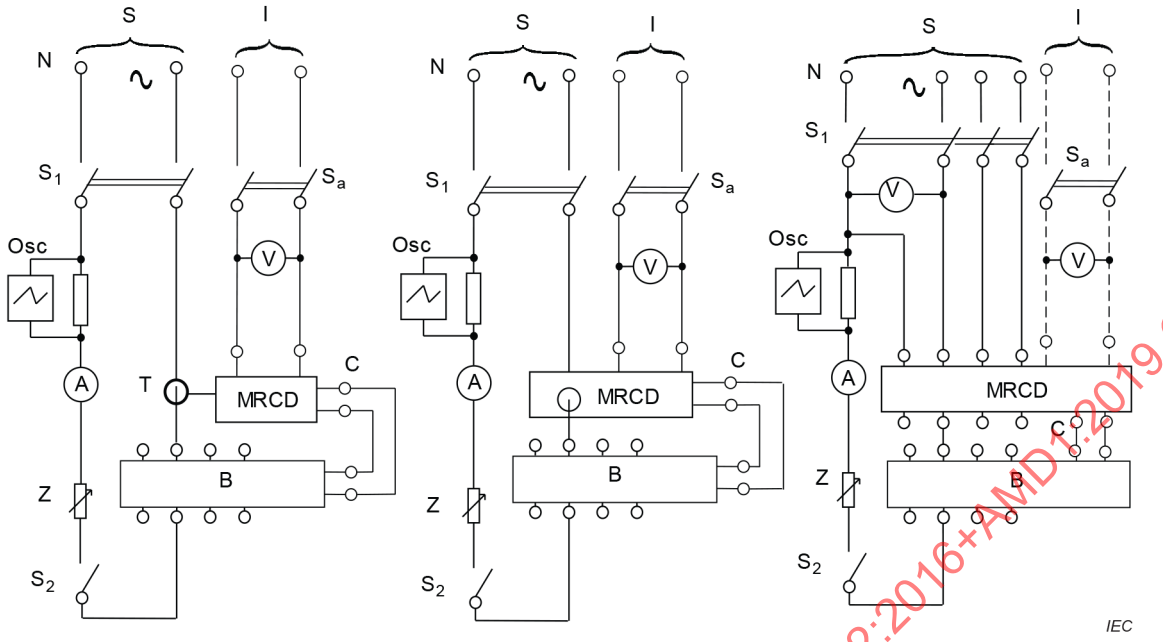
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	D	appareil indiquant le changement d'état
S_2	interrupteur unipolaire		

Figure M.1 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentation régulière du courant différentiel résiduel

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

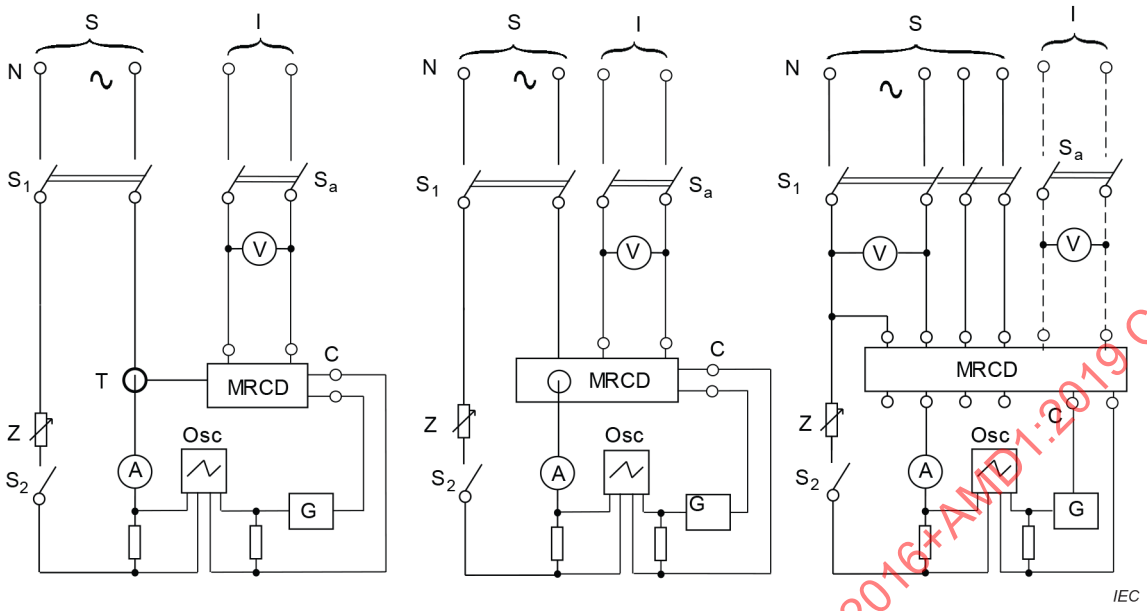
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	B	appareil de coupure de courant
S_2	interrupteur unipolaire	Osc	oscilloscope

Figure M.2 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel (avec appareil de coupure de courant)

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

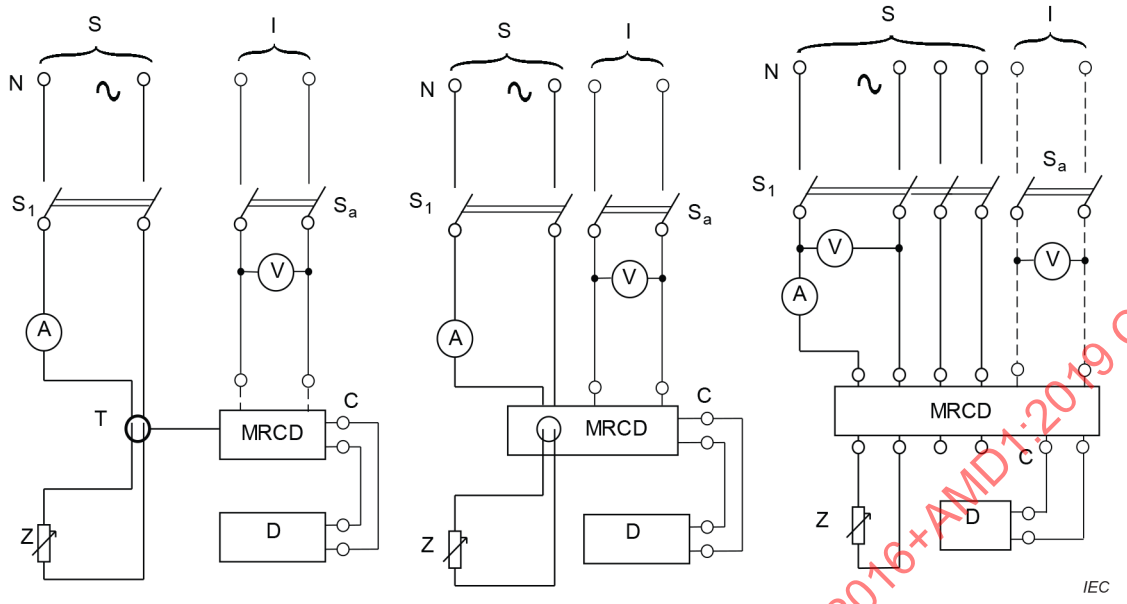
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	G	générateur
S_2	interrupteur unipolaire	Osc	oscilloscope

Figure M.3 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel (sans appareil de coupure de courant)

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

c) MRCD de type à bornes

Légende

S alimentation électrique

I source de tension séparée, le cas échéant

V voltmètre

A ampèremètre

S_1 interrupteur multipolaire

S_a interrupteur auxiliaire

Z impédance réglable

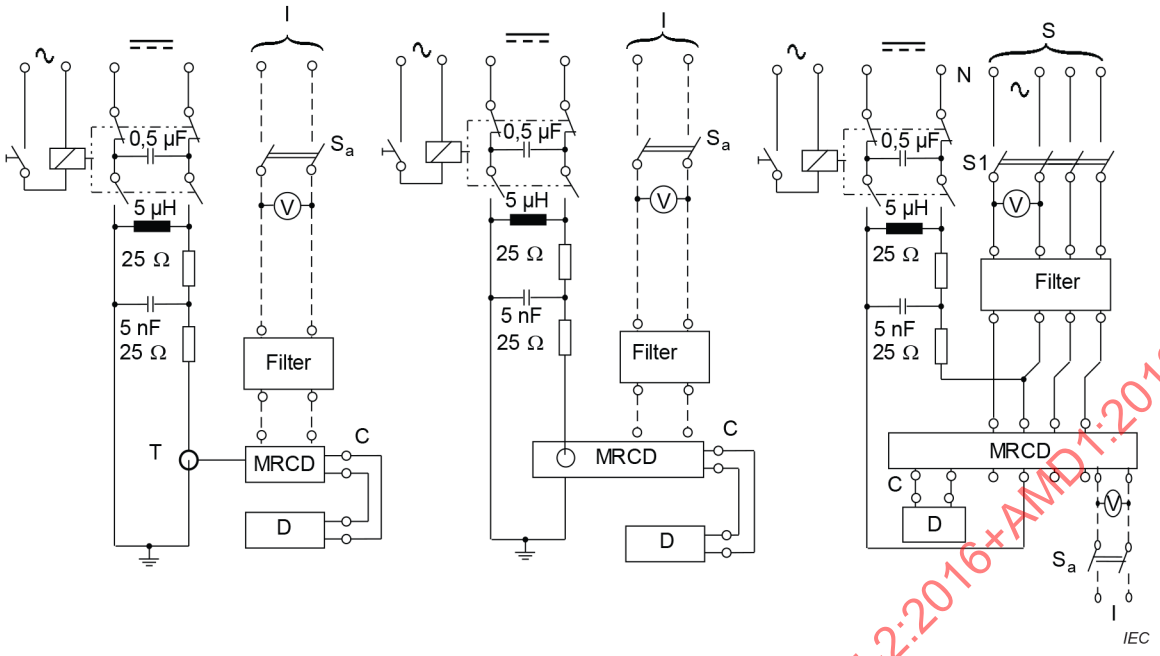
T organe de détection

C circuit de sortie

D appareil indiquant le changement d'état

Figure M.4 – Circuits d'essai pour la vérification de la valeur limite du courant de non-fonctionnement en conditions de surintensité

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

c) MRCD de type à bornes

Légende

S alimentation électrique

V voltmètre

I source de tension séparée, le cas échéant

S_1 interrupteur multipolaire

T organe de détection

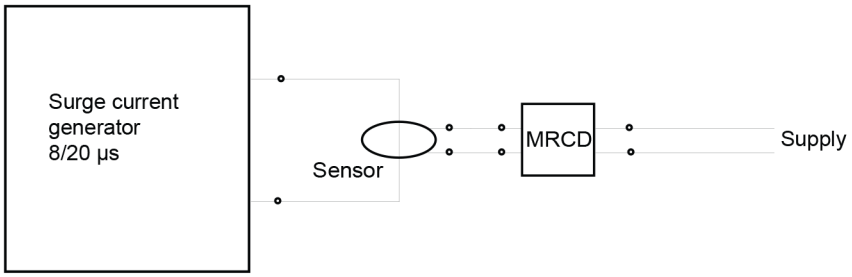
C circuit de sortie

D appareil indiquant le changement d'état

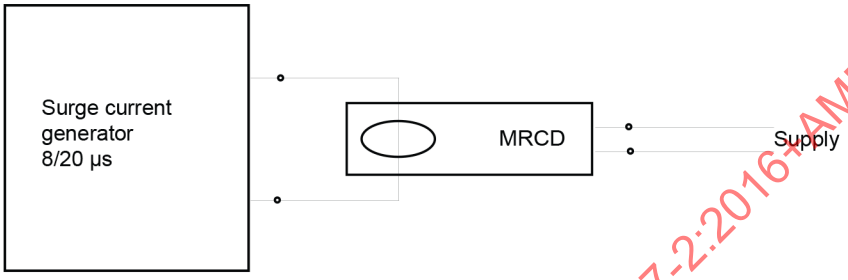
S_a interrupteur auxiliaire

Figure M.5 – Circuits d'essai pour la vérification de la résistance aux déclenchements intempestifs dans le cas de charge de la capacité du réseau

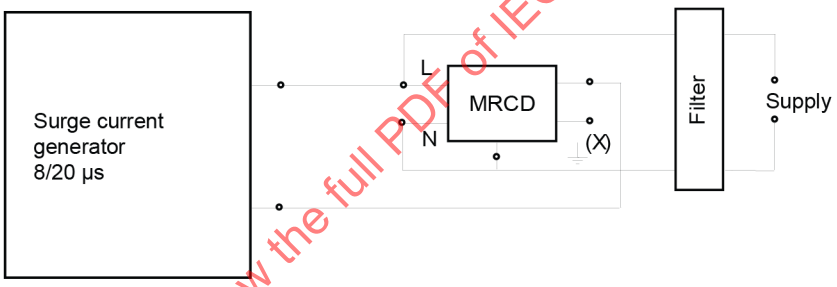
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a) MRCD with separate sensing means



b) MRCD with integral sensing means



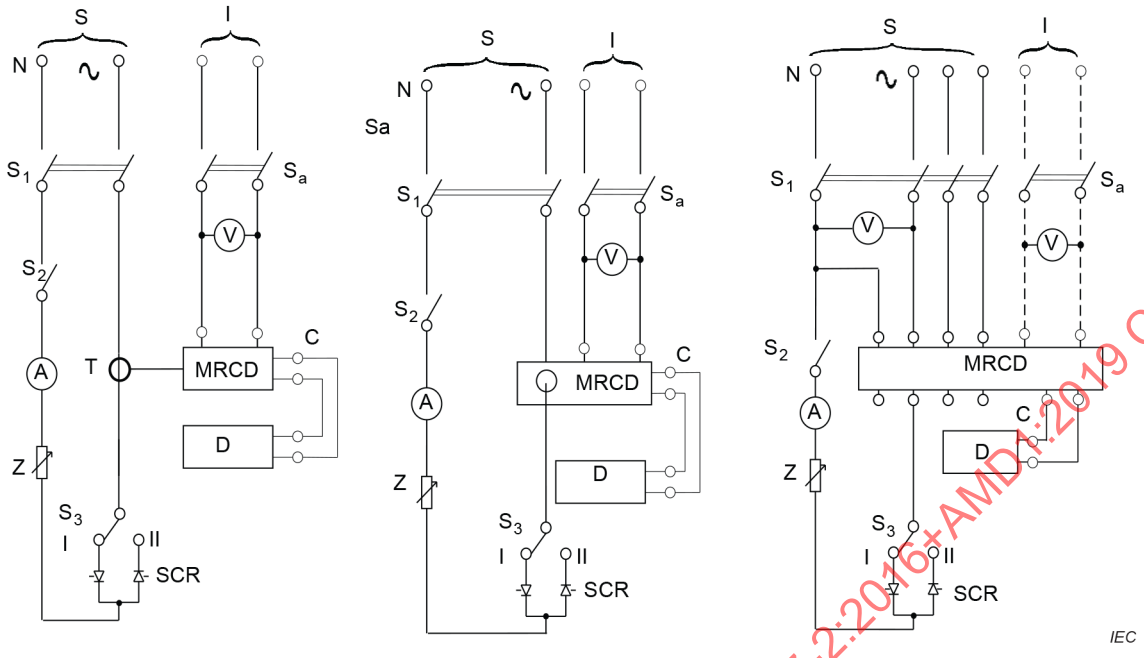
c) Terminals type MRCD

IEC

Anglais	Français
Surge current generator 8/20 µs	Générateur d'onde de courant 8/20 µs
sensor	Détecteur
Supply	Alimentation
a) MRCD with separate sensing means	a) MRCD avec organe de détection séparé
b) MRCD with integral sensing means	b) MRCD avec organe de détection intégré
c) Terminals type MRCD	c) MRCD de type à bornes
Filter	Filtre

Figure M.6 – Circuit d'essai pour la vérification de la résistance aux déclenchements intempestifs dans le cas d'un amorçage sans courant de suite

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

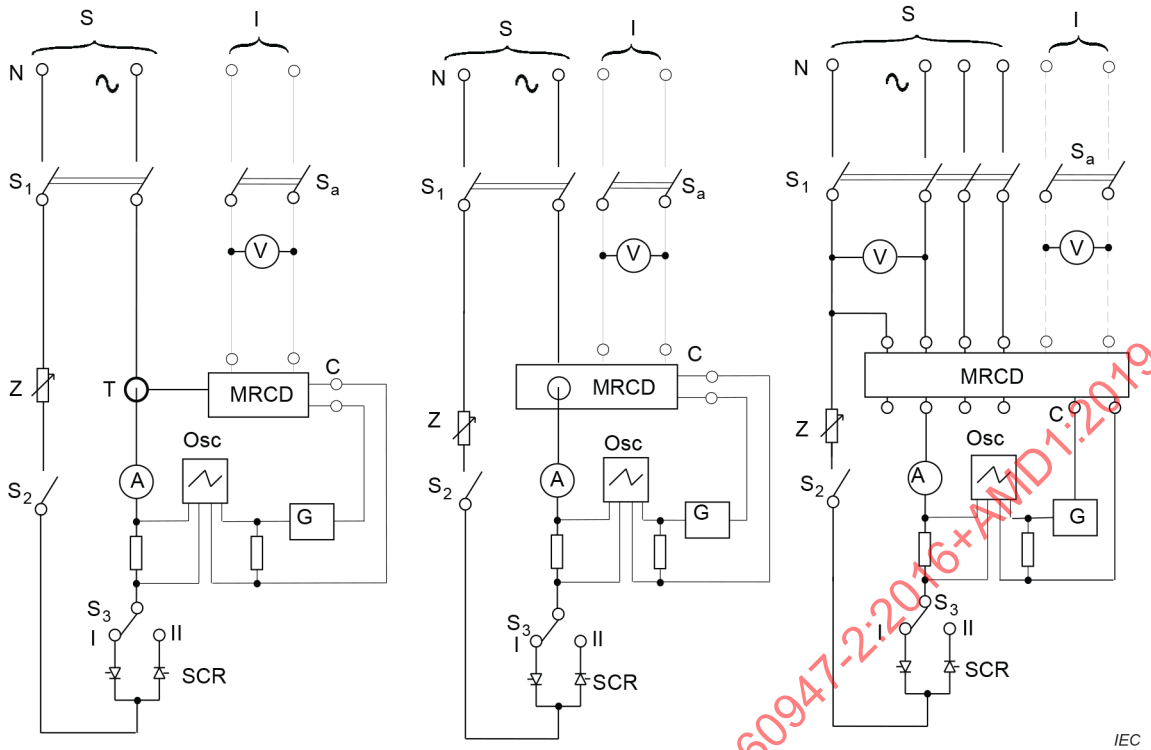
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	D	appareil indiquant le changement d'état
S_2	interrupteur unipolaire	SCR	thyristors
S_3	inverseur		

Figure M.7 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une augmentation régulière d'un courant différentiel résiduel continu pulsé

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

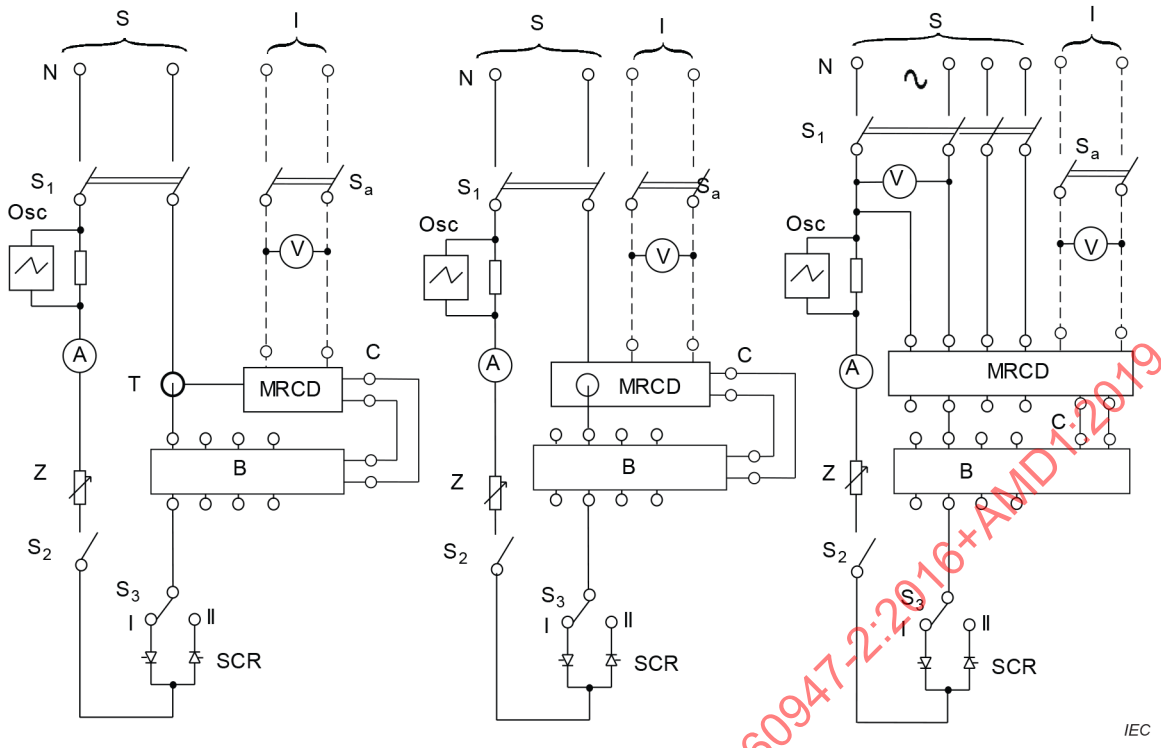
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	G	générateur
S_2	interrupteur unipolaire	Osc	oscilloscope
S_3	inverseur	SCR	thyristors

Figure M.8 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel continu pulsé (sans appareil de coupure de courant)

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a) **MRCD avec organe de détection séparé**

b) **MRCD avec organe de détection intégré**

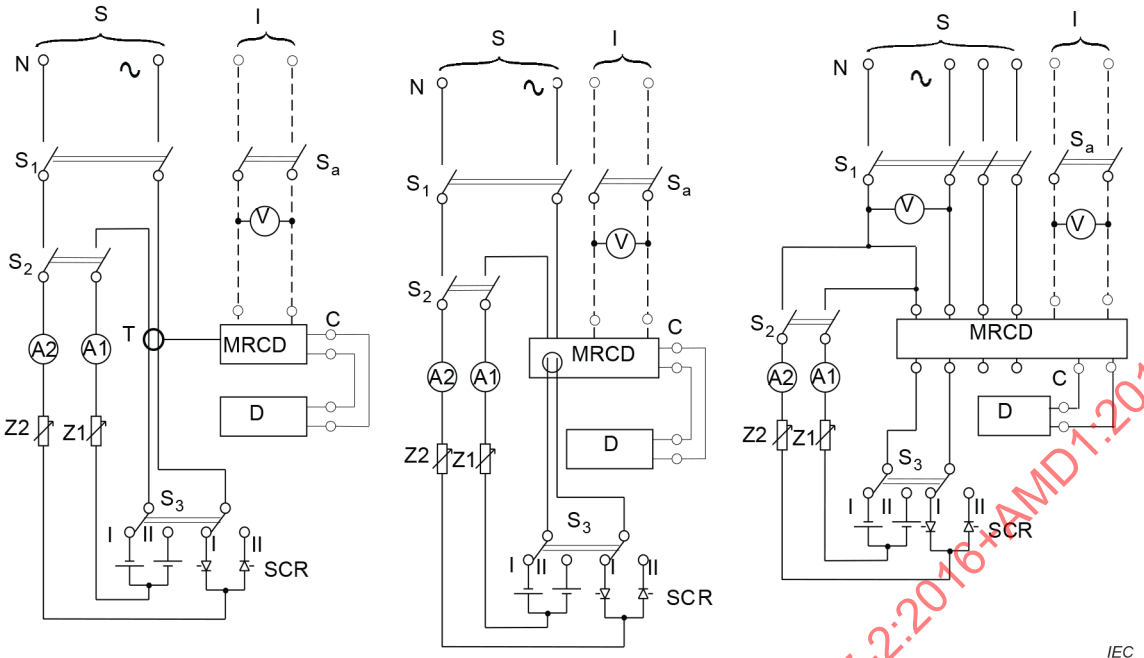
c) **MRCD de type à bornes**

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre	C	circuit de sortie
S_1	interrupteur multipolaire	B	appareil de coupure de courant
S_2	interrupteur unipolaire	Osc	oscilloscope
S_3	inverseur	SCR	thyristors

Figure M.9 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel continu pulsé (avec appareil de coupure de courant)

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

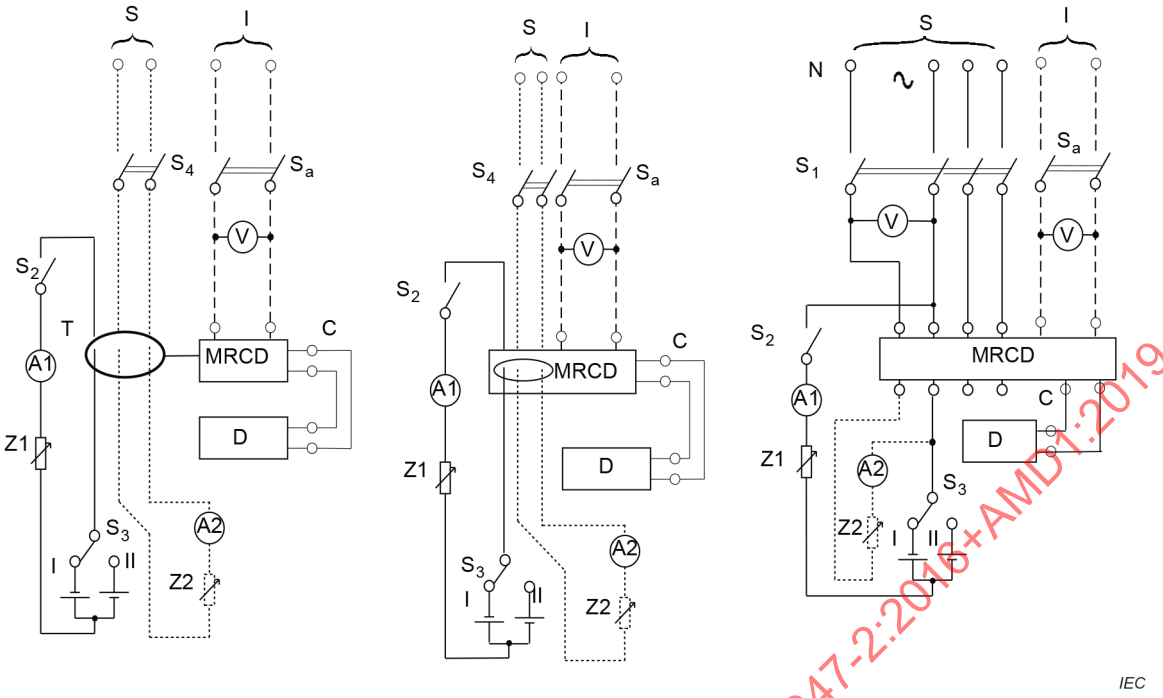
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_3	double inverseur
I	source de tension séparée, le cas échéant	S_a	interrupteur auxiliaire
V	voltmètre	Z	impédance réglable
A1	ampèremètre mesurant le courant continu	T	organe de détection
A2	ampèremètre mesurant le courant alternatif	C	circuit de sortie
S_1	interrupteur multipolaire	D	appareil indiquant le changement d'état
S_2	interrupteur bipolaire	SCR	thyristors

Figure M.10 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'un courant différentiel résiduel continu pulsé auquel est superposé un courant continu lissé

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

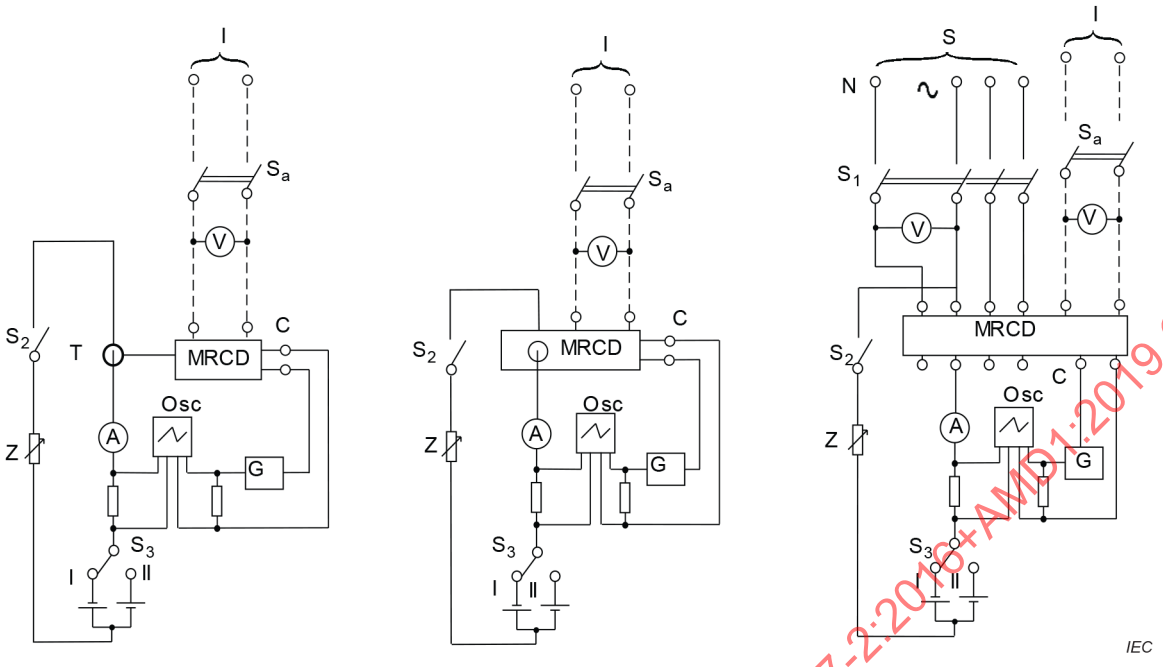
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_3	double inverseur
I	source de tension séparée, le cas échéant	S_4	interrupteur bipolaire
V	voltmètre	S_a	interrupteur auxiliaire
A1	ampèremètre mesurant le courant continu	Z1, Z2	impédances réglables
A2	ampèremètre mesurant le courant alternatif	T	organe de détection
S_1	interrupteur multipolaire	C	circuit de sortie
S_2	interrupteur unipolaire	D	appareil indiquant le changement d'état

Figure M.11 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une montée lente d'un courant différentiel résiduel continu lissé

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

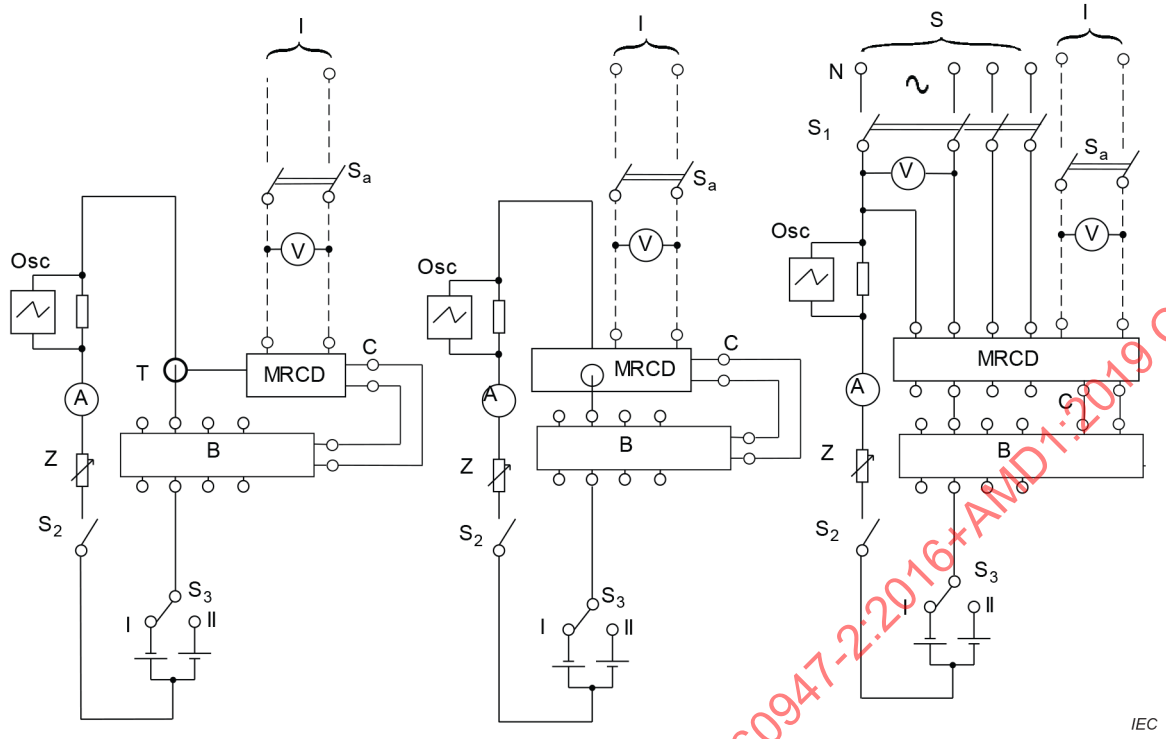
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre mesurant le courant continu	C	circuit de sortie
S_1	interrupteur multipolaire	G	générateur
S_2	interrupteur unipolaire	Osc	oscilloscope
S_3	inverseur		

Figure M.12 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel continu lissé (sans appareil de coupure de courant)

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

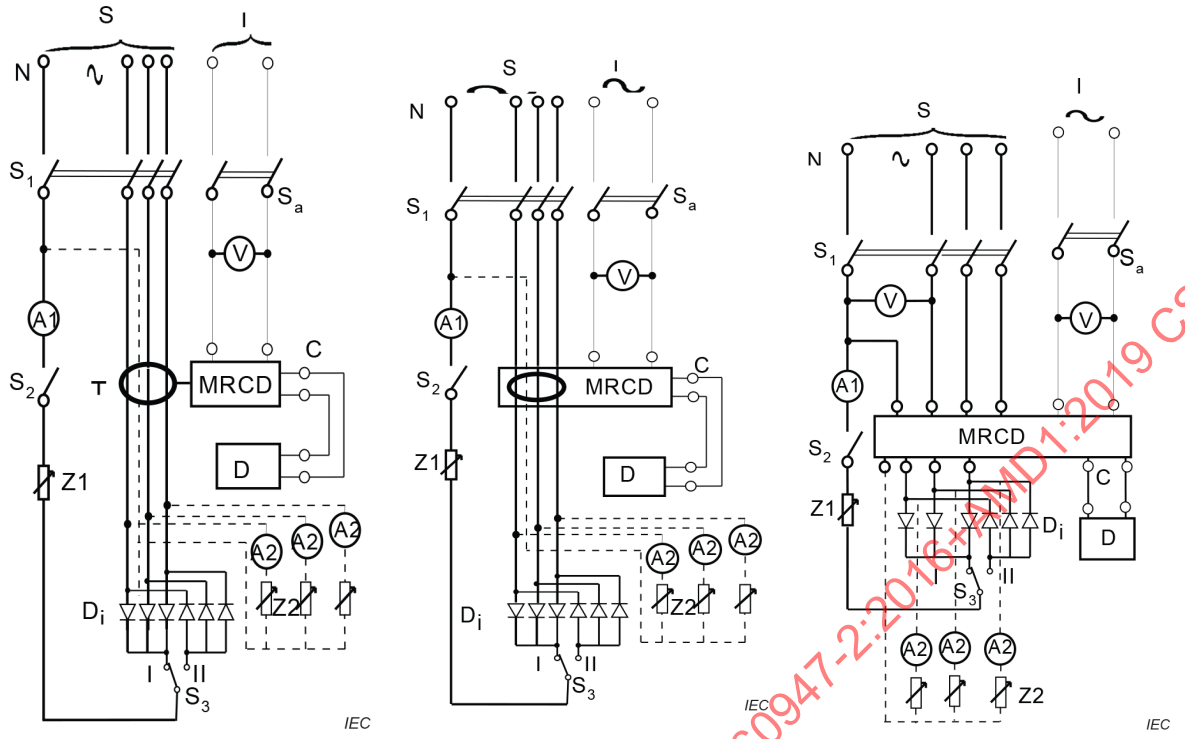
c) MRCD de type à bornes

Légende

S	alimentation électrique	S_a	interrupteur auxiliaire
I	source de tension séparée, le cas échéant	Z	impédance réglable
V	voltmètre	T	organe de détection
A	ampèremètre mesurant le courant continu	C	circuit de sortie
S_1	interrupteur multipolaire	B	appareil de coupure de courant
S_2	interrupteur unipolaire	Osc	oscilloscope
S_3	inverseur		

Figure M.13 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'une apparition subite d'un courant différentiel résiduel continu lissé (avec appareil de coupure de courant)

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a) **MRCD avec organe de détection séparé**

b) **MRCD avec organe de détection intégré**

c) **MRCD de type à bornes**

Légende

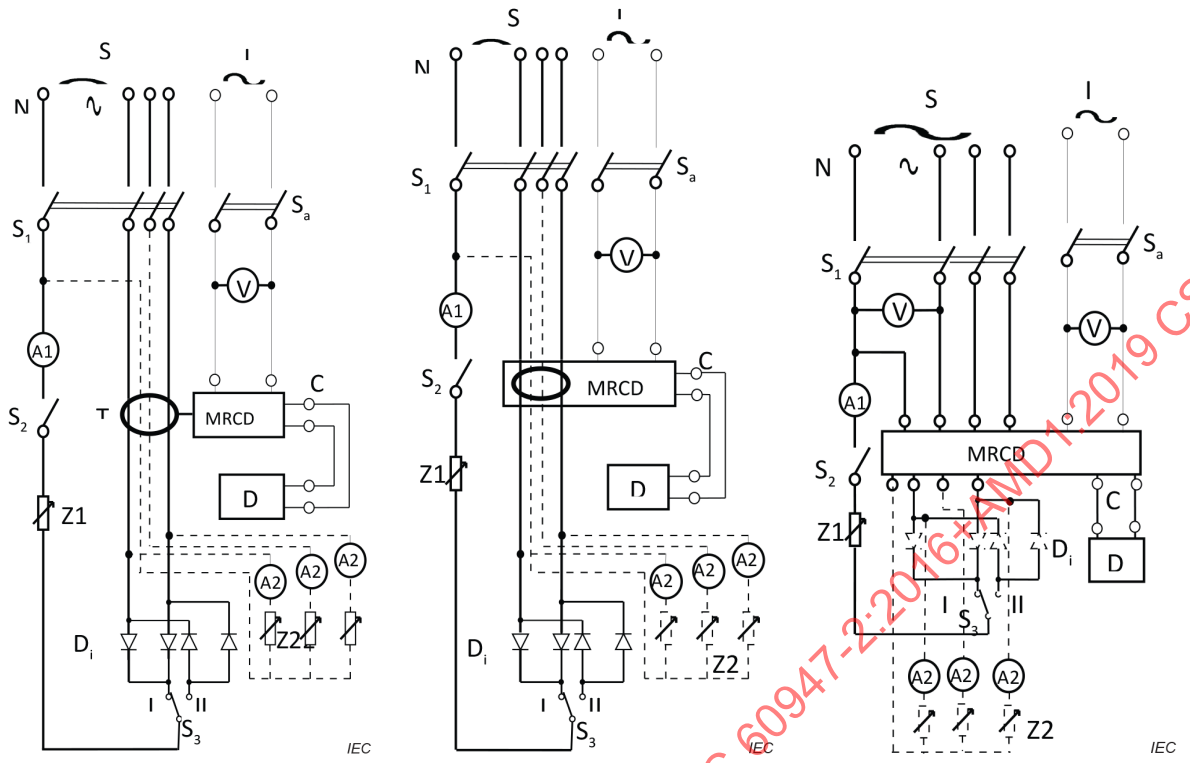
S	alimentation électrique	S_2	interrupteur unipolaire
I	source de tension séparée, le cas échéant	S_a	interrupteur auxiliaire
V	voltmètre	Z1, Z2	impédances réglables
A1	ampèremètre mesurant le courant alternatif	T	organe de détection
A2	ampèremètre mesurant le courant alternatif	C	circuit de sortie
S_1	interrupteur multipolaire	D	appareil indiquant le changement d'état
		D_i	diodes

Pour la vérification du temps de fonctionnement, l'appareil de mesure D est remplacé par un oscilloscope qui contrôle à la fois le courant différentiel résiduel et la sortie du MRCD (voir principe sur la Figure M.8 et la Figure M.12).

Pour la vérification du temps combiné, l'appareil de mesure D est remplacé par un appareil de coupure de courant dont le circuit principal est monté en série avec la voie de passage du courant différentiel résiduel. Le temps combiné est mesuré à l'aide d'un oscilloscope qui contrôle le courant différentiel résiduel (voir principe sur la Figure M.9 et la Figure M.13).

Figure M.14 – Circuits d'essai pour la vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par trois phases

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

c) MRCD de type à bornes

Légende

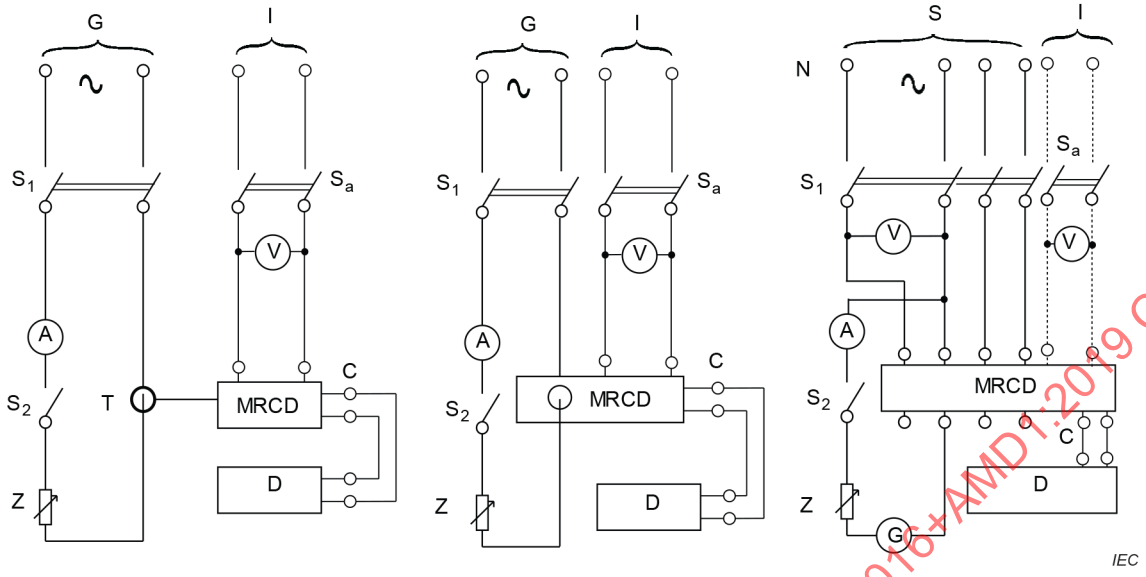
S	alimentation électrique	S_2	interrupteur unipolaire
I	source de tension séparée, le cas échéant	S_a	interrupteur auxiliaire
V	voltmètre	Z1, Z2	impédances réglables
A1	ampèremètre mesurant le courant alternatif	T	organe de détection
A2	ampèremètre mesurant le courant alternatif	C	circuit de sortie
S_1	interrupteur multipolaire	D	appareil indiquant le changement d'état
D_i	diodes		

Pour la vérification du temps de fonctionnement, l'appareil de mesure D est remplacé par un oscilloscope qui contrôle à la fois le courant différentiel résiduel et la sortie du MRCD (voir principe sur la Figure M.8 et la Figure M.12).

Pour la vérification du temps combiné, l'appareil de mesure D est remplacé par un appareil de coupure de courant dont le circuit principal est monté en série avec la voie de passage du courant différentiel résiduel. Le temps combiné est mesuré à l'aide d'un oscilloscope qui contrôle le courant différentiel résiduel (voir principe sur la Figure M.9 et la Figure M.13).

Figure M.15 – Circuits d'essai pour la vérification du fonctionnement correct dans le cas de courants différentiels résiduels continus pouvant résulter de circuits redresseurs alimentés par deux phases

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

c) MRCD de type à bornes

Légende

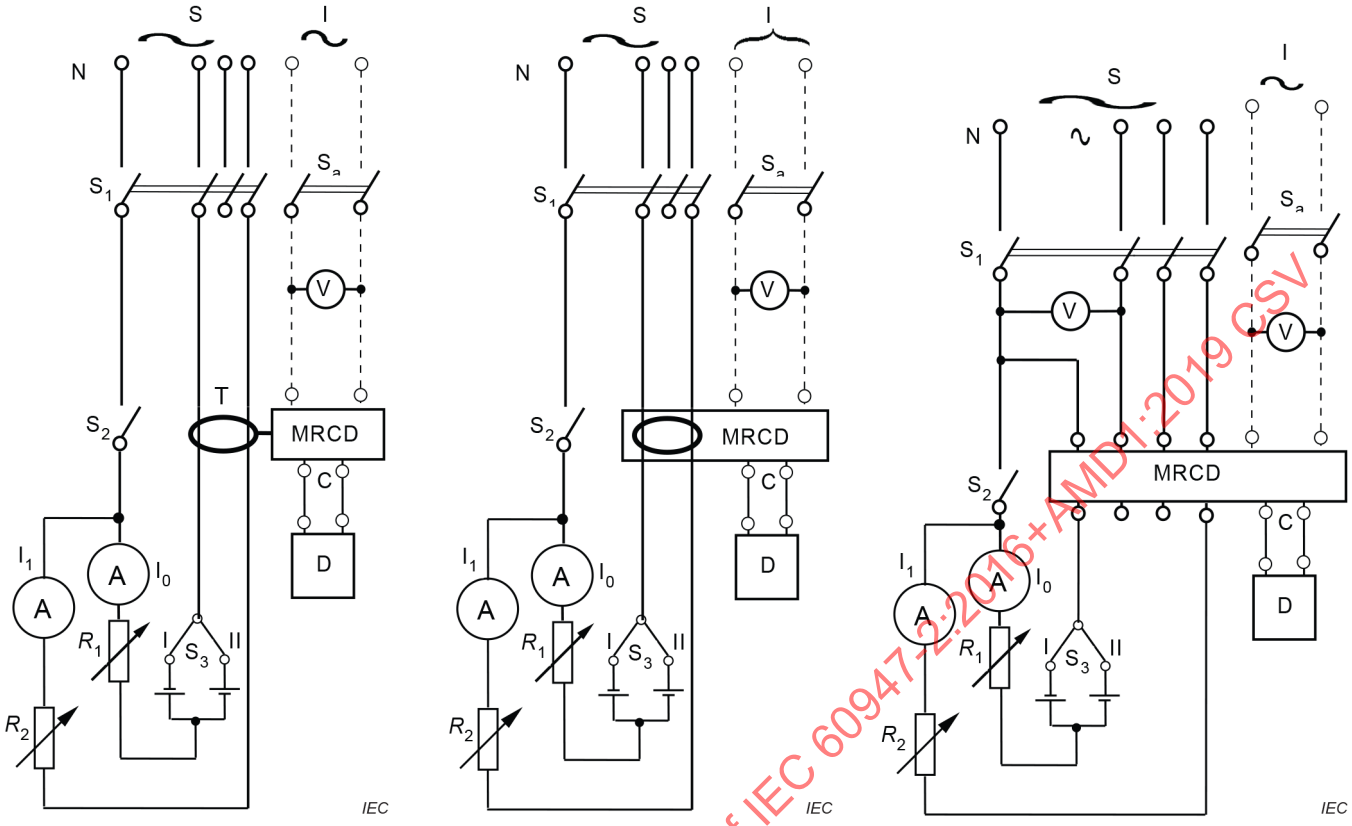
S	alimentation électrique	S_2	interrupteur unipolaire
I	source de tension séparée, le cas échéant	S_a	interrupteur auxiliaire
V	voltmètre	Z	impédance réglable
A	ampèremètre mesurant le courant alternatif	T	organe de détection
S_1	interrupteur multipolaire	C	circuit de sortie
G	générateur	D	appareil indiquant le changement d'état

Pour la vérification du temps de fonctionnement, l'appareil de mesure D est remplacé par un oscilloscope qui contrôle à la fois le courant différentiel résiduel et la sortie du MRCD (voir principe sur la Figure M.8 et la Figure M.12).

Pour la vérification du temps combiné, l'appareil de mesure D est remplacé par un appareil de coupure de courant dont le circuit principal est monté en série avec la voie de passage du courant différentiel résiduel. Le temps combiné est mesuré à l'aide d'un oscilloscope qui contrôle le courant différentiel résiduel (voir principe sur la Figure M.9 et la Figure M.13).

Figure M.16 – Circuits d'essai pour la vérification du fonctionnement correct dans le cas de courants différentiels résiduels composites et de courants différentiels résiduels alternatifs sinusoïdaux jusqu'à 1 000 Hz

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a) MRCD avec organe de détection séparé

b) MRCD avec organe de détection intégré

c) MRCD de type à bornes

Légende

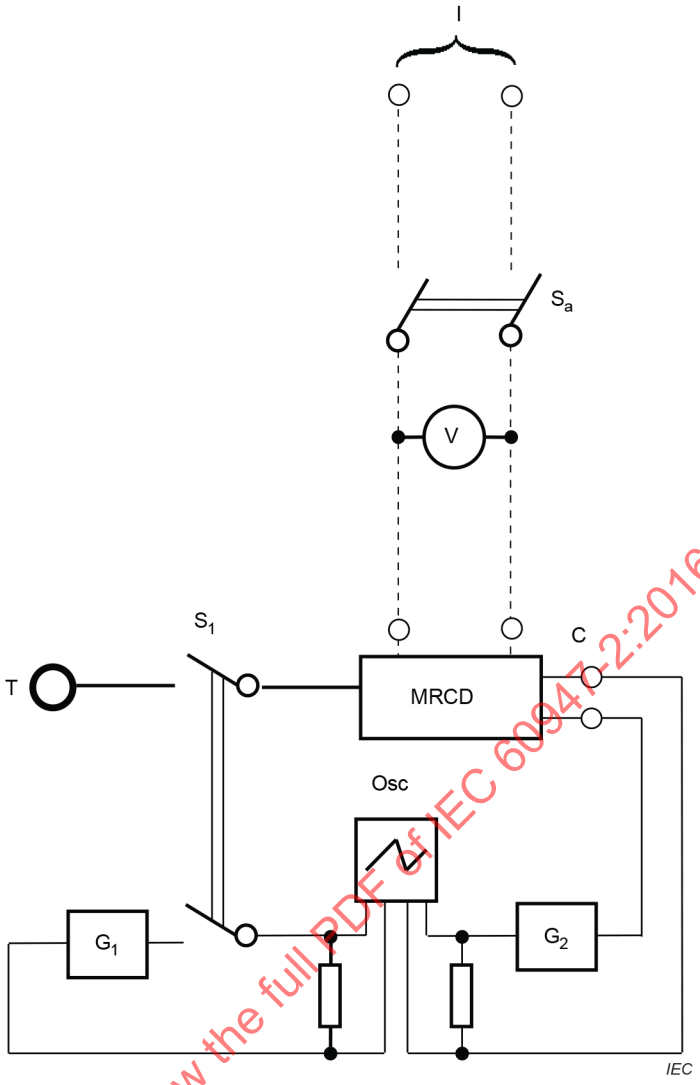
S	alimentation électrique	S_3	interrupteur bidirectionnel
I	source de tension séparée, le cas échéant	S_a	interrupteur auxiliaire
V	voltmètre	R_1, R_2	résistances réglables
A	ampèremètre mesurant le courant alternatif	T	organe de détection
S_1	interrupteur multipolaire	C	circuit de sortie
S_2	interrupteur unipolaire	D	appareil indiquant le changement d'état

Pour la vérification du temps de fonctionnement, l'appareil de mesure D est remplacé par un oscilloscope qui contrôle à la fois le courant différentiel résiduel et la sortie du MRCD (voir principe sur la Figure M.8 et la Figure M.12).

Pour la vérification du temps combiné, l'appareil de mesure D est remplacé par un appareil de coupure de courant dont le circuit principal est monté en série avec la voie de passage du courant différentiel résiduel. Le temps combiné est mesuré à l'aide d'un oscilloscope qui contrôle le courant différentiel résiduel (voir principe sur la Figure M.9 et la Figure M.13).

Figure M.17 – Circuits d'essai pour la vérification du fonctionnement dans le cas d'un courant différentiel résiduel alternatif superposé à un courant continu lissé

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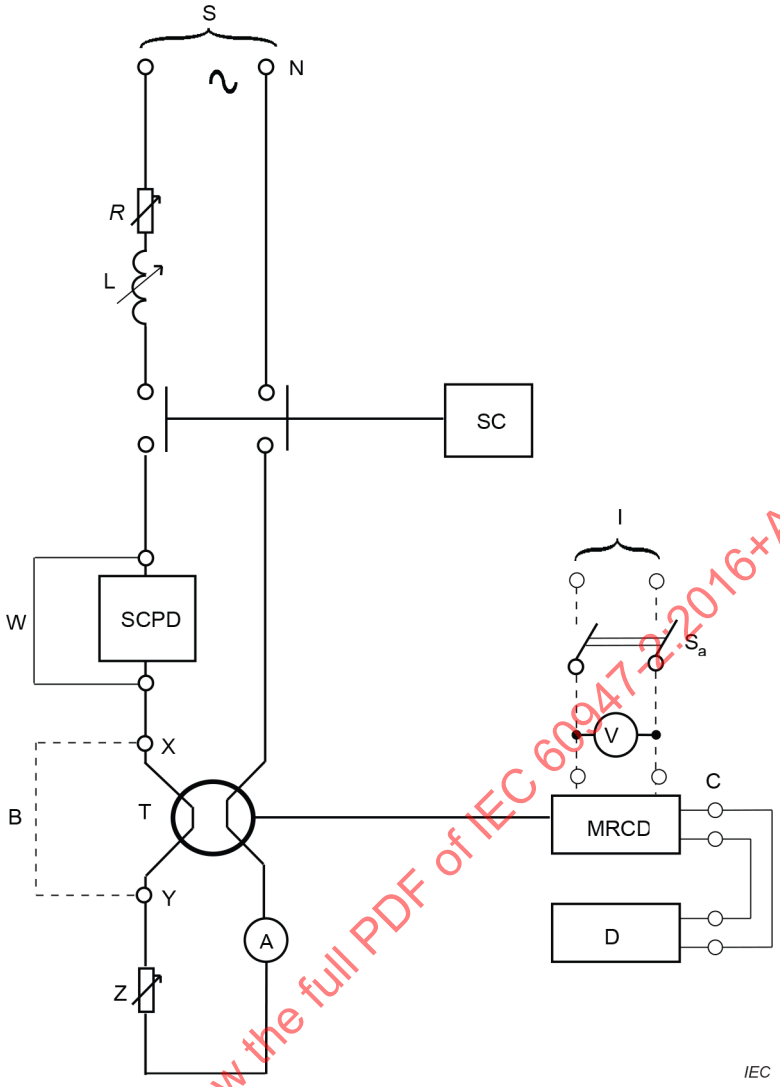


Légende

I	source de tension séparée, le cas échéant	T	organe de détection
V	voltmètre	C	circuit de sortie
S_1	interrupteur multipolaire	G_1, G_2	générateurs
S_a	interrupteur auxiliaire	Osc	oscilloscope

Figure M.18 – Circuit d'essai pour la vérification du comportement des MRCD à organe de détection séparé en cas de défaillance de la connexion de l'organe de détection

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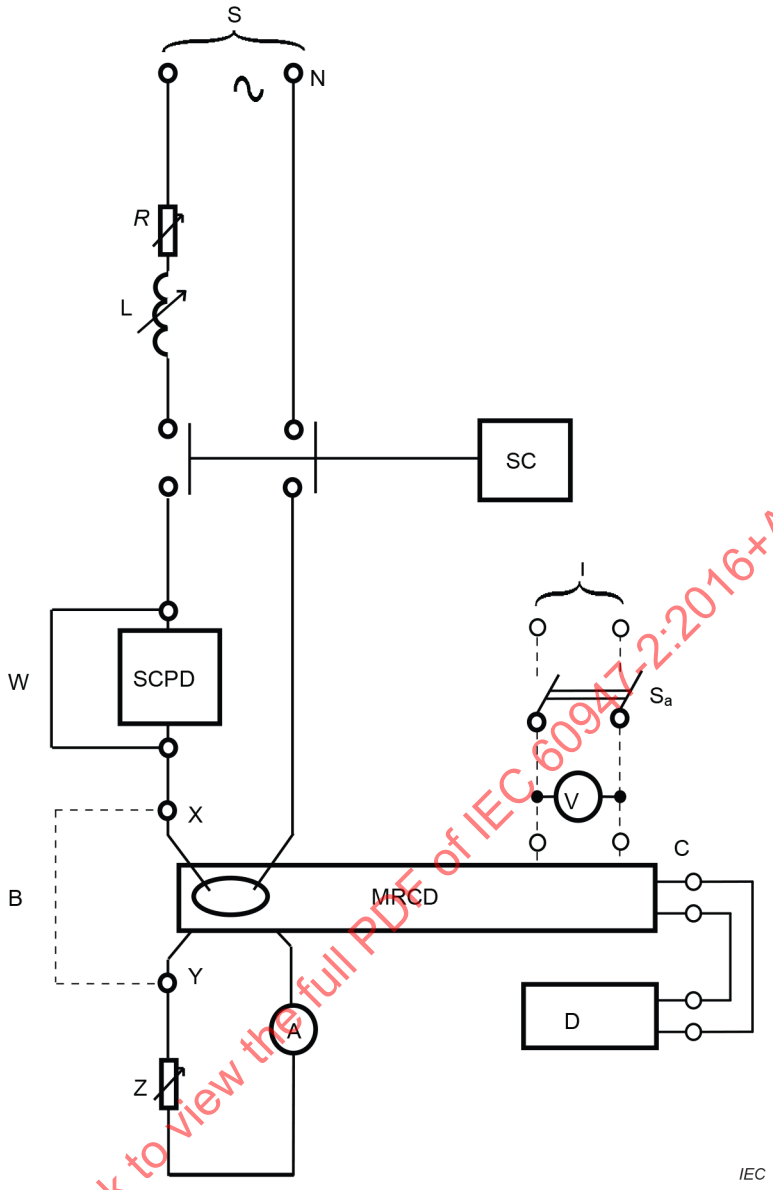


Légende

S	alimentation électrique	L	inductance réglable
I	source de tension séparée, le cas échéant	*R*	résistance réglable
V	voltmètre	Z	impédance réglable
A	ampèremètre	T	organe de détection
S_a	interrupteur auxiliaire	C	circuit de sortie
SC	court-circuiteur	D	appareil indiquant le changement d'état
W	connexion temporaire	SCPD	dispositif de protection contre les courts-circuits
B	connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant l'organe de détection		

Figure M.19 – Circuit d'essai pour la vérification du comportement d'un MRCD à organe de détection séparé dans des conditions de court-circuit

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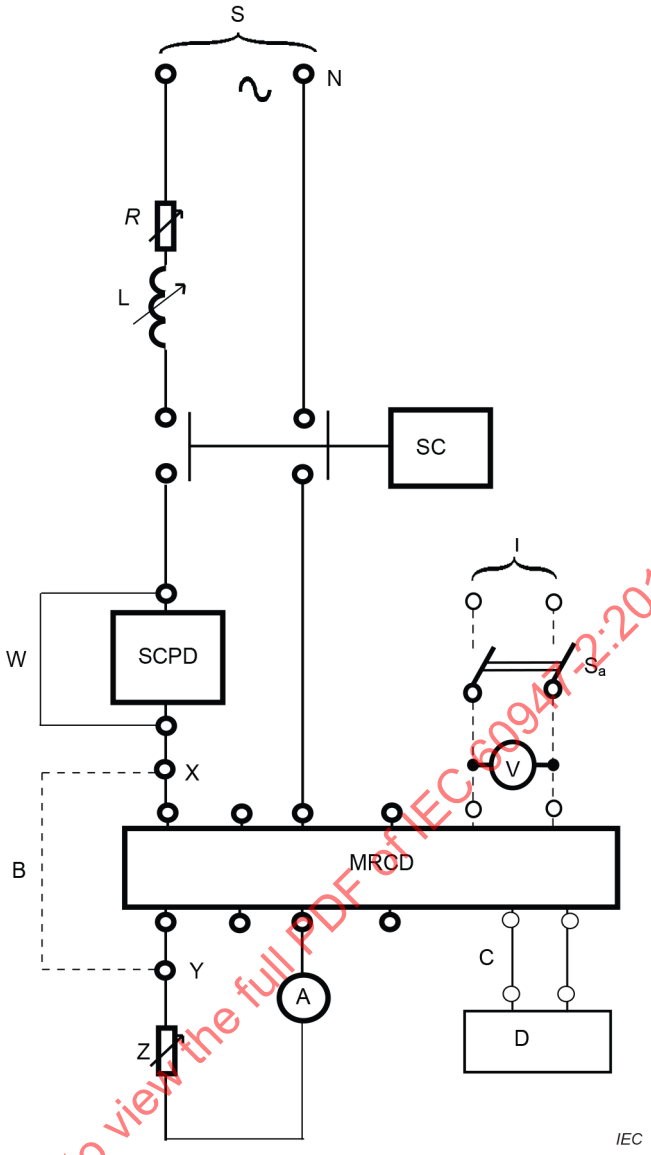


Légende

S	alimentation électrique	B	connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant l'organe de détection
I	source de tension séparée, le cas échéant	L	inductance réglable
V	voltmètre	*R*	résistance réglable
A	ampèremètre	Z	impédance réglable
S_a	interrupteur auxiliaire	C	circuit de sortie
SC	court-circuiteur	D	appareil indiquant le changement d'état
W	connexion temporaire	SCPD	dispositif de protection contre les courts-circuits

Figure M.20 – Circuit d'essai pour la vérification du comportement d'un MRCD à organe de détection intégré dans des conditions de court-circuit

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Légende

S	alimentation électrique	L	inductance réglable
A	ampèremètre	*R*	résistance réglable
S_a	interrupteur auxiliaire	Z	impédance réglable
SC	court-circuiteur	C	circuit de sortie
W	connexion temporaire	D	appareil indiquant le changement d'état
B	connexion pour l'essai de court-circuit différentiel résiduel, remplaçant la connexion traversant l'organe de détection	SCPD	dispositif de protection contre les courts-circuits

Figure M.21 – Circuit d'essai pour la vérification du comportement d'un MRCD de type à bornes dans des conditions de court-circuit

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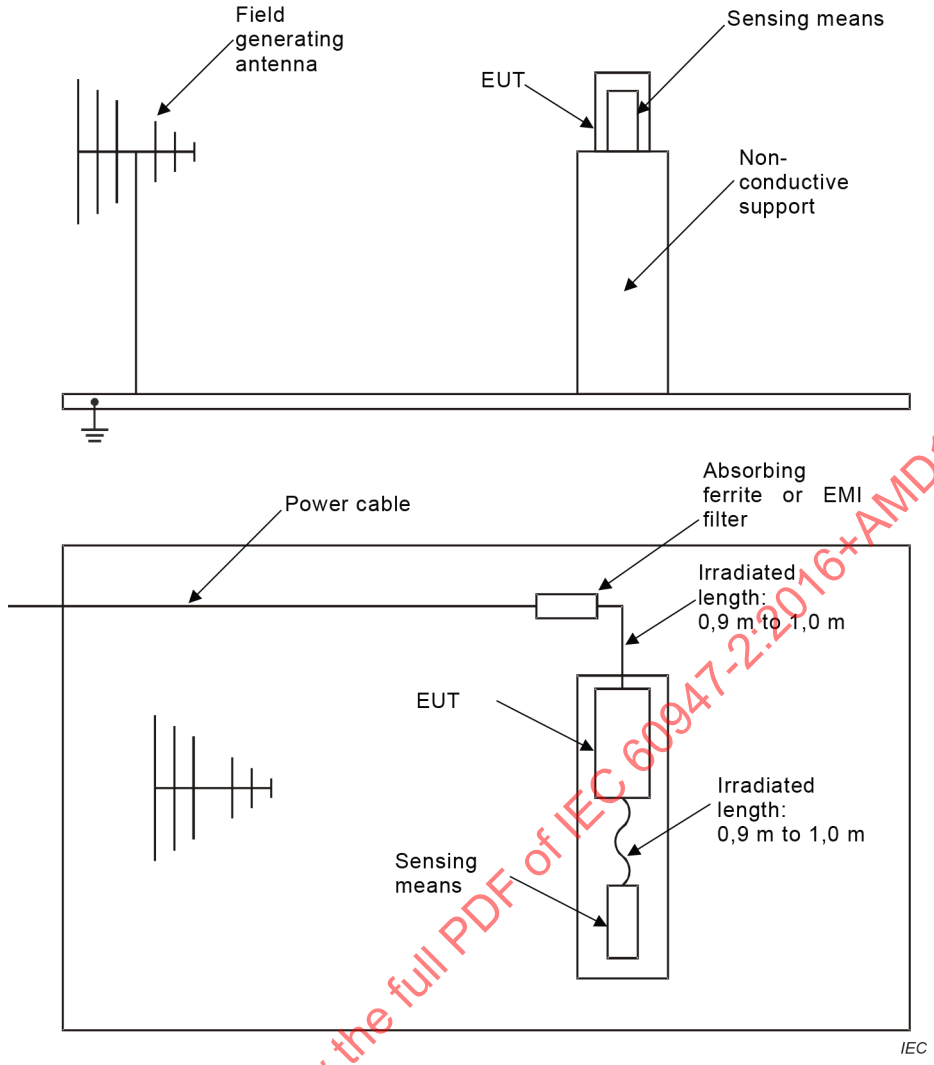


Figure M.22 – Vérification de l'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques – Installation d'essai pour les MRCD à organe de détection séparé (en complément de l'essai de l'Annexe B)

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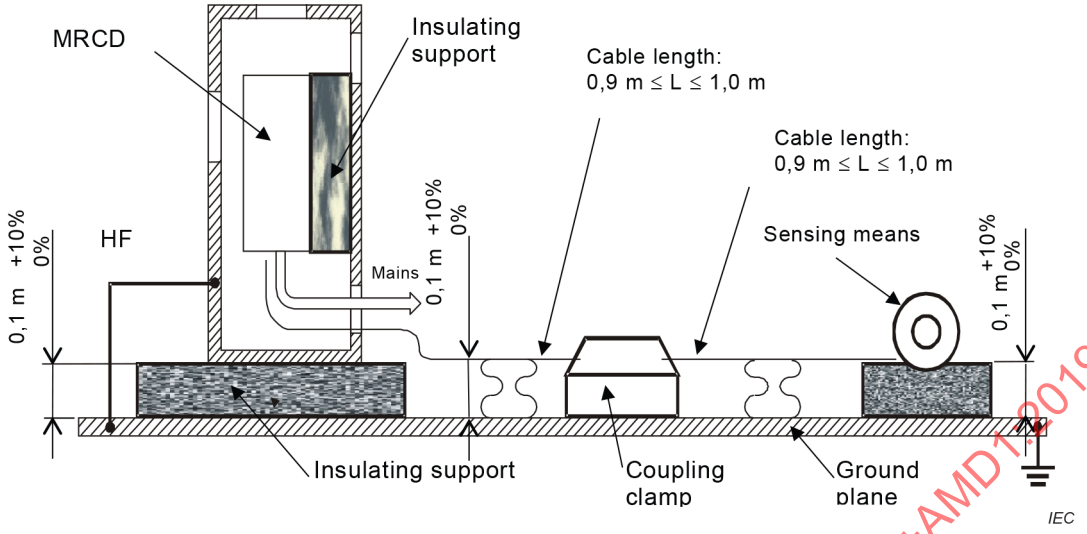
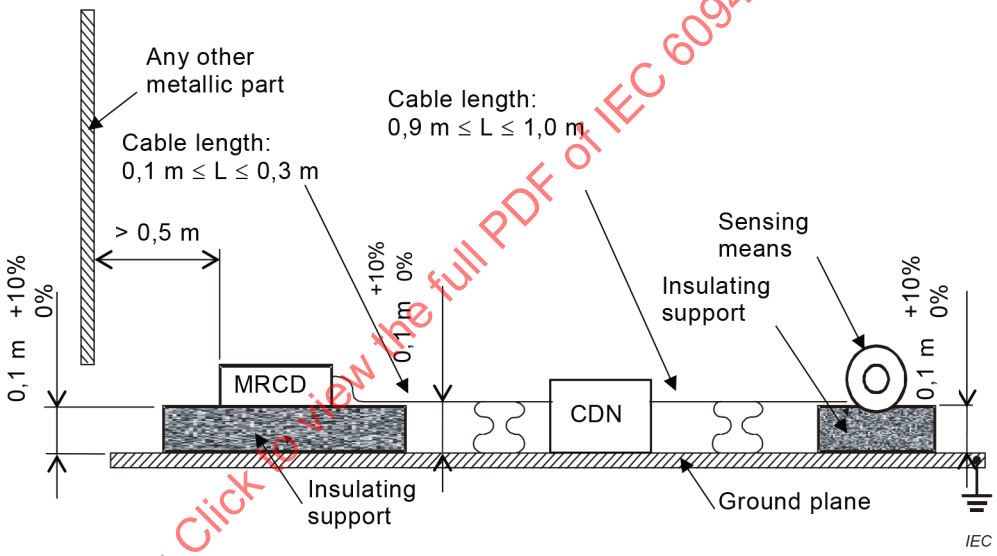


Figure M.23 – Vérification de l'immunité aux transitoires électriques rapides en salves (TER/S) sur la connexion de l'organe de détection d'un MRCD à organe de détection séparé (en complément de l'essai de l'Annexe B)



Légende

RCD réseau de couplage-découplage

Figure M.24 – Vérification de l'immunité aux perturbations conduites, induites par les champs radioélectriques – Installation d'essai pour les MRCD à organe de détection séparé (en complément de l'essai de l'Annexe B)

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Annexe N
(normative)

Compatibilité électromagnétique (CEM) – Exigences supplémentaires et méthodes d'essai pour les appareils non couverts par l'Annexe B, l'Annexe F et l'Annexe M

N.1 Généralités

N.1.1 Champ d'application

La présente annexe est applicable aux appareils, incorporés dans le disjoncteur ou montés sur le disjoncteur, comprenant des circuits électroniques (voir 7.3 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014), et non couverts par l'Annexe B (disjoncteurs à protection incorporée par courant différentiel résiduel), l'Annexe F (disjoncteurs à protection électronique contre les surintensités) et l'Annexe M (appareils modulaires à courant différentiel résiduel).

Elle couvre les auxiliaires de disjoncteur tels que les déclencheurs à minimum de tension, les déclencheurs shunt, les ~~bobines~~ déclencheurs de fermeture, les commandes motorisées, les indicateurs d'état à distance, etc. Les modules de communication ne sont pas couverts par ces exigences.

Elle complète l'Annexe J, pour les conditions d'essai et les critères de comportement spécifiques à ces appareils.

N.1.2 Conditions générales d'essai

Les essais selon la présente annexe peuvent être effectués séparément des séquences d'essai de l'Article 8.

Un appareil neuf peut être utilisé pour chaque essai ou un appareil peut être utilisé pour plusieurs essais, au choix du fabricant.

Pour les appareils comprenant plusieurs tensions assignées d'alimentation, un appareil de chaque caractéristique assignée doit être soumis à essai.

Les essais sur les ~~bobines~~ déclencheurs de fermeture ne sont pas nécessaires si leur construction (bobine et commande électronique) est identique aux déclencheurs shunt équivalents.

Les appareils doivent être incorporés dans le disjoncteur ou être montés sur le disjoncteur, conformément aux instructions du fabricant.

Les déclencheurs à minimum de tension et les accès de puissance destinés à être connectés de façon permanente à un réseau d'alimentation doivent être alimentés à la tension assignée. Dans le cas d'une plage de tensions assignées, ils doivent être alimentés à toute tension appropriée comprise dans cette plage.

Les appareils de fréquences assignées de 50 Hz à 60 Hz peuvent être soumis à essai à l'une ou l'autre de ces fréquences assignées.

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N.2 Immunité

N.2.1 Généralités

N.2.1.1 Conditions d'essai

Les essais d'immunité peuvent être effectués sur un disjoncteur équipé de plusieurs appareils, et peuvent être combinés avec les essais correspondants de l'Annexe B et de l'Annexe F, le cas échéant (par exemple les décharges électrostatiques, les champs électromagnétiques rayonnés aux fréquences radioélectriques, etc.).

Les appareils, à l'exception des ~~bobines~~ déclencheurs de fermeture, doivent être soumis à essai avec le disjoncteur fermé.

Les ~~bobines~~ déclencheurs de fermeture, le cas échéant (voir N.1.1), doivent être soumis~~es~~ à essai avec le disjoncteur prêt à la fermeture (ressorts principaux tendus).

N.2.1.2 Critères de comportement

Critère A: pendant l'essai, l'état du disjoncteur ne doit pas changer et l'état des sorties des modules d'indication à distance ne doit pas changer.

Critère B: pendant l'essai, l'état du disjoncteur ne doit pas changer alors que l'état des sorties des modules d'indication à distance peut changer temporairement, mais doit indiquer l'état correct du disjoncteur après l'essai.

Après les essais, la vérification fonctionnelle simplifiée de N.2.1.3 doit être effectuée.

N.2.1.3 Vérification fonctionnelle simplifiée

Pour les deux critères, après l'essai, le fonctionnement de l'appareil doit être vérifié à la tension assignée, ou, dans le cas d'une plage de tensions assignées, à toute tension appropriée comprise dans cette plage.

a) Un déclencheur à minimum de tension, lorsqu'il est alimenté, ne doit pas empêcher le disjoncteur d'être fermé; lorsque la tension est retirée, le disjoncteur doit déclencher.

b) Un déclencheur shunt, lorsqu'il est alimenté, doit déclencher le disjoncteur.

c) ~~Une bobine~~ Un déclencheur de fermeture, lorsqu'~~elle~~il est alimenté~~e~~, doit fermer le disjoncteur.

d) Une commande motorisée, lorsqu'elle est alimentée conformément aux instructions du fabricant, doit être capable de fermer et d'ouvrir le disjoncteur.

NOTE Cet essai est prévu seulement pour vérifier que l'appareil n'a pas été endommagé pendant les essais d'immunité. Il n'est pas prévu pour vérifier la conformité complète avec les exigences de la partie principale de la présente norme.

N.2.2 Décharges électrostatiques

L'Annexe J est applicable, en particulier J.2.2.

Le critère de comportement B de N.2.1.2 est applicable.

N.2.3 Champs électromagnétiques RF rayonnés

L'Annexe J est applicable, en particulier J.2.3.

Les raccordements d'essai doivent être conformes à la Figure 5 ou à la Figure 6 de l'IEC 61000-4-3:2006, suivant le cas, en prenant en considération les instructions du fabricant pour l'installation. Le type de câble utilisé doit être indiqué dans le rapport d'essai.

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Pour l'étape 1 (voir J.2.3), le critère de comportement A est applicable.

Pour l'étape 2 (voir J.2.3), à chacune des fréquences énumérées en J.2.3, le fonctionnement de l'appareil doit être vérifié selon N.2.1.3. Cet essai n'est pas applicable aux indicateurs d'état à distance.

N.2.4 Transitoires électriques rapides en salves (TER/S)

L'Annexe J est applicable, en particulier J.2.4.

Les raccordements d'essai doivent être conformes aux Figures 11, 12, 13 et 14 de l'IEC 61000-4-4:2012, en prenant en considération les instructions du fabricant pour l'installation.

Le critère de comportement A est applicable.

N.2.5 Ondes de choc

L'Annexe J est applicable, en particulier J.2.5.

Les raccordements d'essai doivent être conformes aux Figures 5, 6, 7, 8, 9, 10 ou 11 de l'IEC 61000-4-5:2014, en prenant en considération les instructions du fabricant pour l'installation.

Le critère de comportement B est applicable.

N.2.6 Perturbations conduites, induites par les champs RF (mode commun)

L'Annexe J est applicable, en particulier J.2.6.

Pour l'étape 1 (voir J.2.6), le critère de comportement A est applicable.

Pour l'étape 2 (voir J.2.6), à chacune des fréquences énumérées en J.2.6, le fonctionnement de l'appareil doit être vérifié selon N.2.1.3. Cet essai n'est pas applicable aux indicateurs d'état à distance.

N.2.7 Creux de tension et interruptions

Ces essais sont applicables seulement aux appareils dotés d'une alimentation permanente en courant alternatif.

Les essais doivent être effectués conformément à l'IEC 61000-4-11, aux niveaux d'essai du Tableau 23 de l'IEC 60947-1:2007/AMD1:2010.

Pendant l'essai, l'état du disjoncteur peut changer. L'état des sorties des modules d'indication à distance peut changer, mais doit indiquer l'état correct du disjoncteur après l'essai. Après l'essai, le fonctionnement correct de l'appareil doit être vérifié selon N.2.1.3.

N.3 Emission

N.3.1 Généralités

Ces essais sont applicables aux appareils comprenant des circuits électroniques ayant des fréquences fondamentales de commutation supérieures à 9 kHz (voir 7.3.3.2.1 de l'IEC 60947-1:2007/AMD2:2014) et prévus pour un fonctionnement permanent (par exemple les déclencheurs à minimum de tension).

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Ils ne sont pas applicables aux déclencheurs shunt prévus seulement pour être utilisés avec un contact d'autocoupure, incorporé ou séparé.

Ils ne sont pas applicables aux commandes motorisées ne comprenant pas de circuits électroniques alimentés de façon permanente, car ces appareils sont utilisés à des intervalles très peu fréquents et la durée de ces utilisations (fermeture, ouverture ou réarmement) est très courte (quelques centaines de millisecondes à quelques secondes).

Chaque appareil doit être soumis à des essais d'émission séparés, et ces essais ne doivent pas être combinés avec les essais correspondants de l'Annexe B et de l'Annexe F.

Les ~~bobines~~ déclencheurs de fermeture, le cas échéant (voir N.1.1), doivent être soumis~~es~~ à essai avec le disjoncteur prêt à la fermeture (ressorts principaux tendus).

Les déclencheurs à minimum de tension et les ~~bobines~~ déclencheurs de fermeture doivent être soumis à essai avec le disjoncteur fermé.

Les déclencheurs shunt et les commandes motorisées doivent être soumis à essai avec le disjoncteur ouvert.

Les indicateurs d'état à distance doivent être soumis à essai avec le disjoncteur fermé.

N.3.2 Perturbations conduites aux fréquences radioélectriques (150 kHz à 30 MHz)

L'Annexe J est applicable, en particulier J.3.2.

N.3.3 Perturbations rayonnées aux fréquences radioélectriques (30 MHz à 1 000 MHz)

L'Annexe J est applicable, en particulier J.3.3.

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Annexe O
(normative)

Disjoncteurs à déclenchement instantané (ICB)

O.1 Généralités

La présente annexe traite des disjoncteurs qui satisfont seulement à la partie court-circuit de la protection contre les surintensités de la partie principale de la présente norme, ci-après désignés ICB. Ils comprennent des déclencheurs instantanés de court-circuit, qui peuvent être réglables, mais pas de déclencheurs de surcharge. Ces appareils sont généralement utilisés conjointement avec d'autres matériels tels que des démarreurs de moteur, des relais à maximum de courant, etc. En combinaison avec des relais à maximum de courant spécifiés, ils offrent une protection complète contre les surintensités (surcharge et court-circuit) à la fois au circuit et au matériel spécifié.

Un ICB fait partie de la gamme des disjoncteurs, étant dérivé d'un disjoncteur équivalent (voir O.2.1) non équipé de déclencheurs de surcharge et incorporant un déclencheur de court-circuit, qui peut être réglable, conçu pour fournir une protection coordonnée contre les surintensités lorsqu'il est associé à des démarreurs de moteur ou à des relais à maximum de courant spécifiés.

O.2 Termes et définitions

En complément des termes et définitions donnés à l'Article 2, les termes et définitions suivants sont applicables.

O.2.1
disjoncteur équivalent
disjoncteur dont l'ICB est dérivé, qui a été soumis à essai conformément à la présente norme et qui possède la même taille que l'ICB

O.3 Valeurs assignées

O.3.1 Généralités

Les caractéristiques de l'Article 4 sont applicables à l'exception de la référence aux déclencheurs de surcharge et avec les compléments suivants.

O.3.2 Courant assigné (I_n)

Le courant assigné d'un ICB ne doit pas excéder le courant assigné du disjoncteur équivalent.

O.3.3 Pouvoir assigné de fermeture en court-circuit

Les ICB peuvent avoir un pouvoir assigné de fermeture en court-circuit différent de celui du disjoncteur équivalent.

NOTE Les ICB peuvent avoir un pouvoir assigné de fermeture en court-circuit égal ou supérieur à celui du disjoncteur équivalent lorsqu'ils sont associés à des démarreurs de moteur ou à des relais à maximum de courant spécifiés, et soumis à essai conformément aux articles appropriés de l'IEC 60947-4-1 (voir O.6.2).

O.3.4 Pouvoirs assignés de coupure en court-circuit

Les ICB peuvent avoir des pouvoirs assignés de coupure en court-circuit différents de ceux du disjoncteur équivalent.

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NOTE Les ICB peuvent avoir un pouvoir assigné de fermeture en court-circuit égal ou supérieur au I_{cu} du disjoncteur équivalent lorsqu'ils sont associés à des démarreurs de moteur ou à des relais à maximum de courant spécifiés, et soumis à essai conformément aux articles appropriés de l'IEC 60947-4-1 (voir O.6.2).

O.4 Informations sur le matériel

Un ICB doit être marqué conformément à 5.2, selon le cas.

Les pouvoirs assignés de fermeture et de coupure en court-circuit doivent être marqués, le cas échéant (voir O.6.1.1). Lorsque l'ICB n'a des caractéristiques assignées que pour le fonctionnement en court-circuit en association avec un démarreur de moteur ou un relais à maximum de courant (voir O.6.2), les caractéristiques assignées en court-circuit de l'association ne doivent pas être marquées sur l'ICB.

~~De plus, l'ICB doit être marqué de la façon suivante:~~

- ~~pour 5.2, point a), ajouter le marquage «ICB»;~~
- ~~pour 5.2, point b), ajouter les réglages du courant assigné instantané de court-circuit I_i (voir 2.20) (valeurs réelles ou multiples du courant assigné).~~

En outre, l'ICB doit être marqué conformément au Tableau O.1.

Tableau O.1 – Informations sur le matériel

Elément	Information	Emplacement du marquage
O1.1	Sigle "ICB"	Visible
O2.1	Courant assigné instantané de réglage de court-circuit I_i (voir 2.20) (valeurs réelles ou multiples du courant assigné)	Marqué
Légende Visible: visible depuis le devant lorsque le disjoncteur est installé en configuration de service et que l'organe de commande est accessible Marqué: marqué sur le matériel		

Les instructions du fabricant doivent attirer l'attention sur le fait qu'en dessous des réglages du courant assigné instantané de court-circuit, un ICB ne procure aucune protection à lui-même ou au circuit contre les surintensités. Une telle protection doit être assurée séparément.

Lorsqu'un ICB n'est pas associé à un appareil de protection spécifié (voir O.6.2), le fabricant doit fournir les données permettant le choix d'une protection adaptée contre les surcharges, par exemple les caractéristiques de tenue de l'ICB jusqu'à son réglage instantané maximal.

O.5 Exigences relatives à la construction et au fonctionnement

Un ICB, étant dérivé du disjoncteur équivalent (voir O.2.1), satisfait à toutes les exigences relatives à la construction et au fonctionnement applicables de l'Article 7, à l'exception de 7.2.1.2.4, point b).

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O.6 Essais

O.6.1 Séquence d'essai de l'ICB seul

O.6.1.1 Généralités

Les essais de ce paragraphe ne sont pas exigés si

– les caractéristiques en court-circuit des déclencheurs de court-circuit et les voies de passage du courant principal de l'ICB sont les mêmes que celles du disjoncteur équivalent, ou

– l'ICB a seulement des caractéristiques assignées et est soumis à essai comme une association (voir O.6.2).

Un échantillon de chacune des valeurs maximale et minimale du courant assigné I_n de chaque taille doit être soumis à essai.

Dans le cas d'une ou de plusieurs différences de construction (voir 2.1.2 et 7.1.6) dans la taille considérée, un échantillon supplémentaire doit être soumis à essai au courant assigné maximal correspondant à chaque construction.

O.6.1.2 Séquences d'essai

Les essais doivent être effectués conformément aux séquences II et III de la présente norme sans la vérification des déclencheurs de surcharge.

Pour les ICB comportant des variantes avec différents nombres de pôles, les essais doivent être effectués sur la variante avec le plus grand nombre de pôles. Les autres variantes doivent être soumises aux essais de la séquence III uniquement (sans vérification des déclencheurs de surcharge).

O.6.1.3 Vérification des déclencheurs de court-circuit

Après l'essai de O.6.1.2, un essai de déclenchement est effectué conformément à 8.3.3.2.2 sur chaque pôle de phase à tour de rôle, au réglage maximal du courant assigné instantané de court-circuit. L'essai est effectué à la valeur du courant de déclenchement déclarée par le fabricant pour les pôles individuels. L'ICB doit déclencher.

O.6.2 ICB associé avec un appareil de protection spécifié (par exemple un démarreur de moteur ou un relais à maximum de courant)

Les exigences d'essai applicables à ces associations sont couvertes dans les sections appropriées de l'IEC 60947-4-1, particulièrement dans les articles suivants:

– coordination avec les appareils de protection contre les courts-circuits,

– exigences supplémentaires pour les combinés de démarrage et les démarreurs protégés aptes au sectionnement,

– fonctionnement en conditions de court-circuit,

– coordination au courant d'intersection entre démarreur et DPCC associé.

NOTE Le symbole DPCC dans l'IEC 60947-4-1 est applicable à différents appareils de protection contre les courts-circuits, y compris l'ICB.

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Annexe P
(normative)

Disjoncteurs à courant continu pour utilisation dans les applications photovoltaïques (PV)

P.1 Champ d'application

Cette annexe s'applique aux disjoncteurs à courant continu de caractéristiques assignées jusqu'à 1 500 V en courant continu, destinés à être utilisés dans les systèmes photovoltaïques (PV), ci-après désignés «Disjoncteurs PV».

Les disjoncteurs utilisés dans les systèmes PV sont soumis à des conditions électriques, d'environnement et de service qui diffèrent des conditions générales prises en compte dans le texte principal de la présente norme.

Les exigences ont donc été adaptées pour refléter ces conditions d'utilisation.

La présente annexe a pour objet de spécifier:

– les exigences applicables aux disjoncteurs à utiliser du côté continu des applications PV,
– les essais destinés à vérifier les caractéristiques de fonctionnement des matériels et leur comportement après l'exposition aux conditions d'environnement en service PV.

P.2 Termes et définitions

L'Article 2 est applicable.

P.3 Classification

L'Article 3 est applicable.

P.4 Caractéristiques des disjoncteurs PV

L'Article 4 est applicable avec la modification suivante:

Un disjoncteur PV conçu pour ne pas être utilisé uniquement dans des applications PV ne doit avoir qu'un seul courant assigné.

La tension assignée de tenue aux chocs (U_{imp}) des disjoncteurs PV doit ~~être conforme aux valeurs indiquées dans le~~ satisfaire au Tableau P.1.

Tableau P.1 – Niveaux assignés de tenue aux chocs des disjoncteurs PV

Valeur maximale de la tension assignée d'emploi (V)	Valeur de la tension assignée de tenue aux chocs (V)
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE Ces valeurs sont basées sur les exigences de l'IEC 60364-7-712 relatives à la catégorie de surtension II, comme défini dans l'IEC 60664-1 et l'IEC/TR 60664-2-1:2011, Annexe D.	

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P.5 Informations sur le matériel

~~Le paragraphe 5.2 est applicable avec les ajouts suivants:~~

~~Un disjoncteur PV doit être marqué «IEC 60947-2:2016, Annexe P» selon les conditions du point 5.2 b).~~

~~Un disjoncteur classé pour ne pas être utilisé uniquement dans des applications PV doit présenter les caractéristiques assignées U_e et I_{cu} / I_{cs} correspondantes se rapportant à cette annexe nettement différenciées des caractéristiques se rapportant au corps de la présente norme.~~

~~La méthode et le schéma de connexion en série des pôles d'un disjoncteur PV (si nécessaire, pour chaque caractéristique assignée) doivent être marqués selon les conditions du point 5.2 c).~~

L'Article 5 est applicable avec les modifications et les ajouts énumérés dans le Tableau P.3.

Les disjoncteurs classés pour ne pas être utilisés uniquement dans des applications PV doivent présenter les caractéristiques assignées U_e et I_{cu} / I_{cs} correspondantes, conformément à la présente annexe, nettement différenciées des caractéristiques assignées se rapportant au corps du présent document.

Tableau P.3 – Informations sur le matériel

Elément	Information	Emplacement du marquage
P2.1	IEC 60947-2:2016 – Annexe P	Marqué
P3.1	Méthode et schéma de connexion en série des pôles, si nécessaire pour chaque caractéristique assignée	Documentation
Légende		
Marqué:	marqué sur le matériel	
Documentation:	spécifié dans la documentation du fabricant	

P.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable avec l'ajout suivant:

Des lignes directrices concernant le déclassement pour une température ambiante jusqu'à 70 °C peuvent être fournies. En outre, des lignes directrices concernant l'utilisation à des températures inférieures à – 5 °C peuvent aussi être fournies.

P.7 Exigences relatives à la construction et au fonctionnement

P.7.1 Exigences relatives à la construction

Le paragraphe 7.1 est applicable.

P.7.2 Exigences relatives au fonctionnement

Le paragraphe 7.2 est applicable avec les modifications suivantes:

Les disjoncteurs PV doivent pouvoir interrompre tout courant jusqu'à leur pouvoir assigné de coupure en court-circuit, y compris un éventuel courant critique de charge, dans le sens direct et dans le sens inverse.

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La conformité à ces exigences est vérifiée par les essais de P.8.3.

En référence à 7.2.4.1, de telles conditions de surcharge ne se produisent pas dans le cas des applications PV. Les conditions de surintensité ne peuvent résulter que d'un court-circuit. Par conséquent, aucun essai selon cet article n'est exigé. Les essais de fonctionnement en court-circuit sont donnés de P.8.3.4 à P.8.3.8.

En référence à 7.2.4.2 pour l'aptitude au fonctionnement en service, les disjoncteurs PV doivent pouvoir satisfaire aux exigences du Tableau P.2.

Tableau P.2 – Nombre de cycles de manœuvres

Courant assigné [a] (A)	Nombre de cycles de manœuvres par heure [b]	Nombre de cycles de manœuvres		
		Sans courant	Avec courant [c]	Total
$I_n \leq 100$	120	9 700	300	10 000
$100 < I_n \leq 315$	120	7 800	200	8 000
$315 < I_n \leq 630$	60	4 800	200	5 000
$630 < I_n \leq 2\,500$	20	2 900	100	3 000
$2\,500 < I_n$	10	1 900	100	2 000

[a] Indique le courant assigné maximal pour une taille donnée.

[b] La colonne 2 indique la fréquence de manœuvre minimale. Cette fréquence peut être augmentée avec l'accord du fabricant; dans ce cas, la fréquence utilisée doit être indiquée dans le rapport d'essai.

[c] Au cours de chaque cycle de manœuvres, le disjoncteur doit rester fermé pendant un temps suffisant pour assurer l'établissement complet du courant mais ne dépassant pas 2 s.

En raison des règles d'installation définies dans l'IEC 60364-7-712, il n'est pas nécessaire de tenir compte du risque d'un double défaut à la terre. Par conséquent, l'Annexe H de la présente norme n'est pas applicable aux disjoncteurs PV.

NOTE Le cas d'un disjoncteur PV devant interrompre un faible courant de défaut sur un seul pôle uniquement est à l'étude.

P.7.3 Compatibilité électromagnétique (CEM)

Le paragraphe 7.3 est applicable.

P.8 Essais

P.8.1 Nature des essais

Le paragraphe 8.1 est applicable.

P.8.2 Conformité aux exigences de construction

Le paragraphe 8.2 est applicable.

P.8.3 Essais de type

Le paragraphe 8.3 est applicable avec les modifications suivantes:

P.8.3.1 Séquences d'essai

En référence à 8.3.1.2, les essais omis de la séquence I peuvent ne pas être réalisés si le disjoncteur PV est dérivé d'un disjoncteur ayant déjà fait l'objet d'essais identiques ou plus

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rigoureux, à l'exception du fait que les caractéristiques de déclenchement contrôlées en courant alternatif ne couvrent pas les caractéristiques en courant continu.

En référence à 8.3.1.4, les programmes d'essai alternatifs ne s'appliquent pas aux disjoncteurs PV.

P.8.3.2 Conditions générales d'essai

Pour tous les essais, la connexion en série des pôles du disjoncteur doit être conforme aux instructions du fabricant.

Les échantillons doivent être choisis et soumis à essai conformément à la colonne «Bornes repérées alimentation/charge-Non» du Tableau 10.

En référence au paragraphe 8.3.2.2.5, la constante de temps pour l'aptitude au fonctionnement en service, les essais de court-circuit et l'essai de courant continu critique de charge doit être égale à 1 ms. Au choix du fabricant, une valeur plus élevée peut être utilisée. Dans ce cas, elle doit être indiquée dans le rapport d'essai.

P.8.3.3 Séquence d'essai I

Le paragraphe 8.3.3 est applicable avec les modifications suivantes:

En référence à 8.3.3.4.3, pour l'aptitude au fonctionnement en service sans courant, le nombre de cycles de manœuvres et le nombre de cycles par heure sont donnés dans le Tableau P.2.

En référence à 8.3.3.4.4, pour l'aptitude au fonctionnement en service avec courant, le nombre de cycles de manœuvres et le nombre de cycles par heure sont donnés dans le Tableau P.2, et la constante de temps doit être conforme à P.8.3.2. La moitié des manœuvres doit être réalisée en faisant circuler les courants dans un sens et l'autre moitié dans l'autre sens.

En référence à 8.3.3.5, l'essai de fonctionnement en surcharge n'est pas applicable.

P.8.3.4 Séquence d'essai II

Le paragraphe 8.3.4 est applicable, avec les modifications énumérées en P.8.3.2.

P.8.3.5 Séquence d'essai III

Le paragraphe 8.3.5 est applicable, avec les modifications énumérées en P.8.3.2.

P.8.3.6 Séquence d'essai IV

Le paragraphe 8.3.6 est applicable, avec les modifications énumérées en P.8.3.2.

P.8.3.7 Séquence d'essai V

Le paragraphe 8.3.7 est applicable, avec les modifications énumérées en P.8.3.2.

P.8.3.8 Séquence d'essai VI

Le paragraphe 8.3.8 est applicable, avec les modifications énumérées en P.8.3.2.

P.8.3.9 Essai de courant continu critique de charge

Le paragraphe 8.3.9 est applicable avec les modifications suivantes:

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Le disjoncteur doit être fermé et ouvert 10 fois sur chacun des courants d'essai, 5 fois avec le courant circulant dans le sens direct et 5 fois avec le courant circulant dans le sens inverse.

La constante de temps doit être conforme à P.8.3.2.

Pendant la vérification du fonctionnement en service (le cas échéant), le disjoncteur doit être soumis à 100 manœuvres au lieu de 50.

P.8.3.10 Essai de cyclage thermique

Les disjoncteurs PV doivent être soumis à un cyclage thermique conformément à l'IEC 60068-2-14, essai Nb, comprenant 50 cycles, chaque cycle comprenant une période de 1 h à – 40 °C, suivie d'une période de 1 h à + 85 °C. La vitesse de variation de la température doit être de 1 K/min. A la fin des 50 cycles, les appareils doivent être ramenés à la température ambiante de 25 ± 5 °C pendant au moins 3 h.

L'appareil doit être ensuite soumis à:

– un examen visuel pour confirmer l'absence de déformation ou de dommage des pièces affectant le fonctionnement normal et la protection,
– la vérification des déclencheurs de surcharge selon 8.3.3.2.3;
– une vérification de l'échauffement aux bornes principales selon 8.3.2.5. L'échauffement ne doit pas dépasser les valeurs données au Tableau 7;
– une vérification de la tenue diélectrique selon 8.3.3.6.

Le nombre d'échantillons doit être conforme aux exigences du Tableau 10 pour la séquence d'essai I.

P.8.3.11 Essai climatique

Les disjoncteurs PV doivent être soumis aux essais climatiques de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 Annexe Q, catégorie B: environnement sujet à la température et à l'humidité, à l'exception du fait que l'essai de chaleur sèche et l'essai à basse température ne sont pas exigés dans la mesure où ils sont considérés couverts par l'essai de cyclage thermique de P.8.3.10.

Lorsque le Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 demande la vérification de l'aptitude au fonctionnement, celle-ci doit être réalisée en effectuant les essais individuels de série de 8.4 de la présente norme, à l'exception des essais diélectriques de 8.4.6 qui sont couverts par les essais du Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

En référence à la note de bas de page g) du Tableau Q.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014, au cours de l'essai de chaleur humide, l'essai fonctionnel doit comprendre les manœuvres mécaniques de 8.4.2 de la présente norme. Lorsque seuls des organes de manœuvre manuels sont disponibles, cet essai peut être réalisé au cours du début de la période froide suivante.

Le nombre d'échantillons doit être conforme aux exigences du Tableau 10 pour la séquence d'essai I. Au choix du fabricant, cet essai peut être combiné à l'essai de cyclage thermique et réalisé sur les mêmes échantillons.

P.8.4 Essais individuels de série

Le paragraphe 8.4 est applicable.

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P.8.5 Essais spéciaux

Le paragraphe 8.5 est applicable.

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Annexe Q

Disponible

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Annexe R
(normative)

Disjoncteurs à protection incorporée par courant différentiel résiduel avec fonctions de refermeture automatique

R.1 Généralités

R.1.1 Préambule

Les DPR conformes à l'Annexe B de la présente norme sont utilisés comme appareils de protection contre les effets des risques de choc électrique.

Les DPR conformes à l'Annexe B nécessitent un réarmement manuel après déclenchement.

Les DPR peuvent être installés dans des emplacements éloignés et/ou sans surveillance tels que des stations de télécommunications ou des installations de feux de signalisation. Le déclenchement d'un DPR de ce type en raison d'un choc de foudre ou d'une fuite à la terre temporaire engendre des délais et des coûts pour se rendre sur le site afin d'effectuer les réparations et de rétablir l'alimentation.

Les résultats d'un tel déclenchement dû à des défauts temporaires, tels que l'interruption totale d'une station de télécommunications mobiles ou le dysfonctionnement d'un système de feux de signalisation, peuvent provoquer des dérangements voire générer un danger mortel.

Les DPR à refermeture automatique sont destinés à améliorer l'efficacité d'exploitation des installations sans surveillance.

Cette annexe est principalement fondée sur les exigences applicables de l'Annexe B de la présente norme.

R.1.2 Champ d'application

La présente annexe est applicable aux DPR, ci-après dénommés CBAR, qui rétablissent l'alimentation par refermeture automatique sans manœuvre manuelle en cas de déclenchement dû à la fonction de courant différentiel résiduel.

Cette annexe s'applique également aux dispositifs de refermeture automatique fournis séparément, qui, lorsqu'ils sont associés à un DPR, satisfont aux exigences d'un CBAR. Pour les besoins de la présente annexe, le terme CBAR couvre également un dispositif de refermeture automatique associé à un DPR.

Cette annexe couvre également les exigences applicables aux CBAR relatives à la compatibilité électromagnétique (CEM).

La présente annexe n'est applicable qu'aux CBAR destinés à être utilisés dans des circuits à courant alternatif.

La fonction de courant différentiel résiduel des CBAR visés par la présente annexe peut ou non dépendre fonctionnellement de la tension d'alimentation. Les CBAR dépendant d'une autre source d'alimentation pour la fonction de courant différentiel résiduel ne sont pas couverts par cette annexe.

La présente annexe a pour objet de spécifier:

a) les caractéristiques spécifiques de la fonction de refermeture automatique;

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b) les exigences spécifiques auxquelles doit répondre le CBAR:
   – dans les conditions normales du circuit;
   – dans des conditions anormales du circuit;
   – dans les conditions de défaut temporaires.
c) les essais qui doivent être effectués pour vérifier la conformité aux exigences du point b) ci-dessus, ainsi que les modes opératoires d'essai appropriés;
d) les informations appropriées sur le matériel.

R.2 Termes et définitions

En complément à l'Article 2 et à l'Article B.2 de la présente norme, les termes et définitions complémentaires suivants s'appliquent:

R.2.1
refermeture automatique
séquence de manœuvres par laquelle, à la suite d'une ouverture, un appareil mécanique de connexion se referme automatiquement en fonction de conditions spécifiques

[SOURCE: IEC 60050-441:1984, 441-16-10, modifiée – terme et complété par «en fonction de conditions spécifiques»]

R.2.2
courant différentiel résiduel de refermeture automatique assigné
$I_{\Delta ar}$
valeur maximale du courant différentiel résiduel pour laquelle un CBAR de type M se referme automatiquement dans les conditions spécifiées (voir R.3.2.1)

R.2.3
sélecteur
commutateur permettant de choisir le mode de refermeture automatique ou manuelle

R.2.4
temps de réarmement
durée maximale, déclarée par le fabricant, au cours de laquelle des manœuvres de refermeture successives peuvent être réalisées

R.2.5
état bloqué
état du CBAR dans lequel la fonction de refermeture automatique est neutralisée et un réarmement manuel est nécessaire

R.2.6
délai de refermeture
pour un CBAR de type TD, temps maximal entre le déclenchement de l'appareil et la refermeture des contacts

Note 1 à l'article: Pour la définition d'un CBAR de type TD, voir R.3.2.2.

R.2.7
temps de refermeture
pour un CBAR de type M, temps maximal entre le moment où la condition de refermeture est remplie et la refermeture des contacts

Note 1 à l'article: Pour la définition d'un CBAR de type M, voir R.3.2.1.

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R.2.8
temps de surveillance
pour les CBAR de type M, temps pendant lequel la surveillance est effective après un déclenchement dû à la fonction de courant différentiel résiduel

R.3 Classification

En complément à l'Article 3 et à l'Article B.3 de la présente norme, les classifications complémentaires suivantes s'appliquent.

R.3.1 Selon la méthode de construction

R.3.1.1 CBAR intégré

CBAR constitué d'un appareil unique comprenant une fonction de refermeture automatique intégrée par le fabricant au disjoncteur.

R.3.1.2 Dispositif de refermeture automatique externe

Dispositif de refermeture automatique raccordé de l'extérieur à un DPR sans modification de ses circuits ou composants internes.

R.3.2 Selon le mode de refermeture automatique

R.3.2.1 Type à surveillance de courant de fuite à la terre (M)

CBAR, ci-après désigné de «type M», qui surveille le circuit aval afin d'évaluer la présence d'un défaut à la terre, et ne permet pas la refermeture lorsque le courant de fuite à la terre évalué dépasse $I_{\Delta ar}$.

La surveillance doit être réalisée en utilisant la tension d'alimentation. Elle peut être permanente ou intermittente.

Les CBAR de type M avec limitation de la tension d'essai surveillent le circuit aval au moyen d'une tension non dangereuse ci-après dénommée «tension de surveillance».

Les CBAR de type M avec limitation du courant d'essai surveillent le circuit aval au moyen d'un courant non dangereux ci-après dénommé «courant de surveillance».

R.3.2.2 Type temporisé (TD)

CBAR, ci-après désigné de «type TD», pour lequel la refermeture automatique a lieu après une temporisation sans tenir compte des conditions du circuit.

R.4 Caractéristiques

L'Article 4 et l'Article B.4 de la présente norme sont applicables avec l'ajout suivant.

R.4.1 Courant assigné différentiel résiduel de refermeture automatique ($I_{\Delta ar}$)

La valeur du courant assigné différentiel résiduel de refermeture automatique doit être déclarée par le fabricant, sans dépasser $I_{\Delta n}$. Le fabricant peut déclarer des valeurs différentes de $I_{\Delta ar}$ pour différentes tensions assignées.

R.4.2 Nombre maximal de manœuvres de refermeture successives

Le temps de réarmement et le nombre maximal de manœuvres de refermeture successives dans le temps de réarmement doivent être déclarés par le fabricant.

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R.5 Marquage et instructions

~~En complément à l'Article 5 et à l'Article B.5 de la présente norme, les marquages supplémentaires suivants doivent s'appliquer:~~

~~a) Les indications suivantes doivent être marquées sur l'appareil, en plus des marquages spécifiés en 5.2 a) et en B.5, et être distinctement visibles après l'installation:~~

~~– indication sur le sélecteur du mode choisi: «refermeture automatique» et «refermeture manuelle».~~

~~b) Les indications suivantes doivent également être marquées sur l'extérieur de l'appareil, comme spécifié au point a), excepté qu'elles peuvent ne pas être visibles après l'installation de l'appareil. Ces indications doivent également figurer dans la documentation du fabricant:~~

~~– tension assignée d'alimentation de circuit de commande (U_s) du CBAR, le cas échéant,~~

~~– courant assigné différentiel résiduel de refermeture automatique ($I_{\Delta ar}$),~~

~~– signification des indicateurs (par exemple, lampes), le cas échéant.~~

~~c) Les indications suivantes doivent être marquées sur l'appareil comme spécifié au point b), ou figurer dans la documentation du fabricant:~~

~~– mode opératoire pour le remplacement de tout fusible intégré,~~

~~– mode opératoire pour le raccordement de la borne de terre si nécessaire pour la fonction de refermeture automatique,~~

~~– temps de réarmement et nombre maximal correspondant de manœuvres de refermeture,~~

~~– temps de surveillance et temps de refermeture pour les CBAR de type M,~~

~~– délai de refermeture pour les CBAR de type TD.~~

L'Article 5 et l'Article B.5 sont applicables avec les ajouts énumérés dans le Tableau R.2.

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Tableau R.2 – Informations sur le matériel

Elément	Information	Emplacement du marquage
R1.1	Indication sur les deux positions du sélecteur: "refermeture automatique" et "refermeture manuelle"	Visible
R2.1	Tension assignée d'alimentation de circuit de commande (U_s) du CBAR, le cas échéant	Marqué
R2.2	Courant assigné différentiel résiduel de refermeture automatique ($I_{\Delta ar}$)	Marqué
R2.3	Signification des indicateurs (par exemple lampes), le cas échéant	Marqué
R3.1	Mode opératoire pour le remplacement d'un quelconque fusible intégré	Documentation
R3.2	Mode opératoire pour le raccordement de la borne de terre si nécessaire pour la fonction de refermeture automatique	Documentation
R3.3	Temps de réarmement et nombre maximal correspondant de manœuvres de refermeture	Documentation
R3.4	Temps de surveillance et temps de refermeture pour les CBAR de type M	Documentation
R3.5	Délai de refermeture pour les CBAR de type TD	Documentation
Légende		
Visible:	visible depuis le devant lorsque le disjoncteur est installé en configuration de service et que l'organe de commande est accessible	
Marqué:	marqué sur le matériel	
Documentation:	spécifié dans la documentation du fabricant	

R.6 Conditions normales de service, de montage et de transport

L'Article 6 est applicable.

R.7 Exigences relatives à la conception et au fonctionnement

R.7.1 Exigences relatives à la conception

En complément au 7.1 et au B.7.1 de la présente norme, les classifications complémentaires suivantes s'appliquent:

R.7.1.1 Choix de mode

L'appareil doit être équipé d'un sélecteur (voir R.2.3).

La conformité est vérifiée par les essais de R.8.4.4.

R.7.1.2 Indicateurs ou voyants

L'appareil doit être doté d'un indicateur montrant l'état bloqué.

Tous les indicateurs doivent être visibles après l'installation.

R.7.1.3 CBAR de type M

Il doit être fait en sorte qu'aucune tension ou aucun courant dangereux ne soit appliqué aux bornes de charge. Une des méthodes suivantes doit être utilisée:

– La tension de surveillance (voir R.3.2.1) doit être fournie par un transformateur assurant une isolation de Classe II entre les circuits primaire et secondaire. La tension de

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surveillance ne doit pas dépasser 25 V en courant alternatif ou 60 V en courant continu; ou

– Le courant de surveillance (voir R.3.2.1) doit être fourni par une source à courant limité ou un appareil à impédance de protection, conforme à l'IEC 61140. Le courant de régime établi ne doit pas dépasser 1 mA en courant alternatif ou 2 mA en courant continu.

R.7.2 Exigences relatives au fonctionnement

En complément aux 7.2 et B.7.2 de la présente norme, les exigences complémentaires suivantes s'appliquent:

R.7.2.1 Généralités

Les CBAR ne doivent se refermer automatiquement qu'après un déclenchement du fait de la fonction de courant différentiel résiduel. La conformité est vérifiée par les essais de R.8.2.

Les CBAR ne doivent pas se refermer automatiquement après une ouverture intentionnelle du disjoncteur. La conformité est vérifiée par les essais de R.8.3.

Lorsque le nombre maximal de manœuvres de refermeture automatique dans le temps de réarmement est atteint, la fonction de refermeture automatique doit être bloquée jusqu'à ce qu'un réarmement manuel soit effectué.

Le temps de réarmement ne doit pas être inférieur à 5 s.

R.7.2.2 CBAR de type M

Après le déclenchement du déclencheur de courant différentiel résiduel, si le courant de fuite à la terre évalué est inférieur à $I_{\Delta ar}$, un CBAR de type M doit automatiquement se refermer dans le temps de refermeture déclaré par le fabricant.

Après le déclenchement du déclencheur de courant différentiel résiduel, si le courant de fuite à la terre évalué est supérieur à $I_{\Delta ar}$, la refermeture automatique doit être neutralisée. Dans ce cas, la surveillance ne doit pas être effective pour une durée supérieure au temps de surveillance déclaré par le fabricant. A la fin de cette période, la fonction de refermeture automatique doit être bloquée.

Le temps de surveillance doit être inférieur à 1 h.

La conformité est vérifiée par les essais de R.8.4.2.

R.7.2.3 CBAR de type TD

Après un déclenchement du fait de la fonction de courant différentiel résiduel, un CBAR de type TD doit se refermer automatiquement dans le délai de refermeture déclaré par le fabricant, à moins qu'il n'ait atteint le nombre maximal de manœuvres de refermeture successives dans le temps de réarmement.

La conformité est vérifiée par les essais de R.8.4.3.

NOTE Un CBAR de type TD ne se referme pas après un court-circuit entre phases mais peut se refermer après un défaut phase-terre.

R.7.2.4 Pouvoir de fermeture et de coupure différentiel résiduel en court-circuit

Les CBAR doivent établir, supporter pendant une durée spécifiée, et interrompre les courants différentiels résiduels de court-circuit.

La conformité est vérifiée par les essais de R.8.7.

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R.7.2.5 Effets des conditions d'environnement

Les CBAR doivent fonctionner de manière satisfaisante, compte tenu des effets des conditions d'environnement.

La conformité est vérifiée par les essais de R.8.8.

R.8 Essais

R.8.1 Conditions générales

En complément à l'Article 8 et à l'Article B.8 de la présente norme, les exigences complémentaires suivantes s'appliquent.

Les CBAR intégrés doivent satisfaire aux exigences d'essai de R.8.2 à R.8.8 à l'exception du fait que les essais de R.8.6 ne s'appliquent qu'aux CBAR aptes au sectionnement.

Un échantillon doit être soumis aux essais de R.8.2, R.8.3 et R.8.4 en séquence.

Les essais de R.8.5 à R.8.8 peuvent être réalisés pendant les séquences d'essai de l'Article 8.

Les CBAR de type externe doivent satisfaire aux exigences d'essai de R.8.9.

Les essais doivent être réalisés en mode refermeture automatique, sauf indication contraire, le CBAR étant alimenté à la tension assignée maximale et à la tension assignée d'alimentation du circuit de commande, le cas échéant.

Le CBAR doit être raccordé selon les instructions du fabricant.

Les essais CEM de B.8.12 doivent être réalisés en mode refermeture automatique et en mode refermeture manuelle.

R.8.2 Vérification de la non-refermeture après déclenchement dans des conditions de surintensité

R.8.2.1 Déclenchement dans des conditions de court-circuit

Le disjoncteur doit être déclenché au moyen de son déclencheur de court-circuit en appliquant un courant d'essai supérieur ou égal à 120 % du courant de réglage de court-circuit sur une combinaison de deux pôles en série choisis au hasard (voir 8.3.3.2.2). Dans le cas d'un courant de réglage réglable, l'essai doit être effectué à tout réglage convenable. L'appareil ne doit pas se refermer automatiquement après déclenchement, dans un délai égal au double du temps de refermeture ou du délai de refermeture, suivant le cas, déclaré par le fabricant, ou 60 s, selon la valeur la plus élevée.

Pour les besoins de cet essai, le déclencheur de court-circuit du disjoncteur peut être réglé à n'importe quelle valeur appropriée, et il est acceptable de séparer la tension d'alimentation du circuit de commande pour la fonction de refermeture automatique, des bornes principales.

R.8.2.2 Déclenchement dans des conditions de surcharge

Le disjoncteur doit être déclenché au moyen de son déclencheur de surcharge en appliquant un courant d'essai supérieur à 130 % du courant de réglage de surcharge et inférieur à 80 % du courant de réglage de court-circuit. Cet essai peut être effectué à une température ambiante quelconque et, dans le cas d'un courant de réglage réglable, à tout réglage convenable. L'appareil ne doit pas se refermer automatiquement après déclenchement, dans

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un délai égal au double du temps de refermeture ou du délai de refermeture, suivant le cas, déclaré par le fabricant, ou 60 s, selon la valeur la plus élevée.

Pour les besoins de cet essai, le déclencheur de surcharge du disjoncteur peut être réglé à n'importe quelle valeur appropriée, et il est acceptable de séparer la tension d'alimentation du circuit de commande pour la fonction de refermeture automatique, des bornes principales.

R.8.3 Vérification de la non-refermeture après ouverture intentionnelle

Le sélecteur étant dans la position «refermeture automatique» et la tension d'alimentation du circuit de commande étant appliquée normalement, le disjoncteur est ouvert manuellement. L'appareil ne doit pas se refermer automatiquement après l'ouverture. La durée de l'essai doit être égale au double du temps de refermeture ou du délai de refermeture déclaré par le fabricant, suivant le cas, ou de 60 s, selon la valeur la plus élevée.

Cet essai doit être répété pour l'ouverture via un déclencheur shunt ou un déclencheur à minimum de tension, suivant le cas, en utilisant toute variante de tension de commande assignée convenable.

R.8.4 Vérification de la fonction de refermeture automatique après un déclenchement sur courant de défaut à la terre

R.8.4.1 Généralités

Les appareils doivent être installés comme en usage normal.

Le circuit d'essai doit être conforme à la Figure R.1.

R.8.4.2 Vérification du fonctionnement correct des CBAR de type M

R.8.4.2.1 En cas de courant différentiel résiduel permanent

L'essai est réalisé sur un seul pôle choisi au hasard. Pour les CBAR à réglages multiples du courant différentiel résiduel de fonctionnement, l'essai doit être réalisé aux valeurs de réglage la plus basse et la plus élevée.

Le circuit d'essai étant étalonné à $I_{\Delta n}$ et l'interrupteur S_1 et le CBAR étant dans la position de fermeture, le courant différentiel résiduel est établi en fermant l'interrupteur S_2. Le CBAR doit déclencher.

L'interrupteur S_2 doit être maintenu dans la position de fermeture pendant le temps de surveillance maximal déclaré par le fabricant (voir R.7.2.2).

La tension ou le courant de surveillance doit satisfaire aux exigences de R.7.1.3.

Le CBAR ne doit pas se refermer automatiquement.

A la fin du temps de surveillance, le CBAR doit être à l'état bloqué, et aucune tension ou aucun courant de surveillance ne doit être présent dans le circuit aval.

R.8.4.2.2 En cas de courant différentiel résiduel temporaire

L'essai est réalisé sur un seul pôle choisi au hasard. Pour les CBAR à réglages multiples du courant différentiel résiduel de fonctionnement, l'essai doit être réalisé aux valeurs de réglage la plus basse et la plus élevée.

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Le circuit d'essai étant étalonné à $I_{\Delta n}$ et l'interrupteur S_1 et le CBAR étant dans la position de fermeture, le courant différentiel résiduel est établi en fermant l'interrupteur S_2. Le CBAR doit déclencher.

Après déclenchement, le courant différentiel résiduel est réduit à la valeur de $I_{\Delta ar}$ correspondant à la tension appliquée.

Le CBAR doit se refermer automatiquement dans le temps de refermeture déclaré par le fabricant.

L'essai est répété autant de fois que nécessaire pour vérifier le nombre maximal d'opérations de refermeture consécutives dans le temps de réarmement, tel que déclaré par le fabricant. A la fin de l'essai, le CBAR doit être à l'état bloqué, et aucune tension ou aucun courant de surveillance ne doit être présent dans le circuit aval.

R.8.4.3 Vérification du fonctionnement correct des CBAR de type TD

L'essai est réalisé sur un seul pôle choisi au hasard, le CBAR étant réglé aux valeurs minimales de $I_{\Delta n}$ et de la temporisation (Δt) suivant le cas.

Le circuit d'essai étant étalonné à $2 \times I_{\Delta n}$ et l'interrupteur S_1 et le CBAR étant dans la position de fermeture, le courant différentiel résiduel est établi en fermant l'interrupteur S_2.

Le CBAR doit déclencher et se refermer automatiquement dans le délai de refermeture, l'essai étant répété pour vérifier le nombre maximal d'opérations de refermeture consécutives dans le temps de réarmement, tel que déclaré par le fabricant.

A la fin de l'essai, le CBAR doit être à l'état bloqué.

R.8.4.4 Vérification du fonctionnement correct du sélecteur

L'essai est réalisé sur un seul pôle choisi au hasard, le sélecteur étant dans la position «refermeture manuelle», le CBAR étant réglé aux valeurs minimales de $I_{\Delta n}$ et de la temporisation, suivant le cas.

Le circuit d'essai étant étalonné à $2 \times I_{\Delta n}$ et l'interrupteur S_1 et le CBAR étant dans la position de fermeture, le courant différentiel résiduel est établi en fermant l'interrupteur S_2. Le CBAR doit déclencher.

Immédiatement après le déclenchement, l'interrupteur S_2 est rouvert; le CBAR ne doit pas se refermer automatiquement après déclenchement, dans un délai égal au double du temps de refermeture ou du délai de refermeture déclaré par le fabricant, suivant le cas, ou 60 s, selon la valeur la plus élevée.

R.8.5 Vérification de l'endurance mécanique

R.8.5.1 Dispositif de refermeture automatique externe combiné à un DPR préalablement soumis à essai selon l'Annexe B ou CBAR préalablement soumis à essai selon l'Annexe B

Le circuit d'essai est conforme à la Figure R.1.

L'essai est réalisé sur un seul pôle choisi au hasard, le CBAR étant réglé aux valeurs minimales de $I_{\Delta n}$ et de la temporisation, suivant le cas.

Le circuit d'essai est étalonné à $2 \times I_{\Delta n}$. L'interrupteur S_1 et le CBAR étant dans la position de fermeture, le courant différentiel résiduel est établi en fermant l'interrupteur S_2.

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Le CBAR doit déclencher et doit se refermer automatiquement.

L'essai doit être répété un tiers du nombre «d'opérations avec courant» spécifié au Tableau 8. Aucun défaut de déclenchement ou de refermeture ne doit être permis.

NOTE En fonction du temps de réarmement et du nombre maximal de manœuvres de refermeture successives correspondant, il peut être nécessaire de réarmer manuellement le CBAR ou de neutraliser la fonction de blocage.

R.8.5.2 CBAR non préalablement soumis à essai selon l'Annexe B

L'essai de R.8.5.1 peut être réalisé séparément ou pendant l'essai de fonctionnement en service de B.8.1.1.1, remplaçant alors les manœuvres réalisées par l'application d'un courant différentiel résiduel.

R.8.6 Vérification de la fonction de sectionnement

R.8.6.1 Généralités

Cette vérification s'applique uniquement aux CBAR aptes au sectionnement.

Les essais de R.8.6.2 et R.8.6.3 doivent être réalisés dans toutes les positions du sélecteur et à l'état bloqué.

R.8.6.2 Courant de fuite entre des contacts ouverts

Les exigences suivantes sont applicables:

a) A la suite de l'essai de 8.3.3.3 (séquence I, essai des propriétés diélectriques), le courant de fuite, mesuré sur chaque pôle avec les contacts en position d'ouverture, à une tension d'essai de 1,1 U_e, ne doit pas dépasser 0,5 mA.

b) A la suite de l'essai de 8.3.3.6 (séquence I, vérification de la tenue diélectrique), le courant de fuite, mesuré sur chaque pôle avec les contacts en position d'ouverture, à une tension d'essai de 1,1 U_e, ne doit pas dépasser 2 mA.

c) A la suite de l'essai de 8.3.4.4 (séquence II, vérification de la tenue diélectrique), le courant de fuite, mesuré sur chaque pôle avec les contacts en position d'ouverture, à une tension d'essai de 1,1 U_e, ne doit pas dépasser 2 mA.

d) S'il y a lieu, à la suite de l'essai de 8.3.5.4 (séquence III, vérification de la tenue diélectrique), le courant de fuite, mesuré sur chaque pôle avec les contacts en position d'ouverture, à une tension d'essai de 1,1 U_e, ne doit pas dépasser 6 mA.

R.8.6.3 Tension de choc entre des contacts ouverts

Pendant l'essai de 8.3.3.3 (séquence I, essai des propriétés diélectriques), la tension d'essai doit être appliquée entre les bornes d'alimentation interconnectées et les bornes de charge interconnectées des CBAR, avec les contacts en position d'ouverture, et sa valeur doit être telle que spécifiée dans le Tableau 14 de l'IEC 60947-1:2007.

Il ne doit y avoir aucune décharge disruptive intempestive pendant les essais.

R.8.7 Vérification du pouvoir de fermeture et de coupure différentiel résiduel en court-circuit

B.8.10 est applicable avec les exigences complémentaires suivantes:

Les essais doivent être effectués en mode refermeture automatique, le cas échéant, la tension d'alimentation (c'est-à-dire la tension d'alimentation du circuit de commande) étant raccordée au CBAR.

Les exigences complémentaires suivantes doivent être satisfaites après l'essai:

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– Le CBAR doit satisfaire à l'essai de ~~B.8.10.4.2~~ B.8.11.4 b) indépendamment du fonctionnement des dispositifs de protection (fusible, etc.);

– En cas de fonctionnement des dispositifs de protection (fusible, etc.), le dispositif d'indication approprié, s'il existe, doit signaler ce fonctionnement. En l'absence de dispositif d'indication, il ne doit pas être possible de refermer le CBAR, même manuellement, lorsque les dispositifs de protection ont fonctionné.

R.8.8 Vérification de la fonction de refermeture automatique après les séquences d'essai de l'Article B.8

A la suite de chacune des vérifications de ~~B.8.1.1.2~~ B.8.1.2.1 (vérification de l'aptitude à supporter les courants de court-circuit), une vérification de la fonction de refermeture automatique doit être réalisée selon R.8.4.2 ou R.8.4.3, suivant le cas.

A la suite de chacune des séquences d'essai B I à B IV de l'Annexe B, une vérification de la fonction de refermeture automatique doit être réalisée selon R.8.4.2 ou R.8.4.3, suivant le cas.

R.8.9 Essais des dispositifs de refermeture automatique de type externe

Les séquences d'essais suivantes doivent être réalisées sur les CBAR classés selon R.3.1.2, conformément au Tableau R.1.

Ces essais sont applicables aux dispositifs de refermeture automatique assemblés avec un DPR et ne remplacent pas les essais de l'Article B.8 réalisés sur le DPR.

Tableau R.1 – Séquences d'essai pour les dispositifs de refermeture automatique de type externe

Séquence (échantillon)	Essai	Paragraphe
1	Vérification de la non-refermeture après déclenchement dans des conditions de surintensité	R.8.2
	Vérification de la non-refermeture après ouverture intentionnelle	R.8.3
	Vérification de la fonction de refermeture automatique après déclenchement sur courant de défaut à la terre	R.8.4
	Vérification de l'endurance mécanique	R.8.5
	Vérification de la fonction de sectionnement	R.8.6
2	Vérification du pouvoir de fermeture et de coupure différentiel résiduel en court-circuit	R.8.7
3	Pouvoir assigné de coupure ultime en court-circuit	8.3.5
	Vérification de la fonction de refermeture automatique après la séquence d'essai de l'Article B.8	R.8.8
4	Vérification des effets des conditions d'environnement	B.8.11
	Vérification de la fonction de refermeture automatique après la séquence d'essai de l'Article B.8	R.8.8
5	Vérification de la résistance aux déclenchements intempestifs dus à des ondes de courant causées par des tensions de choc	B.8.6
	Vérification de la compatibilité électromagnétique	B.8.12
	Vérification de la fonction de refermeture automatique après la séquence d'essai de l'Article B.8	R.8.8

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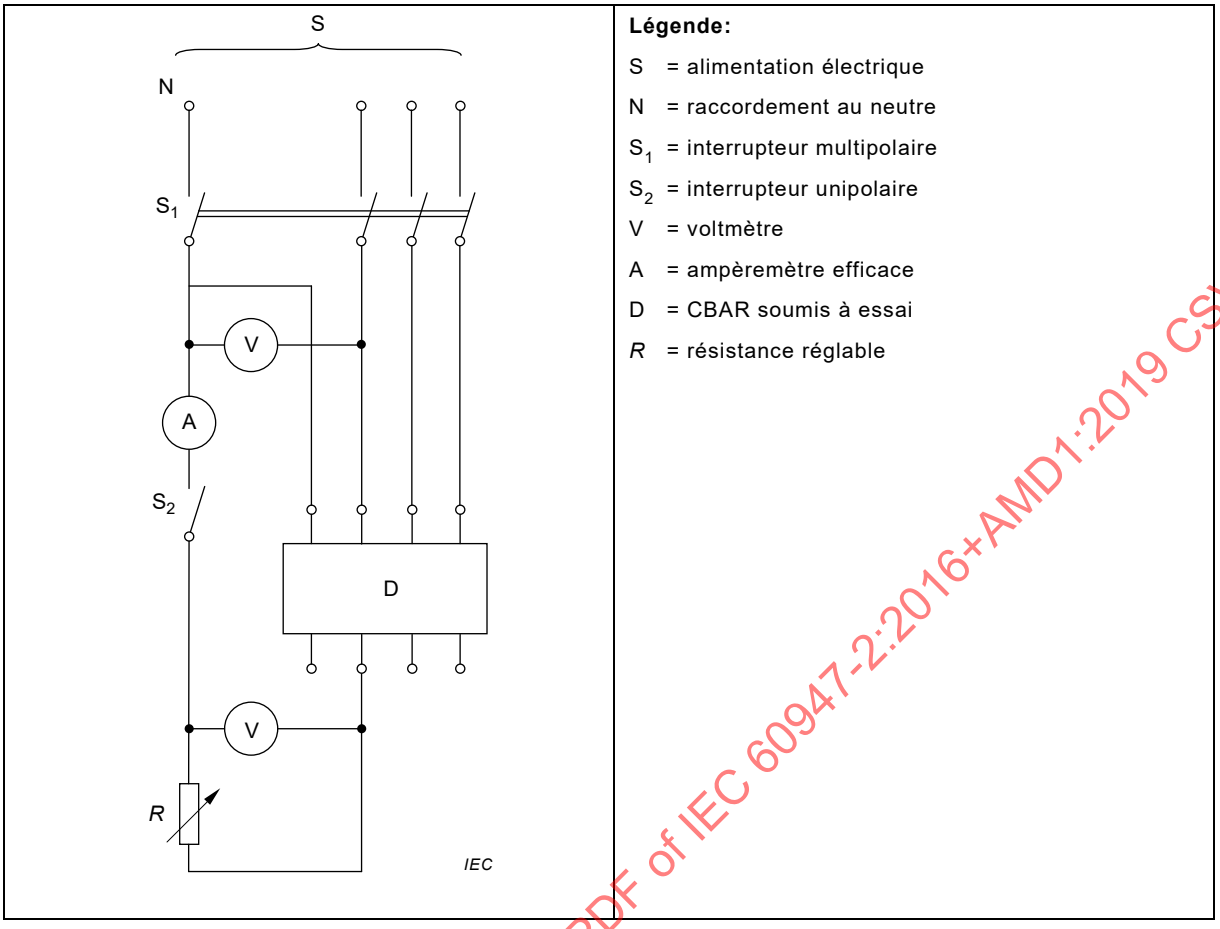


Figure R.1 – Circuit d'essai pour la vérification des fonctions de refermeture automatique

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2 Cette publication a été supprimée.

3 « DB » fait référence à la base de données IEC en ligne.

4 « DB » fait référence à la base de données IEC en ligne.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 60947-2 edition 5.1 contains the fifth edition (2016-06) [documents 121A/71/FDIS and 121A/83/RVD], its corrigendum (2016-11) and its amendment 1 (2019-07) [documents 121A/286/FDIS and 121A/302/RVD].

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 60947-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage.

This fifth edition constitutes a technical revision.

This edition includes the following significant additions with respect to the previous edition:

- tests for verification of selectivity in Annex A (see A.5.3);
- critical load current tests for d.c. circuit-breakers (see 8.3.9);
- new Annex P for circuit-breakers for use in photovoltaic applications;
- new Annex R for residual-current circuit-breakers with automatic reclosing functions.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60947 series, published under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60947-1:2007 and its Amendment 1:2010 and Amendment 2:2014.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1 and its amendments when applicable, for example, 1.2.3 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007/AMD1:2010, or Annex A of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

The contents of the corrigendum of October 2019 have been included in this copy.

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

1.1 Scope and object

This part of IEC 60947 series applies to circuit-breakers, intended to be installed and operated by instructed or skilled persons, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.; it also contains additional requirements for integrally fused circuit-breakers.

Circuit-breakers rated above 1 000 V a.c. but not exceeding 1 500 V a.c. may also be tested to this standard.

It applies whatever the rated currents, the method of construction or the proposed applications of the circuit-breakers may be.

The requirements for circuit-breakers which are also intended to provide earth leakage protection are contained in Annex B.

The additional requirements for circuit-breakers with electronic over-current protection are contained in Annex F.

The additional requirements for circuit-breakers for IT systems are contained in Annex H.

The requirements and test methods for electromagnetic compatibility of circuit-breakers are contained in Annex J.

The requirements for circuit-breakers not fulfilling the requirements for over-current protection are contained in Annex L.

The requirements for modular residual current devices (without integral current breaking device) are contained in Annex M.

The requirements and test methods for electromagnetic compatibility of circuit-breaker auxiliaries are contained in Annex N.

The requirements and test methods for d.c. circuit-breakers for use in photovoltaic (PV) applications are contained in Annex P.

The requirements and test methods for circuit-breakers incorporating residual current protection with automatic reclosing functions are contained in Annex R.

Supplementary requirements for circuit-breakers used as direct-on-line starters are given in IEC 60947-4-1, applicable to low-voltage contactors and starters.

The requirements for circuit-breakers for the protection of wiring installations in buildings and similar applications, and designed for use by uninstructed persons, are contained in IEC 60898.

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The requirements for circuit-breakers for equipment (for example electrical appliances) are contained in IEC 60934.

For certain specific applications (for example traction, rolling mills, marine service, downstream of variable frequency drives, use in explosive atmospheres) particular or additional requirements may be necessary.

NOTE Circuit-breakers which are dealt with in this standard can be provided with devices for automatic opening under predetermined conditions other than those of over-current and undervoltage as, for example, reversal of power or current. This standard does not deal with the verification of operation under such pre-determined conditions.

The object of this standard is to state:

a) the characteristics of circuit-breakers;

b) the conditions with which circuit-breakers shall comply with reference to:

   1) operation and behaviour in normal service;

   2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (selectivity and back-up protection);

   3) dielectric properties;

c) tests intended for confirming that these conditions have been met and the methods to be adopted for these tests;

d) information to be marked on or given with the apparatus.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60228, *Conductors of insulated cables*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

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IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61545, *Connecting devices – Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units*

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1, as well as the following apply.

NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*, IEC 60050-441, the reference to this publication is given in brackets.

2.1
circuit-breaker
a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

2.1.1
frame size
a term designating a group of circuit-breakers, the external physical dimensions of which are common to a range of current ratings.

Note 1 to entry: Frame size is expressed in amperes corresponding to the highest current rating of the group.

Note 2 to entry: Within a frame size, the width may vary according to the number of poles.

Note 3 to entry: This definition does not imply dimensional standardization.

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2.1.2
construction break
a significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing

2.2
integrally fused circuit-breaker
a combination, in a single device, of a circuit-breaker and fuses, one fuse being placed in series with each pole of the circuit-breaker intended to be connected to a phase conductor

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
current-limiting circuit-breaker
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

Note 1 to entry: Reference may be made to either the symmetrical or asymmetrical prospective peak value of let-through current.

Note 2 to entry: The let-through current is also referred to as the cut-off current (see IEC 60050-441:1984, 441-17-12).

Note 3 to entry: Templates for the graphical representation of the cut-off current characteristic and the let-through energy characteristic are given from Figure K.2 to Figure K.5 and examples of the use of the templates in Figure K.6 and in Figure K.7.

2.4
plug-in circuit-breaker
a circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed

Note 1 to entry: Some circuit-breakers may be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

2.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be withdrawn from the main circuit, and, in the disconnected position, to achieve an isolating distance in accordance with specified requirements

2.6
moulded-case circuit-breaker
a circuit-breaker having a supporting housing of moulded insulating material forming an integral part of the circuit-breaker

[SOURCE: IEC 60050-441:1984, 441-14-24]

2.7
air circuit-breaker
a circuit-breaker in which the contacts open and close in air at atmospheric pressure

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
vacuum circuit-breaker
a circuit-breaker in which the contacts open and close within a highly evacuated envelope

[SOURCE: IEC 60050-441:1984, 441-14-29]

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2.9
gas circuit-breaker
a circuit-breaker in which the contacts open and close in a gas other than air at atmospheric or higher pressure

2.10
making-current release
a release which permits a circuit-breaker to open, without any intentional time-delay, during a closing operation, if the making current exceeds a predetermined value, and which is rendered inoperative when the circuit-breaker is in the closed position

2.11
short-circuit release
an over-current release intended for protection against short circuits

2.12
short-time delay short-circuit release
an over-current release intended to operate at the end of the short-time delay

2.13
alarm switch
an auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

2.14
circuit-breaker with lock-out device preventing closing
a circuit-breaker in which each of the moving contacts is prevented from closing sufficiently to be capable of passing current if the closing command is initiated while specified conditions remain established

2.15
short-circuit breaking (or making) capacity
a breaking (or making) capacity for which the prescribed conditions include a short circuit

2.15.1
ultimate short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the circuit-breaker to carry its rated current continuously

2.15.2
service short-circuit breaking capacity
a breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the circuit-breaker to carry its rated current continuously

2.16
opening time
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

– in the case of a directly operated circuit-breaker, the instant of initiation of the opening time is the instant of initiation of a current large enough to cause the circuit-breaker to operate;

– in the case of a circuit-breaker operated by any form of auxiliary power, the instant of initiation of the opening time is the instant of application or removal of the auxiliary power to the opening release.

Note 2 to entry: For circuit-breakers "opening time" is commonly referred to as "tripping time", although, strictly speaking, tripping time applies to the time between the instant of initiation of the opening time and the instant when the opening command becomes irreversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modified – addition of Notes to entry.]

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2.17
over-current protective co-ordination

2.17.1
over-current selectivity
co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the other(s) does (do) not

2.17.2
total selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection without causing the other protective device to operate

2.17.3
partial selectivity
over-current selectivity where, in the presence of two over-current protective devices in series, the protective device on the load side effects the protection up to a given level of over-current, without causing the other protective device to operate

2.17.4
selectivity limit current
I_s
current co-ordinate of the intersection between the total time-current characteristic of the protective device on the load side and the pre-arcing (for fuses), or tripping (for circuit-breakers) time-current characteristic of the other protective device

Note 1 to entry: The selectivity limit current (see Figure A.1) is a limiting value of current:

– below which, in the presence of two over-current protective devices in series, the protective device on the load side completes its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is ensured);

– above which, in the presence of two over-current protective devices in series, the protective device on the load side may not complete its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is not ensured).

2.17.5
take-over current
I_B
current co-ordinate of the intersection between the maximum break time current characteristics of two over-current protective devices in series

Note 1 to entry: This applies to two over-current protective devices in series for operating times ≥ 0,05 s. For operating times < 0,05 s, the two over-current devices in series are considered as an association (see Annex A).

2.18
I^2t characteristic of a circuit-breaker
information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

2.19
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

2.20
rated instantaneous short-circuit current setting
I_i
rated value of the current causing the operation of a release without any intentional time-delay

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2.21
overload current setting
I_r
current setting of an adjustable overload release

Note 1 to entry: In case of a non-adjustable overload release, this value is equal to the rated current I_n.

2.22
programmable logic controller
PLC
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes. Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

[SOURCE: IEC 61131-1:2003, 3.5, modified – deletion of the note.]

2.23
closing release
closing coil
release, energized by a source of voltage, which triggers the closing of the circuit-breaker

Note 1 to entry: A closing release is an auxiliary device of the circuit-breaker, and is different from the "closing device" mentioned in the figures of Annex A, and in IEC 60947-1, which is part of the test setup and is intended to establish the short-circuit current.

3 Classification

Circuit-breakers may be classified:

3.1 According to their selectivity category, A or B (see 4.4)

3.2 According to the interrupting medium, for example:

– air-break;
– vacuum break;
– gas-break.

3.3 According to the design, for example:

– open construction;
– moulded case.

3.4 According to the method of controlling the operating mechanism, viz:

– dependent manual operation;
– independent manual operation;
– dependent power operation;
– independent power operation;
– stored energy operation.

3.5 According to the suitability for isolation:

– suitable for isolation;

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– not suitable for isolation.

3.6 According to the provision for maintenance:

– maintainable;
– non-maintainable.

3.7 According to the method of installation, for example:

– fixed;
– plug-in;
– withdrawable.

3.8 According to the degree of protection provided by the enclosure (see 7.1.12 of IEC 60947-1:2007)

4 Characteristics of circuit-breakers

4.1 Summary of characteristics

The characteristics of a circuit-breaker shall be stated in terms of the following, as applicable:

– type of circuit-breaker (4.2);
– rated and limiting values of the main circuit (4.3);
– selectivity categories (4.4);
– control circuits (4.5);
– auxiliary circuits (4.6);
– releases (4.7);
– integral fuses (integrally fused circuit-breakers) (4.8).

4.2 Type of circuit-breaker

The following shall be stated:

– number of poles;
– kind of current (a.c. or d.c.) and, in the case of a.c., number of phases and rated frequency.

4.3 Rated and limiting values of the main circuit

4.3.1 General

The rated values established for a circuit-breaker shall be stated in accordance with 4.3.2 to 4.4, but it is not necessary to establish all the rated values listed.

4.3.2 Rated voltages

4.3.2.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following amplification:

– Circuit-breakers covered by item a) of Note 2 (of IEC 60947-1:2007)

U_e is generally stated as the voltage between phases.

NOTE 1 In Canada and the USA, the rated operational voltage U_e is stated as

a) the voltage between phases and earth, together with the voltage between phases (for example 277 V/480 V) for three-phase four-wire neutral earthed systems;

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b) the voltage between phases (for example 480 V) for three-phase three-wire unearthed or impedance earthed systems.

Circuit-breakers for unearthed or impedance earthed systems (IT) require additional tests according to Annex H.

– Circuit-breakers covered by item b) of Note 2:

These circuit-breakers require additional tests according to Annex C.

U_e shall be stated as the voltage between phases preceded by the letter C.

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by item b) of Note 2 (of IEC 60947-1:2007) are identified by the voltage between phases only.

4.3.2.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

4.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

4.3.3 Currents

4.3.3.1 Conventional free-air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

4.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

4.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 4.3.2.4 of IEC 60947-1:2007) and is equal to the conventional free-air thermal current (I_{th}).

4.3.3.4 Current rating for four-pole circuit-breakers

Subclause 7.1.9 of IEC 60947-1:2007 applies.

4.3.4 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

4.3.5 Rated duty

The rated duties considered as normal are:

– the eight-hour duty (see 4.3.4.1 of IEC 60947-1:2007),

– the uninterrupted duty (see 4.3.4.2 of IEC 60947-1:2007).

4.3.6 Short-circuit characteristics

4.3.6.1 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of a circuit-breaker is the value of short-circuit making capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage at rated frequency and at a specified power factor for a.c., or time constant for d.c. It is expressed as the maximum prospective peak current.

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For a.c. the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor *n* of Table 2 (see 4.3.6.3).

For d.c., the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity.

A rated short-circuit making capacity implies that the circuit-breaker shall be able to make the current corresponding to that rated capacity at the appropriate applied voltage related to the rated operational voltage.

4.3.6.2 Rated short-circuit breaking capacities

4.3.6.2.1 General

The rated short-circuit breaking capacities of a circuit-breaker are the values of short-circuit breaking capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage, under specified conditions.

A rated short-circuit breaking capacity requires that the circuit-breaker shall be able to break any value of short-circuit current up to and including the value corresponding to the rated capacity at a power-frequency recovery voltage corresponding to the prescribed test voltage values and:

– for a.c., at any power factor not less than that of Table 11 (see 8.3.2.2.4);
– for d.c., with any time constant not greater than that of Table 11 (see 8.3.2.2.5).

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 8.3.2.2.6), no short-circuit breaking capacity is guaranteed.

For a.c., the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in Table 11, irrespective of the value of the inherent d.c. component, on the assumption that the a.c. component is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;
– rated service short-circuit breaking capacity.

4.3.6.2.2 Rated ultimate short-circuit breaking capacity (I_{cu})

The rated ultimate short-circuit breaking capacity of a circuit-breaker is the value of ultimate short-circuit breaking capacity (see 2.15.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.5. It is expressed as the value of the prospective breaking current, in kA (r.m.s. value of the a.c. component in the case of a.c.).

4.3.6.2.3 Rated service short-circuit breaking capacity (I_{cs})

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 2.15.2) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.4. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example I_{cs} = 25 % I_{cu}).

I_{cs} shall be at least equal to 25 % of I_{cu}.

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Table 1 (void)

4.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor, for a.c. circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 2.

Table 2 – Ratio *n* between short-circuit making capacity and short-circuit breaking capacity and related power factor (for a.c. circuit-breakers)

Short-circuit breaking capacity kA r.m.s.	Power factor	Minimum value required for n $n = \frac{\text{short - circuit making capacity}}{\text{short - circuit breaking capacity}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 7.2.1.1 and 7.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 2. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

4.3.6.4 Rated short-time withstand current (I_{cw})

The rated short-time withstand current of a circuit-breaker is the value of short-time withstand current assigned to that circuit-breaker by the manufacturer under the test conditions specified in 8.3.6.3.

For a.c., the value of this current is the r.m.s. value of the a.c. component of the prospective short-circuit current, assumed constant during the short-time delay.

The short-time delay associated with the rated short-time withstand current shall be at least 0,05 s, preferred values being as follows:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

The rated short-time withstand current shall be not less than the appropriate values shown in Table 3.

Table 3 – Minimum values of rated short-time withstand current

Rated current I_n A	Rated short-time withstand current I_{cw} – Minimum values kA
$I_n \leq 2\,500$	12 I_n or 5 kA, whichever is the greater

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I_n > 2 500	30 kA

4.4 Selectivity categories

Circuit-breakers according to this standard are divided into two selectivity categories:

– **Selectivity category B** comprises circuit-breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 4.3.6.4.

Selectivity of circuit-breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.

– **Selectivity category A** comprises all other circuit-breakers.

These circuit-breakers may provide selectivity under short-circuit conditions by other means.

A circuit-breaker of selectivity category A may have an intentional short-time delay with a short-time withstand current less than that according to 4.3.6.4. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two selectivity categories (see Table 9 and 8.3.4, 8.3.5, 8.3.6 and 8.3.8).

Table 4 (void)

4.5 Control circuits

4.5.1 Electrical control circuits

Subclause 4.5.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, with the following addition:

If the rated control supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 5.

Table 5 – Preferred values of the rated control supply voltage, if different from that of the main circuit

Direct current V	Single-phase alternating current V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic)

Subclause 4.5.2 of IEC 60947-1:2007 applies.

4.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

4.7 Releases

4.7.1 Types

For the purpose of this standard, the following types of releases are considered:

1) shunt release;

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2) over-current release:
   a) instantaneous;
   b) definite time delay;
   c) inverse time delay:
      – independent of previous load;
      – dependent on previous load (for example thermal type release).

NOTE 1 The term "overload release" is used to identify over-current releases intended for protection against overloads (see 2.4.30 of IEC 60947-1:2007). The term "short-circuit release" is used to identify over-current releases intended for protection against short circuits (see 2.11).

NOTE 2 The term "adjustable release" used in this standard also includes interchangeable releases.

3) undervoltage release (for opening);
4) closing release;
5) other releases.

4.7.2 Characteristics

The following characteristics shall be considered:

1) shunt release and undervoltage release (for opening), and closing release:
   – rated control circuit voltage (U_c);
   – kind of current;
   – rated frequency, if a.c.
2) over-current release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if a.c.;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

The rated current of an over-current release is the value of current (r.m.s. if a.c.) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 8.3.2.5, without the temperature-rise exceeding the values specified in Table 7.

4.7.3 Current setting of over-current releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 4.7.1, item 2)), the current setting (or range of current-settings, as applicable) shall be marked or displayed on the release or on its scale. The marking or display may be either directly in amperes or as a multiple of the current value. Means shall be available from the manufacturer to read the display regardless of the status of the circuit-breaker.

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 6, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

In the case of indirect releases operated by current transformers, the marking may refer either to the primary current of the current transformer through which they are supplied, or to the current setting of the overload release. In either case, the ratio of the current transformer shall be stated.

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– the operating value of overload releases other than those of the thermal type is independent of the ambient air temperature within the limits of –5 °C to +40 °C;

– for releases of the thermal type, the values stated are for a reference temperature of +30 °C ± 2 °C. The manufacturer shall be prepared to state the influence of variations in the ambient air temperature (see 7.2.1.2.4, item b)).

4.7.4 Tripping time setting of over-current releases

The tripping time shall be stated as follows, depending on the type of over-current release:

1) Definite time-delay over-current releases

   The time-delay of such releases is independent of the over-current. The tripping time setting shall be stated as the duration in seconds of the opening time of the circuit-breaker, if the time-delay is not adjustable, or the extreme values of the opening time, if the time-delay is adjustable.

2) Inverse time-delay over-current releases

   The time-delay of such releases is dependent on the over-current.

   The time/current characteristics shall be given in the form of curves supplied by the manufacturer. These shall indicate how the opening time, starting from the cold state, varies with current within the range of operation of the release. The manufacturer shall indicate, by suitable means, the tolerances applicable to these curves.

   These curves shall be given for each extreme value of the current setting and, if the time setting for a given current setting is adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

   It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006.

4.8 Integral fuses (integrally fused circuit-breakers)

Subclause 4.8 of IEC 60947-1:2007/AMD1:2010 applies.

The manufacturer shall provide the necessary information.

5 Product information

5.1 Nature of the information

Subclause 5.1 of IEC 60947-1:2007 applies, as far as appropriate for a particular design.

In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 2.1.1). See Annex G.

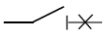
5.2 Marking

Each circuit-breaker shall be marked in a durable manner; data to be provided and corresponding locations are indicated in Table 13.

Table 13 – Product information

Item	Information	Marking location
1.1	rated current (I_n)	Visible

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Item	Information	Marking location
1.2	suitability for isolation, if applicable, with the symbol  (IEC 60617-S00288:2001-07 combined with IEC 60617-S00219:2001-07)	Visible
1.3	indication of the open and closed position with O (IEC 60417-5008;2002-10) and I (IEC 60417-5007;2002-10) respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007)	Visible
2.1	manufacturer's name or trade mark	Marked
2.2	type designation or catalogue reference	Marked
2.3	IEC 60947-2, if the manufacturer claims compliance with the standard	Marked
2.4	selectivity category A or B	Marked
2.5	rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H)	Marked
2.6	unsuitability for IT systems, if applicable, with the symbol  (IEC 60417-6363:2016-07)	Marked
2.7	rated impulse withstand voltage (U_{imp})	Marked
2.8	value (or range) of the rated frequency, and/or the indication "d.c." (or the symbol ⎓ (IEC 60417-5031:2002-10))	Marked
2.9	rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e)	Marked
2.10	rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e)	Marked
2.11	rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B	Marked
2.12	range of the current setting (I_r) of the adjustable overload release	Marked [a]
2.13	range of the rated instantaneous short-circuit current setting (I_i), for adjustable releases	Marked [a]
2.14	reference temperature for non-compensated thermal releases, if different from 30 °C	Marked
2.15	terminals identification, according to 7.1.8.4 of IEC 60947-1:2007	Marked
2.16	line and load terminals, if applicable	Marked
2.17	neutral pole terminals, if applicable, by the letter N	Marked
2.18	protective earth terminal, where applicable, by the symbol  (IEC 60417-5019:2006-08) (see 7.1.10.3 of IEC 60947-1:2007)	Marked
3.1	rated short-circuit making capacity (I_{cm}), if higher than that specified in 4.3.6.1	Literature
3.2	rated insulation voltage (U_i), if higher than the maximum rated operational voltage	Literature
3.3	pollution degree if other than 3	Literature
3.4	conventional enclosed thermal current (I_{the}) if different from the rated current	Literature
3.5	IP code, where applicable (see Annex C of IEC 60947-1:2007/AMD1:2010)	Literature
3.6	minimum enclosure size and ventilation data (if any) to which marked ratings apply	Literature
3.7	details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures	Literature
3.8	suitability for environment A or environment B per Annex J, as applicable	Literature
3.9	RMS sensing, if applicable, in accordance with F.4.1.1	Literature
3.10	minimum cable cross-section, if different from Table 9 of IEC 60947-1:2007, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu}	Literature
3.11	values of tightening torque for the circuit-breaker terminals	Literature
3.12	current derating for terminals and connections, if applicable	Literature
4.1	for closing releases (see 2.23) and/or motor-operators, rated control circuit voltage, kind of current and rated frequency for a.c.	Aux
4.2	rated control circuit voltage of the shunt release and/or of the under-voltage release (or of the no-voltage release), kind of current and rated frequency for a.c.	Aux
4.3	rated current of indirect over-current releases	Aux

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Item	Information	Marking location
4.4	number and type of auxiliary contacts, rated operational currents at the rated operational voltages, and rated frequency for a.c.	Aux
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked:marked on the circuit-breaker Literature:provided in the manufacturer's literature Aux:marked on the auxiliaries or on the circuit-breaker, if marking space is sufficient; additionally, data shall be made available in the manufacturer's literature		
[a] Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.		

5.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Additional information for the decommissioning and dismantling of the circuit-breaker shall be provided to the user in the case of a foreseeable hazardous condition, for example due to stored energy or hazardous substances.

6 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007/AMD2:2014 applies with the following addition:

Pollution degree (see 6.1.3.2 of IEC 60947-1:2007).

Unless otherwise stated by the manufacturer, a circuit-breaker is intended for installation under environmental conditions of pollution degree 3.

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

Subclause 7.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies with the following modifications:

The requirements of 7.1.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 do not apply to parts with a mass lower than 2 g (insignificant mass, in accordance with 3.14 of IEC 60695-2-11:2014). For products containing a plurality of small parts, the total mass of non-tested parts located in close proximity to each other shall not exceed 10 g. Proximity shall be based on engineering judgment that takes into consideration the risk of propagation of fire.

Where, in 7.1.2.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, the test temperature is to be specified, the value required by this document for the parts necessary to retain in position current-carrying parts is:

– 960 °C for the main circuit;
– 850 °C for the other circuits.

7.1.2 Withdrawable circuit-breakers

In the disconnected position, the isolating contacts of the main circuit and, where applicable, auxiliary circuits of withdrawable circuit-breakers shall have isolating distances which comply

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with the requirements specified for the isolating function, taking account of manufacturing tolerances and changes in dimensions due to wear.

The withdrawable mechanism shall be fitted with a reliable indicating device which indicates unambiguously the positions of the isolating contacts.

The withdrawable mechanism shall be fitted with interlocks which only permit the isolating contacts to be separated or reclosed when the main contacts of the circuit-breaker are open.

In addition, the withdrawable mechanism shall be fitted with interlocks which only permit the main contacts to be closed

– when the isolating contacts are fully closed, or
– when the specified isolating distance is achieved between the fixed and moving parts of the isolating contacts (disconnected position).

When the circuit-breaker is in the disconnected position, means shall be provided to ensure that the specified isolating distances between the isolating contacts cannot be inadvertently reduced.

7.1.3 Additional requirements for circuit-breakers suitable for isolation

For additional requirements concerning performance, see 7.2.7.

Subclause 7.1.7 of IEC 60947-1:2007/AMD1:2010 applies with the following addition:

If the tripped position is not the indicated open position, it should be clearly identified.

7.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2007 and in Table 15 of IEC 60947-1:2007/AMD1:2010.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:2007, clearances shall be obtained from Table F.2 of IEC 60664-1:2007.

7.1.5 Requirements for the safety of the operator

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

Compliance is checked by the provisions of 8.3.2.6.1, item b).

7.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 2.1.2) if any one of the following features are not the same:

– material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
– size, material, configuration and method of attachment of the main contacts;
– any integral manual operating mechanism, its materials and physical characteristics;
– moulding and insulating materials;
– the principle of operation, materials and construction of the arc extinction device;
– the basic design of the over-current tripping devices, admitting, however, the variations detailed in a), b) and c) below.

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Variations in the following do not constitute a construction break:

a) dimensions of terminals, provided that creepage and clearance distances are not reduced;

b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;

c) secondary windings of current transformer operated releases;

d) external operating means, additional to the integral operating means;

e) type designation and/or purely aesthetic features (e.g. labels);

f) in the case of the 2-pole and 4-pole variants, replacement of the trip unit in one pole by a link, to provide an unprotected neutral;

g) creating a 2-pole breaker from a 3-pole breaker by removing the centre current path;

h) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;

i) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

7.1.7 Additional requirements for circuit-breakers provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies with the following addition:

If a pole with an appropriate making and breaking capacity is used as a neutral pole, then all poles, including the neutral pole, may operate substantially together.

7.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs)

Annex S of IEC 60947-1:2007 applies. For the purposes of this standard, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

7.2 Performance requirements

7.2.1 Operating conditions

7.2.1.1 Closing

7.2.1.1.1 General

For a circuit-breaker to be closed safely on to the making current corresponding to its rated short-circuit making capacity, it is essential that it should be operated with the same speed and the same firmness as during the type test for proving the short-circuit making capacity.

7.2.1.1.2 Dependent manual closing

For a circuit-breaker having a dependent manual closing mechanism, it is not possible to assign a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

Such a circuit-breaker should not be used in circuits having a prospective peak making current exceeding 10 kA.

However, this does not apply in the case of a circuit-breaker having a dependent manual closing mechanism and incorporating an integral fast-acting opening release which causes the circuit-breaker to break safely, irrespective of the speed and firmness with which it is closed on to prospective peak currents exceeding 10 kA; in this case, a rated short-circuit making capacity can be assigned.

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7.2.1.1.3 Independent manual closing

A circuit-breaker having an independent manual closing mechanism can be assigned a short-circuit making capacity rating irrespective of the conditions of mechanical operation.

7.2.1.1.4 Dependent power closing

The power-operated closing mechanism, including intermediate control relays where necessary, shall be capable of securing the closing of the circuit-breaker in any condition between no-load and its rated making capacity, when the supply voltage, measured during the closing operation, remains between the limits of 110 % and 85 % of the rated control supply voltage, and, when a.c., at the rated frequency.

At 110 % of the rated control supply voltage, the closing operation performed on no-load shall not cause any damage to the circuit-breaker.

At 85 % of the rated control supply voltage, the closing operation shall be performed when the current established by the circuit-breaker is equal to its rated making capacity within the limits allowed by the operation of its relays or releases and, if a maximum time limit is stated for the closing operation, in a time not exceeding this maximum time limit.

7.2.1.1.5 Independent power closing

A circuit-breaker having an independent power closing operation can be assigned a rated short-circuit making capacity irrespective of the conditions of power closing.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating in accordance with the manufacturer's specification.

7.2.1.1.6 Stored energy closing

This type of closing mechanism shall be capable of ensuring closing of the circuit-breaker in any condition between no-load and its rated making capacity.

When the stored energy is retained within the circuit-breaker, a device shall be provided which indicates when the storing mechanism is fully charged.

Means for charging the operating mechanism, as well as the closing control components, shall be capable of operating when the auxiliary supply voltage is between 85 % and 110 % of the rated control supply voltage.

It shall not be possible for the moving contacts to move from the open position unless the charge is sufficient for satisfactory completion of the closing operation.

When the energy storing mechanism is manually operated, the direction of operation shall be indicated.

This last requirement does not apply to circuit-breakers with an independent manual closing operation.

7.2.1.2 Opening

7.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 2.4.23 of IEC 60947-1:2007) and, unless otherwise agreed between manufacturer and user, circuit-breakers shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

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7.2.1.2.2 Opening by undervoltage releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies.

7.2.1.2.3 Opening by shunt releases

Subclause 7.2.1.4 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.1.2.4 Opening by over-current releases

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker with an accuracy of ±20 % of the tripping current value of the current setting for all values of the current setting of the short-circuit current release.

Where necessary for over-current co-ordination (see 2.17), the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 2.5.19 of IEC 60947-1:2007) as a function of prospective current (r.m.s. symmetrical);

– I^2t characteristics (see 2.18) for circuit-breakers of selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 8.3.5.1).

Conformity with this information may be checked during the relevant type tests in test sequences II and III (see 8.3.4 and 8.3.5).

NOTE 1 It is possible to provide other forms of data to verify co-ordination characteristics of circuit-breakers, for example, tests on combinations of short-circuit protective devices.

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

The release shall cause tripping of the circuit-breaker with an accuracy of ±10 % of the tripping current value of the current setting for all values of current setting of the overload release.

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 6.

At the reference temperature (see 4.7.3) and at 1,05 times the current setting (see 2.4.37 of IEC 60947-1:2007), i.e. with the conventional non-tripping current (see 2.5.30 of IEC 60947-1:2007), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 2.5.30 of IEC 60947-1:2007) from the cold state, i.e. with the circuit-breaker at the reference temperature.

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see 2.5.31 of IEC 60947-1:2007), tripping shall then occur in less than the conventional time later.

NOTE 2 The reference temperature is the ambient air temperature on which the time-current characteristic of the circuit-breaker is based.

Table 6 – Characteristics of the opening operation of inverse time-delay over-current opening releases at the reference temperature

All poles loaded		Conventional time h
Conventional non-tripping current	Conventional tripping current	
1,05 times current setting	1,30 times current setting	2 [a]
[a] 1 h when $I_n \leq 63$ A		

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If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 6 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 %/K.

The width of the temperature band shall be at least 10 K on either side of the reference temperature.

7.2.2 Temperature-rise

7.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 8.3.2.5, shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.3.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 7 during the tests made in accordance with 8.3.4.5 and 8.3.6.4.

7.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 7 are applicable only if the ambient air temperature remains within the limits given in 6.1.1 of IEC 60947-1:2007/AMD2:2014.

7.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the over-current releases that may be associated with it, shall be capable of carrying its rated current I_n, under the conditions of Clause 8, without the temperature rises exceeding the limits specified in Table 7.

7.2.2.4 Control circuits

The control circuits, including control circuit devices, used for the closing and opening operations of a circuit-breaker, shall permit the rated duty, as specified in 4.3.5, and also the temperature-rise tests under the test conditions specified in 8.3.2.5, to be made without the temperature rises exceeding the limits specified in Table 7.

The requirements of this subclause shall be verified on a new circuit-breaker. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 8.3.3.7.

7.2.2.5 Auxiliary circuits

Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional thermal current without the temperature-rises exceeding the limits specified in Table 7 when tested in accordance with 8.3.2.5.

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Table 7 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which need not be touched for normal operation:	
Metallic	50
non-metallic	60
[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.	
[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 8.	

7.2.3 Dielectric properties

7.2.3.1 General

Subclauses 7.2.3 a) and 7.2.3 b) of IEC 60947-1:2007 apply.

Type tests shall be made in accordance with 8.3.3.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 8.3.3.6.

Routine tests shall be made in accordance with 8.4.6.

7.2.3.2 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1:2007 applies.

For circuit-breakers rated above 1 000 V a.c., the impulse withstand voltage shall be agreed between the manufacturer and the user but shall not be less than the corresponding values for 1 000 V a.c.

7.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

Power-frequency tests are used in the following cases:

– dielectric tests as type tests for the verification of solid insulation;
– dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
– routine tests.

7.2.3.4 Clearances

Subclause 7.2.3.3 of IEC 60947-1:2007/AMD2:2014 applies.

7.2.3.5 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

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7.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 8.3.3.4.1, item 3) of IEC 60947-1:2007/AMD1:2010/AMD2:2014, or d.c. tests (test voltages for d.c. tests are under consideration).

For the purposes of this standard, circuits incorporating solid-state devices shall be disconnected for the tests.

7.2.3.7 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

7.2.4 Ability to make and break under no load, normal load and overload conditions

7.2.4.1 Overload performance

This requirement applies to circuit-breakers of rated current up to and including 630 A.

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 8.3.3.5.

Each operating cycle consists of a making operation followed by a breaking operation.

7.2.4.2 Operational performance capability

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 8:

– for the test of operational performance without current in the main circuit under the test conditions specified in 8.3.3.4.3;
– for the test of operational performance with current in the main circuit under the test conditions specified in 8.3.3.4.4.

Each operating cycle consists of, either a closing operation followed by an opening operation (test of operational performance without current), or a making operation followed by a breaking operation (test of operational performance with current).

Table 8 – Number of operating cycles

1	2	3	4	5
Rated current [a]	Number of operating cycles per hour [b]	Number of operating cycles		
A		Without current	With current [c]	Total
$I_n \leq 100$	120	8 500	1 500	10 000
$100 < I_n \leq 315$	120	7 000	1 000	8 000
$315 < I_n \leq 630$	60	4 000	1 000	5 000
$630 < I_n \leq 2\,500$	20	2 500	500	3 000
$2\,500 < I_n$	10	1 500	500	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

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7.2.5 Ability to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 4.3.6.1 and 4.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 4.3.6.2.

The rated short-time withstand current shall be in accordance with 4.3.6.4.

NOTE It is the manufacturer's responsibility to ensure that the tripping characteristic of the circuit-breaker is compatible with the capability of the circuit-breaker to withstand the inherent thermal and electrodynamic stresses.

7.2.6 Vacant

7.2.7 Additional requirements for circuit-breakers suitable for isolation

Subclause 7.2.7 of IEC 60947-1:2007 applies and tests shall be made in accordance with 8.3.3.3, 8.3.3.6, 8.3.3.10, 8.3.4.4, 8.3.5.4 and 8.3.7.8, as applicable.

7.2.8 Specific requirements for integrally fused circuit-breakers

NOTE For the co-ordination between circuit-breakers and separate fuses associated in the same circuit, see 7.2.9.

An integrally fused circuit-breaker shall comply with this standard in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 8.3.7).

The circuit-breaker shall function, without causing the fuses to operate, at the occurrence of over-currents not exceeding the selectivity limit current I_s declared by the manufacturer.

For all over-currents up to and including the rated ultimate short-circuit breaking capacity assigned to the composite unit, the circuit-breaker shall open when one or more fuses operate (in order to prevent single-phasing). If the circuit-breaker is stated by the manufacturer to be with lock-out device preventing closing (see 2.14), it shall not be possible to reclose the circuit-breaker until either the melted fuse-links or any missing fuse-links have been replaced or the lock-out means has been reset.

7.2.9 Co-ordination between a circuit-breaker and another short-circuit protective device

For the co-ordination between a circuit-breaker and another short-circuit protective device, see Annex A.

7.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

8 Tests

8.1 Kind of tests

8.1.1 General

Subclause 8.1 of IEC 60947-1:2007 applies, with the following additions:

The tests to verify the characteristics of circuit-breakers are:

– type tests (see 8.3);

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– routine tests (see 8.4);

– special tests (see 8.5).

8.1.2 Type tests

Type tests include the following tests:

Test	Subclause
Temperature-rise	8.3.2.5
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Short-circuit breaking capacities	8.3.4 and 8.3.5
Short-time withstand current (where applicable)	8.3.6
Performance of integrally fused circuit-breakers	8.3.7
Critical d.c. load current	8.3.9

Type tests shall be carried out by the manufacturer, in his workshop or at any suitable laboratory of his choice.

8.1.3 Routine tests

Routine tests comprise the tests listed in 8.4.

8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

8.3 Type tests

In order to avoid repetition of identical tests applicable to the various test sequences, the general test conditions have been grouped together at the beginning of this subclause under three headings:

– test conditions applicable to all sequences (8.3.3 to 8.3.8);

– test conditions applicable to temperature-rise tests (8.3.2.5);

– test conditions applicable to short-circuit tests (8.3.2.6).

Wherever appropriate, these general test conditions refer back to, or are based on, the general rules of IEC 60947-1.

Each test sequence refers back to the general test conditions applicable. This requires the use of cross-references, but enables each test sequence to be presented in a much simplified form.

Throughout this clause the term "test" has been used for every test to be made; "verification" should be interpreted as "test for the verification" and has been used where it is intended to verify the condition of the circuit-breaker following an earlier test in a test sequence whereby it may have been adversely affected.

In order to facilitate locating a particular test condition or test, an alphabetical index is given below, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

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8.3.1 Test sequences

8.3.1.1 General

Type tests are grouped together in a number of sequences, as shown in Table 9.

For each sequence, tests shall be made in the order listed unless otherwise specified in this standard.

8.3.1.2 Tests omitted from sequence I and made separately

With reference to 8.1.1 of IEC 60947-1:2007, the following tests of test sequence I (see 8.3.3) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (8.3.3.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 8.3.3.2.3 only on the phase poles at the maximum setting, at room temperature and without the additional test of item b) to verify the time-current characteristic;

– test of dielectric properties (8.3.3.3);

– test of under-voltage releases of 8.3.3.4.2.3 and 8.3.3.4.3 to verify the requirements of 7.2.1.3 of IEC 60947-1:2007, and tests of under-voltage releases at alternative frequencies (see 8.3.2.1);

– test of shunt releases of 8.3.3.4.2.4 and 8.3.3.4.3 to verify the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014, and tests of shunt releases at alternative frequencies (see 8.3.2.1);

– additional tests for operational performance capability without current for withdrawable circuit-breakers (8.3.3.4.5).

8.3.1.3 Applicability of sequences according to the relationship between short-circuit ratings

The applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} is given in Table 9a.

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Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	8.3.2.1
Arrangement of circuit-breakers for short-circuit tests	8.3.2.6.1
Frequency	8.3.2.2.3
Power factor	8.3.2.2.4
Records (interpretation of)	8.3.2.6.6
Recovery voltage	8.3.2.2.6
Short-circuit test circuits	8.3.2.6.2
Short-circuit test procedure	8.3.2.6.4
Temperature-rise test	8.3.2.5
Time constant	8.3.2.2.5
Tolerances	8.3.2.2.2
Tests (for overall schema of test sequences, see Table 9)	**Subclause**
Critical d.c. load current	8.3.9
Dielectric properties	8.3.3.3
Dielectric withstand (verification)	8.3.3.6 – 8.3.4.4 – 8.3.5.4 – 8.3.6.6 – 8.3.7.4 – 8.3.7.8 – 8.3.8.6
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H – see H.2
Indication of main contact position	8.3.3.10
Integrally fused circuit-breakers (short-circuit tests)	8.3.7.2 – 8.3.7.6 – 8.3.7.7
Operational performance capability	8.3.3.4 – 8.3.4.3 – 8.3.4.5
Overload performance	8.3.3.5
Overload releases (verification)	8.3.3.8 – 8.3.4.6 – 8.3.5.2 – 8.3.5.5 – 8.3.6.2 – 8.3.6.7 – 8.3.7.5 – 8.3.7.9 – 8.3.8.2 – 8.3.8.8
Service short-circuit breaking capacity	8.3.4.2 – 8.3.8.4
Short-circuit breaking capacity test at maximum short-time withstand current	8.3.6.5
Short-time withstand current	8.3.6.3 – 8.3.8.3
Temperature-rise (verification)	8.3.3.7 – 8.3.4.5 – 8.3.6.4 – 8.3.7.3 – 8.3.8.7
Tripping limits and characteristics	8.3.3.2
Ultimate short-circuit breaking capacity	8.3.5.3
Withdrawable circuit-breakers (additional tests)	8.3.3.4.5

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Table 9 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (8.3.3)	All circuit-breakers	Tripping limits and characteristics Dielectric properties Mechanical operation and operational performance capability Overload performance (where applicable) Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Verification of undervoltage and shunt releases (where applicable) Verification of main contact position (where applicable)
II Rated service short-circuit breaking capacity (8.3.4)	All circuit-breakers [b]	Rated service short-circuit breaking capacity Verification of operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
III Rated ultimate short-circuit breaking capacity (8.3.5)	All circuit-breakers [c] of selectivity category A and circuit-breakers of selectivity category B with instantaneous override[d]	Verification of overload releases Rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
IV Rated short-time withstand current (8.3.6)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with an assigned short-time withstand current (see 4.4)	Verification of overload releases Rated short-time withstand current Verification of temperature-rise Short-circuit breaking capacity at maximum short-time withstand current Verification of dielectric withstand Verification of overload releases
V Performance of integrally fused circuit-breakers (8.3.7)	Stage 1 Integrally fused circuit-breakers Stage 2	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand Verification of overload releases Short-circuit at 1,1 times the take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
VI Combined test sequence (8.3.8)	Circuit-breakers of selectivity category B: when $I_{cw} = I_{cs}$ (replaces test sequences II and IV) when $I_{cw} = I_{cs} = I_{cu}$ (replaces test sequences II, III and IV)	Verification of overload releases Rated short-time withstand current Rated service short-circuit breaking capacity Operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
Critical d.c. load current (8.3.9)	Circuit-breakers with d.c. ratings	Critical d.c. load current tests
Individual pole short-circuit test sequence (Annex C)	Circuit-breakers for use on phase-earthed systems	Individual pole short-circuit breaking capacity (I_{su}) Verification of dielectric withstand Verification of overload releases
Test sequence for circuit-breakers for IT systems (Annex H)	Circuit-breakers for use in IT systems	Individual pole short-circuit breaking capacity (I_{IT}) Verification of dielectric withstand Verification of overload releases

a For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs} , I_{cu} and I_{cw}, see Table 9a.

b Except where Sequence VI is applied.

c Except
- where $I_{cs} = I_{cu}$ (but see 8.3.5),
- where sequence VI is applied,
- for integrally fused circuit-breakers.

d See note to 8.3.5.1

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Table 9a – Applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} [a]

I_{cs}, I_{cu} and I_{cw} relationship	Test sequence	Selectivity category			
		A	A Integrally fused	B	B Integrally fused
CASE 1	I	X	X	X	X
	II	X	X	X	X
$I_{cs} \neq I_{cu}$ for selectivity category A	III	X		X [b]	
$I_{cs} \neq I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 2	I			X	X
$I_{cs} = I_{cw} \neq I_{cu}$ for selectivity	II			X	X
category B	III			X [b]	
	IV			X	X
	V				X
	VI (combined)			X [c]	X [c]
CASE 3	I	X	X	X	X
	II	X	X	X	X
$I_{cs} = I_{cu}$ for selectivity category A	III				
$I_{cs} = I_{cu} \neq I_{cw}$ for selectivity	IV	X [d]		X	X
category B	V		X		X
CASE 4	I			X	
	II			X	
$I_{cs} = I_{cu} = I_{cw}$ for selectivity	III				
category B	IV			X	
	V				
	VI (combined)			X [c]	

[a] This table applies to any one value of U_e. For multiple U_e ratings, the table applies to each U_e rating. The applicability of a test sequence is indicated by X in the relevant space.

[b] Test applicable only if $I_{cu} > I_{cw}$.

[c] At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of selectivity category B, in which case it replaces test sequences II and IV.

[d] Test sequence IV applies only to circuit-breakers with a rated short-time withstand current (see 4.4).

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8.3.1.4 Alternative test programmes for a.c. circuit-breakers having a different number of poles

These alternative test programmes may only be applied to a.c. ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 9, and construction breaks are the same for all variants. In the case of 1-pole circuit-breakers the voltage ratings shall be equal to or lower than the line-to neutral voltage of the variant tested to Table 9. A 2-pole circuit-breaker produced by removing the centre current path from a 3-pole circuit-breaker tested to programme 1 or programme 2 of this subclause need not be tested as it is considered to be covered by the tests on the 3-pole variant.

Compliance with the test requirements is met by carrying out one of the alternative programmes 1 or 2 below.

– Programme 1: The applicable test sequences according to Table 9 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9b shall be carried out on the other variants.

– Programme 2: The applicable test sequences according to Table 9 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 9c shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated below:

	Programme 1					**Programme 2**			
	1-pole	2-poles	3-poles	4-poles		1-pole	2-poles	3-poles	4-poles
Construction 1[a]	□	□	■	□		○	○	○	■
Construction 2	–	–	■	□		–	–	–	■
Construction 3	–	–	■	□		–	–	–	■
…	–	–	■	□		–	–	–	■
Construction *n*	–	–	■	□		–	–	–	■
Key	■ fully tested per Table 9 □ tested per Table 9b ○ tested per Table 9c – no test required								
[a] Construction 1 is the construction which covers the max rating.									

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Table 9b – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General	X	X
	8.3.3.2.2	Short-circuit releases	X[a]	X[e]
	8.3.3.2.3 a)[k] – instantaneous/definite time-delay – inverse time-delay or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: 	X X	 X[e]
	8.3.3.2.4	Additional test for definite time-delay releases:		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation	X[d]	X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers	X	
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current	X 4th pole and adjacent pole only (see 8.3.2.6.4)	
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breakers for IT systems		

NOTE The applicability of a test or test sequence is indicated by X in the relevant space.

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[a] One test on one pair of phase poles chosen at random. In the case of an electronic trip unit, this test may be made on one pole chosen at random.

[b] This test sequence also applies when, for the 3-pole testing, Sequence III on the 3-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] In case of 4-poles devices with different levels of neutral protection (e.g. 60 % or 100 %), only the variant with the highest level has to be tested according to Table 9b.

[g] One sample of maximum current rating only, for each test sequence.

[h] One sample of maximum current rating for each test sequence; in the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

Table 9c – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 8.3.1.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
I	8.3.3.2	Test of tripping limits and characteristics		
	8.3.3.2.1	General		X
	8.3.3.2.2	Short-circuit releases		X [e]
	8.3.3.2.3 a)[k] or 8.3.3.2.3 b)[k] (as applicable)	Overload releases: – instantaneous/definite time-delay – inverse time-delay		X[e]
	8.3.3.2.4	Additional test for definite time-delay releases		
	8.3.3.3	Dielectric properties	X	X
	8.3.3.4	Mechanical operation and operational performance capability		
	8.3.3.4.1	General	X	X
	8.3.3.4.2	Construction and mechanical operation		X[d, e]
	8.3.3.4.3	Operational performance capability without current	X	X
	8.3.3.4.4	Operational performance capability with current	X	X
	8.3.3.4.5	Withdrawable circuit-breakers		
	8.3.3.5	Overload performance	X	X
	8.3.3.6	Verification of dielectric withstand	X	X
	8.3.3.7	Verification of temperature-rise	X	X
	8.3.3.8	Verification of overload releases		
	8.3.3.9	Verification of undervoltage and shunt releases	X	X
	8.3.3.10	Verification of the main contact position	X	X
II	8.3.4	Rated service short-circuit breaking capacity		
III	8.3.5[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	8.3.6	Rated short-time withstand current		
V	8.3.7	Performance of integrally fused circuit-breakers	X	X
VI	8.3.8	Combined test sequence		

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Test sequence	Test subclause	Test	Applicability to 3-pole variant[g]	Applicability to 1-pole or 2-pole variants[g]
Annex C		Individual pole short-circuit test sequence		
Annex H		Test sequence for circuit-breaker for IT systems		

NOTE The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Vacant.

[b] This test sequence also applies when, for the 4-poles testing, Sequence III on the 4-poles variant is replaced by Sequence II or Sequence VI (see Table 9).

[c] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (8.3.3.4.2.3) and shunt releases (8.3.3.4.2.4).

[e] Applicable only to 1-pole variant; not required for 2-poles variants.

[f] Vacant.

[g] One sample of maximum current rating only, for each test sequence.

[h] Vacant.

[i] Vacant.

[j] Vacant.

[k] This test is not required for electronic trip units.

8.3.2 General test conditions

NOTE Tests according to the requirements of this standard do not preclude the need for additional tests concerning circuit-breakers incorporated in assemblies, for example tests in accordance with IEC 61439 series.

8.3.2.1 General requirements

Unless otherwise agreed by the manufacturer, each test sequence shall be made on a sample circuit-breaker (or set of samples) in a clean and new condition.

The number of samples to be tested for each test sequence and the test conditions (for example setting of overload releases, terminal connections), according to the circuit-breaker parameters, are given in Table 10 or, where applicable, for the alternative test programmes in Table 9b and Table 9c (see 8.3.1.4).

Where necessary, additional information is given in the relevant subclauses.

Unless otherwise specified, tests are to be performed on a circuit-breaker having the maximum rated current for a given frame size and are deemed to cover all rated currents of that frame size.

In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, further samples shall be tested in accordance with Table 9b and/or Table 10 as applicable.

Unless otherwise stated, short-circuit releases shall be set at maximum (time and current) for all tests.

The circuit-breakers to be tested shall, in all their essential details, correspond to the design of the type which they represent.

Unless otherwise stated, the tests shall be made with the same kind of current and, in the case of a.c., at the same rated frequency and with the same number of phases as in the intended service. Tests performed at 50 Hz cover 60 Hz applications and vice-versa, except for the performance of under-voltage and shunt releases (see 7.2.2 of IEC 60947-1:2007/AMD2:2010 and 7.2.2.6 of IEC 60947-1:2007).

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If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 7.2.1.1.4. In addition, electrically controlled mechanisms shall be energized via the appropriate circuit-breaker control circuits complete with switching devices. It shall be verified that the circuit-breaker operates correctly on no-load when it is operated under the above conditions.

In case of circuit-breakers with dependent manual operation (see 2.4.12 of 60947-1:2007), the circuit-breaker shall be operated with an operating speed, during actuation, of 0,1 m/s ± 25 %, this speed being measured where the operating means of the test apparatus touches the actuating means of the circuit-breaker under test. For rotary handles the angular velocity shall correspond substantially to the above conditions, referred to the speed of the operating means (at its extremities) of the circuit-breaker under test.

The circuit-breaker under test shall be mounted complete on its own support or an equivalent support.

Circuit-breakers shall be tested in free air.

If a circuit-breaker may be used in specified individual enclosures and has been tested in free air, it shall be additionally tested in the smallest of such enclosures stated by the manufacturer, using a new sample, for each of the following:

a) A short-circuit test according to 8.3.5, at U_e max, and corresponding I_{cu}, with release settings at maximum (see Footnote [a] of Table 10).

b) A temperature rise test according to the general conditions of 8.3.2.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 4.3.3.2). The temperature rises shall meet the requirements of 7.2.2 except that the temperature rise of the terminals shall not exceed 70 K.

Details of these tests, including the dimensions of the enclosure, shall be stated in the test report.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one circuit-breaker only.

However, if a circuit-breaker may be used in specified individual enclosures and is tested throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air need not be made provided that such enclosure is bare metallic, without insulation. Details, including the dimensions of the enclosure, shall be stated in the test report.

For the tests in free air concerning overload performance, short-circuit, and short-time withstand current where applicable, a metallic screen shall be placed on all sides of the circuit-breaker in accordance with the manufacturer's instructions. Details, including distances of the metallic screen from the circuit-breaker, shall be stated in the test report.

The characteristics of the metallic screen shall be as follows:

- structure: woven wire mesh; or
  perforated metal; or
  expanded metal;
- ratio hole area/total area: 0,45 to 0,65;
- size of hole: not exceeding 30 mm^2;
- finish: bare or conductive plating;
- resistance: shall be included in the calculation for the prospective fault current in the fusible element circuit (see 8.3.4.1.2, item d) of IEC 60947-1:2007) when measured from the furthest point on the metallic screen likely to be reached by arc emissions.

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The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see Table 13, item 3.11).

Maintenance or replacements of parts is not permitted.

If, for convenience of testing, it appears useful to increase the severity of a test (for example to adopt a higher frequency of operation in order to reduce the duration of the test), this shall not be done without the consent of the manufacturer.

For single-phase tests on individual poles of multipole circuit-breakers intended for use on phase-earthed systems, see Annex C.

For additional tests for circuit-breakers for unearthed or impedance earth systems (IT), see Annex H.

Table 10 – Number of samples for test *(1 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temper-ature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 8.3.3		X	g
II (I_{cs}) and VI (combined)	X			X		2	1		X	U_e	X		X	h
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X		X	h
							2	X		U_e	X			b
							3		X	U_e	X		X	j
		X		X	X	3	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e max	X		X	k
			X	X	X	4	1		X	U_e max corr.		X	X	h
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X		X	e
							4		X	U_e max	X		X	k
III (I_{cu})	X			X		2	1		X	U_e	X			g
							2	X		U_e	X			b
	X				X	3	1		X	U_e	X			g
							2	X		U_e	X			b
							3		X	U_e	X			c
		X		X	X	3	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e max	X			d
			X	X	X	4	1		X	U_e max corr.		X		g
							2	X		U_e max corr.		X		b
							3		X	U_e intermed.	X			e
							4		X	U_e max	X			d

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Table 10 *(2 of 2)*

Test sequence	Number of marked U_e ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Temperature-rise verification	Footnotes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.	Corr.	Max.		
IV (I_{cw}) [l]	X			X	X	2	1		X	U_e max		X		X	X	g
							2		X	U_e max		X		X	X	m
			X	X	X	3	1		X	U_e max corr.		X	X		X	g
							2		X	U_e max corr.	X		X		X	i
							3		X	U_e max	X		X		X	n, d
V Integral fused (I_{cu})	X	X	X	X	X	2	1		X	U_e max	X				X	f, g
							2	X		U_e max	X					b
Individual pole (Annex C) (I_{su})	X	X	X	X	X	2	1		X	U_e max	I_{su}					g
							2	X		U_e max	I_{su}					–
Individual pole (Annex H) (I_{IT})	X	X	X	X	X	1	1		X	U_e max	I_{IT}					g

Key

Mul. = multiple; Corr. = corresponding; Intermed. = intermediate

NOTE 1 Table 10 applies to the test programmes of Table 9. In the case of the alternative test programmes (see 8.3.1.4), Table 9b and Table 9c are applicable.

NOTE 2 The applicability of a test or test sequence is indicated by X in the relevant space.

[a] Min means the minimum I_n of a given frame size; in the case of adjustable overload releases, it means the minimum setting of the minimum I_n. Max means the maximum I_n of a given frame size.

[b] This sample is omitted in the following cases:

–a circuit-breaker having a single non-adjustable current setting for a given frame size;

–a circuit-breaker provided only with a shunt release (i.e. without an integral overcurrent release);

–a circuit-breaker with electronic overcurrent protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).

[c] Connections reversed.

[d] Connections reversed, if terminals unmarked.

[e] To be agreed between testing station and manufacturer.

[f] If terminals unmarked, an additional sample shall be tested with connections reversed.

[g] In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction, under the conditions applicable to sample 1.

[h] The requirement of footnote g applies to sequence VI (combined) and also to sequence II where $I_{cs} = I_{cu}$.

[i] This sample is selected based on the highest value of thermal energy (I_{cw}^2t; where "t" is the corresponding short-time delay, see 4.3.6.4). This sample is omitted if the highest thermal energy condition is met by sample 1 or 3.

[j] This sample, with connections reversed, is only required when sequence III is replaced by sequence II (I_{cu}= I_{cs}, see 8.3.5).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced by sequence II ($I_{cu} = I_{cs}$, see 8.3.5) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 8.3.8), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 4.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

[n] This sample is only required when sequence III is replaced by sequence IV ($I_{cu} = I_{cw}$, see 8.3.5).

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8.3.2.2 Test quantities

8.3.2.2.1 Values of test quantities

Subclause 8.3.2.2.1 of IEC 60947-1:2007 applies.

8.3.2.2.2 Tolerances on test quantities

Subclause 8.3.2.2.2 of IEC 60947-1:2007 applies.

8.3.2.2.3 Frequency of the test circuit for a.c.

All tests shall be made at the rated frequency of the circuit-breaker. For all short-circuit tests, if the rated breaking capacity is essentially dependent on the value of the frequency, the tolerance shall not exceed ±5 %.

If the manufacturer declares the rated breaking capacity to be substantially unaffected by the value of the frequency, the tolerance shall not exceed ±25 %.

8.3.2.2.4 Power factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

Table 11 – Values of power factors and time constants corresponding to test currents

Test current *I* kA	Power factor			Time constant ms		
	Short-circuit	Operational performance capability	Overload	Short-circuit	Operational performance capability	Overload
$I \leq 3$	0,9			5		
$3 < I \leq 4{,}5$	0,8			5		
$4{,}5 < I \leq 6$	0,7			5		
$6 < I \leq 10$	0,5	0,8	0,5	5	2	2,5
$10 < I \leq 20$	0,3			10		
$20 < I \leq 50$	0,25			15		
$50 < I$	0,2			15		

8.3.2.2.5 Time constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies with the following modification:

Table 16 of IEC 60947-1:2007 is replaced by Table 11 of this standard.

8.3.2.2.6 Power-frequency recovery voltage

Subclause 8.3.2.2.3, item a) of IEC 60947-1:2007/AMD2:2014 applies.

8.3.2.2.7 Ripple of the test current for d.c.

The test current shall comply with the requirements of 6.3.1 of IEC 62475:2010.

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8.3.2.3 Evaluation of test results

The condition of the circuit-breaker after tests shall be checked by the verifications applicable to each sequence.

A circuit-breaker is deemed to have met the requirements of this standard if it meets the requirements of each sequence as applicable.

The case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of a superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

8.3.2.4 Test reports

Subclause 8.3.2.4 of IEC 60947-1:2007 applies.

8.3.2.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 7.2.2.

Subclause 8.3.3.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except 8.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 8.3.2.1.

During the temperature rise test of sequence I (see 8.3.3.7) coils of under-voltage releases, where applicable, shall be supplied at one rated frequency and corresponding voltage, chosen at random. Additional tests to verify coils at other rated frequencies and voltages shall be made outside the sequence.

For four-pole circuit-breakers, a test shall first be carried out on the 3-phase poles; for the neutral pole, the additional single-phase test of 8.3.3.3.4 of IEC 60947-1:2007 applies only when there is a construction break between the neutral pole and the phase poles (see 7.1.6), in which case the test current is the rated current of the neutral pole.

8.3.2.6 Test conditions for short-circuit tests

8.3.2.6.1 General requirements

Subclause 8.3.4.1.1 of IEC 60947-1:2007 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 8.3.2.1.

b) Unless it can be shown that, with the manual operating means in any position, there is no opening around the manual operating means through which a music wire of 0,26 mm diameter can be inserted so as to reach the arc chamber area, the following test arrangement shall apply:

   For opening operations only, a clear, low density polyethylene sheet, 0,05 mm ± 0,01 mm thick, of a size 100 mm × 100 mm, positioned as shown in Figure 1, fixed and reasonably stretched in a frame, is placed at a distance of 10 mm from:

   – either the maximum projection of the manual closing means of a circuit-breaker without recess for this closing means;

   – or the rim of the recess for the manual closing means of a circuit-breaker with recess for this closing means.

   The polyethylene sheet shall have the following physical properties:

   – density at 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3;

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– melting point: 110 °C to 120 °C.

On the side remote from the circuit-breaker there shall be an appropriate backing to obviate tearing of the polyethylene sheet due to the pressure wave which may occur during the short-circuit test (see Figure 1).

For tests other than those in an individual enclosure, a shield which may be of insulating material or of metal is placed between the metallic screen and the polyethylene sheet (see Figure 1).

NOTE This test arrangement applies to O operations only, since it is difficult to arrange for CO operations and it is accepted that O operations are no less severe than CO operations (see 8.3.2.6.4).

c) The circuit-breaker shall be operated during tests to simulate service conditions as closely as possible

A circuit-breaker having a dependent power operation shall be closed during tests with the control supply (voltage or pressure) at 85 % of its rated value.

A circuit-breaker having an independent power operation shall be closed during tests with the operating mechanism charged to its maximum value stated by the manufacturer.

A circuit-breaker having a stored energy operation shall be closed during tests with the operating means charged at 85 % of the rated voltage of the auxiliary supply.

d) If a circuit-breaker is fitted with adjustable over-current releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without over-current releases but fitted with a shunt release, this release shall be energized by the application of a voltage equal to 70 % of the rated control supply voltage of the release (see 7.2.1.2.3), at a time not earlier than that of the initiation of the short-circuit nor later than 10 ms after the initiation of the short-circuit.

e) For all these tests, the line side of the test circuit shall be connected to the corresponding terminals of the circuit-breaker as marked by the manufacturer. In the absence of such markings, the test connections shall be as specified in Table 10.

8.3.2.6.2 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies.

8.3.2.6.3 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

8.3.2.6.4 Test procedure

8.3.2.6.4.1 General

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies, with the following addition.

8.3.2.6.4.2 Common tests on one-, two-, three- and four-pole circuit-breakers

After calibration of the test circuit in accordance with 8.3.2.6.3, the temporary connections are replaced by the circuit-breaker under test and its connecting cables if applicable.

Tests for the performance under short-circuit conditions shall be made according to the sequences in Table 9 (see 8.3.1).

For circuit-breakers having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

– approximately 50 cm on the supply side;

– approximately 25 cm on the load side.

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For ratings ≤ 20 A, the manufacturer may specify a larger cross-section, in which case this cross-section shall be used for all relevant short-circuit tests, and stated in the test report. In addition, a verification of inverse-time delay releases according to 8.3.3.2.3 b) shall be made with this cross-section.

The sequence of operations shall be that which is applicable to each test sequence, as specified in 8.3.4.2, 8.3.5.3, 8.3.6.5 and 8.3.7.7.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.3 Additional tests on four-pole circuit-breakers

Additional sequences of operations on one or more new samples, in accordance with Table 10, shall be carried out on the fourth pole and its adjacent pole, according to test sequences III or V, as applicable, and test sequence IV if applicable. This requirement applies even when test sequence III is replaced by test sequence II (I_{cu} = I_{cs}) or test sequence IV is replaced by test sequence VI (I_{cw} = I_{cs}), i.e., additional tests according to test sequence III or V, and test sequence IV, as applicable, are required.

Alternatively, at the request of the manufacturer, these tests may be combined with the tests of 8.3.2.6.4.2 and made on the same samples, in which case the test in each relevant test sequence shall comprise

– the test on three adjacent poles,

– the test on the fourth pole and the adjacent pole.

The tests on the fourth pole and the adjacent pole are made at an applied voltage of $U_e/\sqrt{3}$, in the circuit shown in Figure 12 of IEC 60947-1:2007/AMD1:2010 with the connections C1 and C2 removed. The test current shall be agreed between manufacturer and user but shall be not less than 60 % of I_{cu} or I_{cw}, as applicable.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 8.3.1.4.

8.3.2.6.4.4 Test operations

The following symbols are used for defining the sequence of operations:

O represents a breaking operation;

CO represents a making operation followed, after the appropriate opening time, by a breaking operation:

t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the circuit-breaker (see 2.19), but not less than 3 min. The actual value of *t* shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, but not exceeding 1 h, during which time the circuit-breaker shall not be displaced. Attempts to reclose the circuit-breaker during the resetting time shall be spaced by at least 1 min.

The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests may be recorded in the test report (see 7.2.1.2.4, item a)).

8.3.2.6.5 Behaviour of the circuit-breaker during short-circuit making and breaking tests

Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies.

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8.3.2.6.6 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

8.3.2.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 8.3.4.2, 8.3.5.3, 8.3.6.5, 8.3.7.2, 8.3.7.7, 8.3.8.4, as applicable, the following conditions shall be met:

– there shall be no damage to the insulation on conductors used to wire the device;
– the polyethylene sheet, where applicable, shall show no holes visible with normal or corrected vision without additional magnification. Minuscule holes of less than 0,26 mm diameter can be ignored;
– the case shall not be broken but hairline cracks are acceptable.

NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting very high fault currents and are of superficial nature. Consequently, they do not develop through the entire thickness of the moulded case of the device.

Additionally, after the short-circuit tests, the circuit-breaker shall comply with the verifications specified for each test sequence, as applicable.

8.3.3 Test sequence I: General performance characteristics

8.3.3.1 General

This test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Tripping limits and characteristics	8.3.3.2
Dielectric properties	8.3.3.3
Mechanical operation and operational performance capability	8.3.3.4
Overload performance (where applicable)	8.3.3.5
Verification of dielectric withstand	8.3.3.6
Verification of temperature-rise	8.3.3.7
Verification of overload releases	8.3.3.8
Verification of undervoltage and shunt releases (if applicable)	8.3.3.9
Verification of main contact position (for circuit-breakers suitable for isolation)	8.3.3.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

See 8.3.1 for tests that may be omitted from the sequence and made on separate samples.

8.3.3.2 Test of tripping limits and characteristics

8.3.3.2.1 General

Subclause 8.3.3.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.3.2.5).

When the over-current opening release is normally a built-in part of the circuit-breaker, it shall be verified inside the corresponding circuit-breaker.

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Any separate release shall be mounted approximately as under normal service conditions. The complete circuit-breaker shall be mounted in accordance with 8.3.2.1. The equipment under test shall be protected against undue external heating or cooling.

The connections of the separate release, if appropriate, or of the complete circuit-breaker shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Tables 9 and 10 of 8.3.3.3.4 of IEC 60947-1:2007) and of length according to 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

For circuit-breakers with adjustable over-current releases, tests shall be made at:

a) minimum current setting and minimum time-delay setting, as applicable; and

b) maximum current setting and maximum time-delay setting, as applicable,

in each case with conductors corresponding to the rated current I_n (see 4.7.2).

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

For circuit-breakers having a neutral pole provided with an overload release, the verification of this overload release shall be made on the neutral pole alone.

The tests may be made at any convenient voltage.

8.3.3.2.2 Short-circuit releases

The operation of short-circuit releases (see 4.7.1) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained:

– for 0,2 s in the case of instantaneous releases (see 2.20);

– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate:

– within 0,2 s in the case of instantaneous releases (see 2.20);

– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers with an electronic overcurrent release, the operation of the short-circuit releases shall be verified by one test only on each pole individually.

For circuit-breakers with electromagnetic overcurrent releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. For circuit-breakers having an identified neutral pole provided with a short-circuit release, the neutral pole shall be tested in series with one phase pole chosen at random. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for individual poles), at which value they shall operate:

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– within 0,2 s in the case of instantaneous releases (see 2.20);

– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

8.3.3.2.3 Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 4.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For a.c. tests, the test currents shall have no asymmetry. For d.c. tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms. The operation of multipole overload releases shall be verified with all phase poles loaded simultaneously with the test current.

Definite time-delay releases shall, in addition, comply with the requirements of 8.3.3.2.4.

At a test current having a value equal to 90 % of the current setting, the release shall not operate, the current being maintained

– for 0,2 s in the case of instantaneous releases (see 2.20),

– for an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

At a test current having a value equal to 110 % of the current setting, the release shall operate

– within 0,2 s in the case of instantaneous releases (see 2.20),

– within an interval of time equal to twice the time-delay stated by the manufacturer, in the case of definite time-delay releases.

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test current for this release shall have a value equal to 1,2 times 110 % of the current setting.

b) Inverse time-delay releases

The operating characteristics of inverse time-delay overload releases shall be verified in accordance with the performance requirements of 7.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test currents for this release shall be those given in Table 6 except that the test current at the conventional tripping current shall be multiplied by the factor 1,2.

For releases dependent on ambient air temperature, the operating characteristic shall be verified at the reference temperature (see 4.7.3 and Table 13 item 2.14), the release being energized on all phase poles.

If this test is made at a different ambient air temperature, a correction shall be made in accordance with the manufacturer's temperature/current data.

For thermal-magnetic releases declared by the manufacturer to be independent of ambient air temperature, the operating characteristic shall be verified by two measurements, one at 30 °C ± 2 °C, the other at 20 °C ± 2 °C or at 40 °C ± 2 °C, the release being energized on all phase poles.

For electronic releases, the operating characteristic shall be verified at the ambient temperature of the test room (see 6.1.1 of IEC 60947-1:2007/AMD2:2014), the release being energised on all phase poles.

An additional test, at a current value to be agreed between manufacturer and user, shall be made to verify that the time/current characteristics of the release conform (within the stated tolerances) to the curves provided by the manufacturer.

NOTE In addition to the tests in this subclause, the releases of circuit-breakers are also verified on each pole singly, during test sequences III, IV, V and VI (see 8.3.5.2, 8.3.5.5, 8.3.6.2, 8.3.6.7, 8.3.7.5, 8.3.7.9, 8.3.8.2 and 8.3.8.8).

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8.3.3.2.4 Additional tests for definite time-delay releases

Definite time-delay releases shall be tested to verify the values of the time-delay and the non-tripping duration

a) Time-delay

This test is made at a current equal to 1,5 times the current setting:

- in the case of overload releases, with all phase poles loaded;
- for circuit-breakers having an identified neutral pole provided with an overload release (see 8.3.3.2.1), the test current for this release shall be 1,5 times the current setting;
- in the case of electromagnetic short-circuit releases, with two poles in series carrying the test current, using successively all possible combinations of phase poles having a short-circuit release.
- in the case of electronic short-circuit releases, on one pole chosen at random.

The time-delay measured, shall be between the limits stated by the manufacturer.

If the test current overlaps with another tripping characteristic (e.g. an instantaneous tripping characteristic), the trip setting (e.g. I_{sd}, see Figure K.1) and the test current shall be reduced as necessary to prevent premature tripping. Both values shall be recorded in the test report.

b) Non-tripping duration

This test is made under the same conditions as for the test of item a) above for both overload and short-circuit releases:

Firstly, the test current equal to 1,5 times the current setting is maintained for a time interval equal to the non-tripping duration stated by the manufacturer; then, the current is reduced to the value corresponding to the overload current setting (I_r) and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

8.3.3.3 Test of dielectric properties

Subclause 8.3.3.4.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies, except for item 5), with the following additions:

(i) with reference to 8.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2007: the normal positions of operation include the tripped position, if any;

(ii) with reference to 8.3.3.4.1, item 3 c), of IEC 60947-1:2007/AMD1:2010/AMD2:2014: for the purposes of this standard circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) circuit-breakers not declared as suitable for isolation shall be tested with the test voltage applied across the poles of the main circuit, the line terminals being connected together and the load terminals being connected together. The test voltage shall be in accordance with Table 12 of IEC 60947-1:2007;

(iv) for circuit-breakers suitable for isolation (see 3.5) and having an operational voltage greater than 50 V, the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(v) circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater;

(vi) withdrawable circuit-breakers (see 7.1.2) shall be subject to verification of impulse withstand voltage, as per 8.3.3.4.1, item 2) b) of IEC 60947-1:2007. The test voltage shall be selected from Table 14 of IEC 60947-1:2007, and shall be applied between the withdrawable unit's main contacts and their associated fixed contacts, in the disconnected position. Acceptance criteria are as per 8.3.3.4.1, item 2) d) of IEC 60947-1:2007.

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8.3.3.4 Tests of mechanical operation and of operational performance capability

8.3.3.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 8.3.2.1 except that, for the purpose of these tests, the circuit-breaker may be mounted on a metal frame. The circuit-breaker shall be protected against undue external heating or cooling.

The tests shall be made at the ambient temperature of the test room.

The control supply voltage of each control circuit shall be measured at its terminals at the rated current.

All resistors or impedances forming part of the control device shall be in circuit, However, no supplementary impedances shall be inserted between the current source and the terminals of the device.

The tests of 8.3.3.4.2, 8.3.3.4.3 and 8.3.3.4.4 shall be made on the same circuit-breaker but the order in which these tests are carried out is optional. However, for the tests of undervoltage and shunt releases the tests of 8.3.3.4.2 and 8.3.3.4.3 may, alternatively, be made on a new sample.

In the case of maintainable circuit-breakers, if it is desired to carry out a number of operations greater than that specified in Table 8, these additional operations shall be carried out first, followed by maintenance in accordance with the manufacturer's instructions, and then by the number of operations in accordance with Table 8, without any further maintenance being permitted during the remainder of this test sequence.

For convenience of testing it is permissible to subdivide each of the tests into two or more periods. No such period should, however, be less than 3 h.

8.3.3.4.2 Construction and mechanical operation

8.3.3.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 7.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 7.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

8.3.3.4.2.2 Mechanical operation

Tests shall be made as specified in 8.3.3.4.1 for the following purposes:

– to prove satisfactory tripping of the circuit-breaker with the closing release energized;
– to prove satisfactory behaviour of the circuit-breaker when the closing operation is initiated with the tripping device actuated;
– to prove that the operation of a power-operated device, when the circuit-breaker is already closed, shall neither cause damage to the circuit-breaker nor endanger the operator.

The mechanical operation of a circuit-breaker may be checked under no-load conditions.

A circuit-breaker with dependent power operation shall comply with the requirements stated in 7.2.1.1.4.

A circuit-breaker with dependent power operation shall operate with the operating mechanism charged to the minimum and maximum limits stated by the manufacturer.

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A circuit-breaker with stored energy operation shall comply with the requirements stated in 7.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control supply voltage. It shall also be verified that the moving contacts cannot be moved from the open position when the operating mechanism is charged to slightly below the full charge as evidenced by the indicating device.

For a trip-free circuit-breaker it shall not be possible to maintain the contacts in the touching or closed position when the tripping release is in the position to trip the circuit-breaker.

If the closing and opening times of a circuit-breaker are stated by the manufacturer, such times shall comply with the stated values.

8.3.3.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 7.2.1.3 of IEC 60947-1:2007. For this purpose, the release shall be fitted to a circuit-breaker having the maximum current rating for which the release is suitable.

i) Drop-out voltage

It shall be verified that the release operates to open the circuit-breaker between the voltage limits specified.

The voltage shall be reduced from rated control supply voltage at a rate to reach 0 V in approximately 30 s.

The test for the lower limit is made without current in the main circuit and without previous heating of the release coil.

In the case of a release with a range of rated control supply voltage, this test applies to the maximum voltage of the range.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control supply voltage to the release and rated current in the main poles of the circuit-breaker. This test may be combined with the temperature-rise test of 8.3.3.7.

In the case of a release with a range of rated control supply voltage, this test is made at both the minimum and maximum rated control supply voltages.

ii) Test for limits of operation

Starting with the circuit-breaker open, at the temperature of the test room, and with the supply voltage at 30 % rated maximum control supply voltage, it shall be verified that the circuit-breaker cannot be closed by the operation of the actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the circuit-breaker can be closed by the operation of the actuator.

iii) Performance under overvoltage conditions

With the circuit-breaker closed and without current in the main circuit, it shall be verified that the undervoltage release will withstand the application of 110 % rated control supply voltage for 4 h without impairing its functions.

8.3.3.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. For this purpose, the release shall be fitted to a circuit-breaker having the maximum rated current for which the release is suitable.

It shall be verified that the release will operate to open the circuit-breaker at 70 % rated control supply voltage when tested at an ambient temperature of +55 °C ± 2 °C without current in the main poles of the circuit-breaker. In the case of a release having a range of rated control supply voltages, the test voltage shall be 70 % of the minimum rated control supply voltage.

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8.3.3.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 8.3.2.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 8; the number of operating cycles per hour is given in column 2 of this table.

The tests shall be carried out without current in the main circuit of the circuit-breaker.

For circuit-breakers which can be fitted with shunt releases, 10 % of the total number of operating cycles shall be closing/tripping operations, with the shunt release energized at maximum rated control supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles shall be closing/tripping operations at the minimum rated control supply voltage, this voltage to the release being removed after each closing operation, to trip the circuit-breaker.

In each case, half the relevant number of operating cycles shall be made at the beginning and the other half at the end of the tests.

For circuit-breakers fitted with undervoltage releases, prior to the operational performance test, without the undervoltage release being energized, it shall be verified that the circuit-breaker cannot be closed by attempting 10 times to effect a closing operation of the circuit-breaker.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing releases, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature-rises of the electrical components do not exceed the limits indicated in Table 7.

In the case of manually operated circuit-breakers, they shall be operated as in normal use.

8.3.3.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, the test circuit being in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 8.

The circuit-breaker shall be operated so as to make and break its rated current at its maximum rated operational voltage, assigned by the manufacturer, at a power factor or time constant as applicable in accordance with Table 11, the tolerance being in accordance with 8.3.2.2.2.

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

For circuit-breakers fitted with adjustable releases, the tests shall be made with the overload setting at maximum and the short-circuit setting at minimum.

The tests shall be made on a circuit-breaker with its own closing mechanism. In the case of circuit-breakers fitted with electrical or pneumatic closing releases, these devices shall be supplied at their rated control supply voltage or at their rated pressure. Precautions shall be taken to ensure that the temperature rises of the electrical components do not exceed the values indicated in Table 7.

Manually operated circuit-breakers shall be operated as in normal use.

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8.3.3.4.5 Additional test of operational performance capability without current for withdrawable circuit-breakers

A test of operational performance capability without current shall be carried out on the withdrawal mechanism and associated interlocks of withdrawable circuit-breakers.

The number of operating cycles shall be 100.

After this test, the isolating contacts, withdrawal mechanism and interlocks shall be suitable for further service. This shall be verified by inspection.

8.3.3.5 Overload performance

This test applies to circuit-breakers of rated current up to and including 630 A.

NOTE 1 At the request of the manufacturer, the test can also be made on circuit-breakers of rated current higher than 630 A.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007.

The test shall be made at a voltage corresponding to the maximum operational voltage $U_{e\ max}$ assigned by the manufacturer to the circuit-breaker, taking into account the requirement for recovery voltage of Table 12 (see also 8.3.2.2.3 a) of IEC 60947-1:2007/AMD2:2014).

For circuit-breakers fitted with adjustable releases, the test shall be made with its releases set at maximum.

The circuit-breaker shall be opened nine times manually and three times automatically by the action of an overload release, except for circuit-breakers having a short-circuit release of a maximum setting less than the test current, in which case all 12 operations shall be automatic.

If the testing means do not withstand the let-through energy occurring during the automatic operation, the test may be performed as follows, with the agreement of the manufacturer:

– 12 manual operations;
– three additional operations with automatic opening, made at any convenient voltage.

During each of the manually operated cycles, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The number of operating cycles per hour shall be that specified in column 2 of Table 8. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced sufficiently so that the circuit-breaker may be closed, the full current being established.

If test conditions at the testing station do not permit testing at the operating rate given in Table 8, a slower rate may be used, but details shall be stated in the test report.

The values of the test current and of the recovery voltage shall be in accordance with Table 12, at the power factor or time constant, as applicable, in accordance with Table 11, the tolerances being in accordance with 8.3.2.2.2.

NOTE 2 With the agreement of the manufacturer the test can be made under more severe conditions than specified.

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Table 12 – Test circuit characteristics for overload performance

	Alternating current	Direct current
Current	6 I_n	2,5 I_n
Recovery voltage	1,05 $U_{e\ max}$	1,05 $U_{e\ max}$
$U_{e\ max}$ = maximum operational voltage of the circuit-breaker.		

Tests on a.c. rated circuit-breakers shall be made at a frequency between 45 Hz and 62 Hz.

The prospective current at the supply terminals of the circuit-breaker shall be at least 10 times the test current, or at least 50 kA, whichever of the two values is the lower.

8.3.3.6 Verification of dielectric withstand

8.3.3.6.1 General

The test shall be performed on the circuit-breaker whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

8.3.3.6.2 Test voltage

Subclause 8.3.3.4.1, item 4) b), of IEC 60947-1:2007/AMD1:2010 applies.

8.3.3.6.3 Application of the test voltage

The test voltage shall be applied for 5 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the circuit-breaker open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014 is not required. For the purposes of this standard, circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For circuit-breakers suitable for isolation the leakage current shall be measured in accordance with 8.3.3.3, item (iv), except that the leakage current shall not exceed 2 mA.

8.3.3.6.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

8.3.3.7 Verification of temperature-rise

Following the test according to 8.3.3.6, a temperature-rise test shall be made at the conventional thermal current according to 8.3.2.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 7.

8.3.3.8 Verification of overload releases

Immediately following the test according to 8.3.3.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 7.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. Alternatively, this test may be made using a 3-phase supply.

This test may be made at any convenient voltage.

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The operating time shall not exceed the conventional tripping time.

With the manufacturer's consent, a time interval between the tests of 8.3.3.7 and 8.3.3.8 may occur.

The test may, alternatively, be made at the ambient air temperature at a test current corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

8.3.3.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 8.3.3.4.2.3 i), except that the tests for upper and lower limits shall be made at the temperature of the test room without current in the main circuit. The release shall not operate at 70 % of the minimum control supply voltage and shall operate at 35 % of the maximum rated control supply voltage.

Circuit-breakers fitted with shunt releases shall be subjected to the test of 8.3.3.4.2.4, except that the test may be made at the temperature of the test room. The release shall operate at 70 % of the minimum rated control supply voltage.

8.3.3.10 Verification of the main contact position

For circuit-breakers suitable for isolation (see 3.5), following the verification of 8.3.3.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007/AMD1:2010.

8.3.4 Test sequence II: Rated service short-circuit breaking capacity

8.3.4.1 General

Except when the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to all circuit-breakers and comprises the following tests:

Test	Subclause
Rated service short-circuit breaking capacity	8.3.4.2
Verification of operational performance capability	8.3.4.3
Verification of dielectric withstand	8.3.4.4
Verification of temperature-rise	8.3.4.5
Verification of overload releases	8.3.4.6

For the case where $I_{cs} = I_{cu}$, see 8.3.5.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.4.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 4.3.6.2.3.

The power factor for this test shall be according to Table 11, for the appropriate test current.

The sequence of operations shall be:

O – *t* – CO – *t* – CO

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In the case of integrally fused circuit-breakers, any blown fuse shall be replaced after each operation. The time interval *t* may need to be extended for this purpose.

8.3.4.3 Verification of operational performance capability

Following the test according to 8.3.4.2, the operational performance capability shall be verified in accordance with 8.3.3.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 8.3.4.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 8.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 10.

8.3.4.4 Verification of dielectric withstand

Following the test according to 8.3.4.3, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured in accordance with 8.3.3.6.

8.3.4.5 Verification of temperature-rise

Following the test according to 8.3.4.4, the temperature-rise at the main terminals shall be verified in accordance with 8.3.2.5. The temperature-rise shall not exceed the values given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.4.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.4.6 Verification of overload releases

Immediately following the test according to 8.3.4.5, the operation of overload releases shall be verified in accordance with 8.3.3.8.

With the manufacturer's consent, a time interval between the tests of 8.3.4.5 and 8.3.4.6 may occur.

8.3.5 Test sequence III: Rated ultimate short-circuit breaking capacity

8.3.5.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers of selectivity category A and to circuit-breakers of selectivity category B having a rated ultimate short-circuit breaking capacity higher than the rated short-time withstand current.

NOTE For this type of selectivity category B circuit-breaker, the instantaneous release operates at values of current in excess of those stated in column 2 of Table 3 (4.3.6.4); this type of release can be referred to as "instantaneous override".

For circuit-breakers of selectivity category B having a rated short-time withstand current equal to their rated ultimate short-circuit breaking capacity, this test sequence need not be made, since, in this case, the ultimate short-circuit breaking capacity is verified when carrying out test sequence IV.

For integrally fused circuit-breakers, test sequence V applies in place of this sequence.

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Where $I_{cs} = I_{cu}$, this test sequence need not be made, in which case construction break tests are required in Sequence II (see Table 10) and the following verifications shall additionally be made in test sequence II:

– the verification of 8.3.5.2, at the beginning of the test sequence;

– the verification of 8.3.5.5, at the end of the test sequence.

This test sequence comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.5.2
Rated ultimate short-circuit breaking capacity	8.3.5.3
Verification of dielectric withstand	8.3.5.4
Verification of overload releases	8.3.5.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.5.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting on each pole separately. This test may be made at any convenient voltage.

If the ambient temperature differs from the reference temperature, the test current shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature, on a pole singly.

8.3.5.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 8.3.5.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 8.3.2.

The sequence of operations shall be:

O – *t* – CO

8.3.5.4 Verification of dielectric withstand

Following the test according to 8.3.5.3 the dielectric withstand shall be verified according to 8.3.3.6. For circuit breakers suitable for isolation, the leakage current shall not exceed 6 mA.

8.3.5.5 Verification of overload releases

Following the test according to 8.3.5.4, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

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The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.6 Test sequence IV: Rated short-time withstand current

8.3.6.1 General

Except where the test sequence VI (combined) applies (see 8.3.8), this test sequence applies to circuit-breakers with a rated short-time withstand current (see 4.4); it comprises the following tests:

Test	Subclause
Verification of overload releases	8.3.6.2
Rated short-time withstand current	8.3.6.3
Verification of temperature-rise	8.3.6.4
Short-circuit breaking capacity at maximum short-time withstand current	8.3.6.5
Verification of dielectric withstand	8.3.6.6
Verification of overload releases	8.3.6.7

Where integrally fused circuit-breakers are of selectivity category B, they shall meet the requirements of this sequence.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.6.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.6.3 Test of rated short-time withstand current

Subclause 8.3.4.3 of IEC 60947-1:2007 applies with the following addition:

For the purpose of this test only, any over-current release, including the instantaneous override, if any, likely to operate during the test, shall be rendered inoperative.

8.3.6.4 Verification of temperature-rise

Following the test according to 8.3.6.3, the temperature-rise at the main terminals shall be verified according to 8.3.2.5. The temperature-rise shall not exceed the value given in Table 7.

With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (8.3.6.6). This verification need not be made where, for a given frame size, the test of 8.3.7.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.6.5 Test of short-circuit breaking capacity at the maximum short-time withstand current

Following the test according to 8.3.6.4, a short-circuit test shall be made with the following sequence of operations:

O – *t* – CO

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under the general conditions of 8.3.2, with a value of prospective current equal to that of the short-time withstand current test (see 8.3.6.3) and at the highest voltage applicable to the rated short-time withstand current.

The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release, and the instantaneous override, if any, shall not operate. If the circuit-breaker has a making current release (see 2.10), this requirement does not apply to the CO operation, if the prospective current exceeds the pre-determined value, since it will then operate; this exception also applies to the test on the fourth pole and the adjacent pole, in accordance with 8.3.2.6.4.3.

8.3.6.6 Verification of dielectric withstand

Following the test carried out according to 8.3.6.5, the dielectric withstand shall be verified according to 8.3.3.6.

8.3.6.7 Verification of overload releases

Following the test according to 8.3.6.6, the operation of overload releases shall be verified in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.7 Test sequence V: Performance of integrally fused circuit-breakers

8.3.7.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the following tests:

	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	8.3.7.2
	Verification of temperature-rise	8.3.7.3
	Verification of dielectric withstand	8.3.7.4
Stage 2	Verification of overload releases	8.3.7.5
	Short-circuit at 1,1 times take-over current	8.3.7.6
	Short-circuit at ultimate short-circuit breaking capacity	8.3.7.7
	Verification of dielectric withstand	8.3.7.8
	Verification of overload releases	8.3.7.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 8.3.7.2 to 8.3.7.4;
– Stage 2 comprises the tests according to 8.3.7.5 to 8.3.7.9.

The two stages may be carried out:

– on two separate circuit-breakers, or
– on the same circuit-breaker, with maintenance between them, or
– on the same circuit-breaker, without any maintenance, in which case the test according to 8.3.7.4 may be omitted.

The test according to 8.3.7.3 need only be made if $I_{cs} > I_s$.

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Tests according to 8.3.7.2, 8.3.7.6 and 8.3.7.7 shall be made at the maximum operational voltage of the circuit-breaker.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.7.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer (see 2.17.4).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one O operation at the conclusion of which the fuses shall still be intact.

8.3.7.3 Verification of temperature-rise

NOTE This verification of temperature-rise is made since the fuses can have blown during the short-circuit test of test sequence II, 8.3.4.2, in which case the test of 8.3.7.2 is more severe.

Following the test according to 8.3.7.2 the temperature-rise at the main terminals shall be verified, in accordance with 8.3.2.5.

The temperature-rise shall not exceed the value given in Table 7.

8.3.7.4 Verification of dielectric withstand

Following the test according to 8.3.7.3 the dielectric withstand shall be verified according to 8.3.3.6.

8.3.7.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.7.6 Short-circuit at 1,1 times the take-over current

Following the test according to 8.3.7.5 a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer (see 2.17.5).

For the purpose of this test the fuses shall be fitted.

The test shall consist of one "O" operation at the conclusion of which at least two of the fuses shall have blown.

8.3.7.7 Short-circuit at rated ultimate short-circuit breaking capacity

Following the test according to 8.3.7.6, a short-circuit test is made under the same general conditions as in 8.3.7.2, with a value of prospective current equal to the ultimate short-circuit breaking capacity I_{cu}, as declared by the manufacturer.

For the purpose of this test, a new set of fuses shall be fitted.

The sequence of operations shall be:

O – *t* – CO

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a further new set of fuses being fitted during the time interval *t*, which may need to be extended for that purpose.

8.3.7.8 Verification of dielectric withstand

Following the test according to 8.3.7.7 and with a new set of fuses fitted, the dielectric withstand shall be verified according to 8.3.5.4.

8.3.7.9 Verification of overload releases

Following the test according to 8.3.7.8, the operation of overload releases shall be verified in accordance with 8.3.5.2 except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.8 Test sequence VI: combined test sequence

8.3.8.1 General

At the discretion of, or in agreement with the manufacturer, this test sequence may be applied to circuit-breakers of selectivity category B:

a) when the rated short-time withstand current and the rated service short-circuit breaking capacity have the same value (I_{cw} = I_{cs}); in this case it replaces test sequences II and IV;

b) when the rated short-time withstand current, the rated service short-circuit breaking capacity and the rated ultimate short-circuit breaking capacity have the same value (I_{cw} = I_{cs} = I_{cu}); in this case it replaces test sequences II, III and IV.

This test sequence comprises the following tests:

Test	Subclauses
Verification of overload releases	8.3.8.2
Rated short-time withstand current	8.3.8.3
Rated service short-circuit breaking capacity*	8.3.8.4
Verification of operational performance capability	8.3.8.5
Verification of dielectric withstand	8.3.8.6
Verification of temperature-rise	8.3.8.7
Verification of overload releases	8.3.8.8
* For circuit-breakers falling into the case of 8.3.8.1b) above, this is also the rated ultimate short-circuit breaking capacity.	

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10.

8.3.8.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 8.3.5.2.

8.3.8.3 Test of rated short-time withstand current

Following the test according to 8.3.8.2, a test shall be made at the rated short-time withstand current according to 8.3.6.3.

This test does not need to be made on the sample of minimum I_n specified in Table 10.

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8.3.8.4 Test of rated service short-circuit breaking capacity

Following the test according to 8.3.8.3, a test shall be made at the rated service short-circuit breaking capacity according to 8.3.4.2, at the highest voltage applicable to the rated short-time withstand current. The circuit-breaker shall remain closed for the short-time corresponding to the maximum available time setting of the short-time delay short-circuit release.

During this test the instantaneous override (if any) shall not operate, and the making current release (if any) shall operate.

8.3.8.5 Verification of operational performance capability

Following the test according to 8.3.8.4, the operational performance capability shall be verified in accordance with 8.3.4.3.

8.3.8.6 Verification of dielectric withstand

Following the test according to 8.3.8.5, the dielectric withstand shall be verified according to 8.3.3.6.

For circuit-breakers suitable for isolation, the leakage current shall be measured according to 8.3.3.6.

8.3.8.7 Verification of temperature-rise

Following the test according to 8.3.8.6, the temperature-rise at the main terminals shall be verified in accordance with 8.3.4.5.

The temperature-rise shall not exceed the value given in Table 7.

This verification need not be made where, for a given frame size, the test of 8.3.8.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

8.3.8.8 Verification of overload releases

After cooling down following the test according to 8.3.8.7, the operation of overload releases shall be verified in accordance with 8.3.3.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 8.3.5.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

8.3.9 Critical d.c. load current test

This test applies only to circuit-breakers with d.c. ratings.

The circuit-breaker condition and method of installation shall be as specified in 8.3.2.1, and the test circuit in accordance with 8.3.3.5.2 of IEC 60947-1:2007 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 10 – sequence I, except that for application of footnote g, construction breaks relative to the over-current tripping devices shall not be considered.

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The test shall be made at the maximum operational d.c. voltage (U_e max) assigned by the manufacturer to the circuit-breaker.

For circuit-breakers fitted with adjustable releases, the test shall be made with the releases set at the maximum.

The circuit-breaker shall be closed and opened 5 times on to each of the test currents listed below. If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

During each CO cycle, the circuit-breaker shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s.

The time constant shall be in accordance with Table 11 as for operational performance; at the discretion of the manufacturer, a higher value may be used, in which case this value shall be stated in the test report.

The number of operating cycles per hour shall be in accordance with Table 8.

The arcing time during the test shall be recorded and shall not exceed 1 s.

The test current values shall be: 4 A, 8 A, 16 A, 32 A and 63 A d.c., with ± 10 % tolerance, but not exceeding the rated current; the critical value is determined by taking the maximum mean arcing time, for each direction of current if applicable. The highest and lowest values of test current shall demonstrate shorter mean arcing times than the critical value; if necessary, the range of test currents shall be extended upwards or downwards by applying a 2 times ratio as many times as necessary, up to, but not exceeding, the rated current to find the critical value. If no critical value of current is found within these criteria, no further test according to this subclause is required.

The tolerances on test quantities other than the current shall be in accordance with 8.3.2.2.2.

Following this test, the same sample shall be subjected to an operational performance verification of 50 operations, under the same conditions, at the current and in the direction corresponding to the critical value. After this test, the dielectric withstand shall be verified according to 8.3.3.6 with a d.c. test voltage.

8.4 Routine tests

8.4.1 General

For the definition of routine tests, see 2.6.2 and 8.1.3 of IEC 60947-1:2007.

The following tests apply:

– mechanical operation (8.4.2);
– verification of the calibration of overcurrent releases (8.4.3);
– verification of the operation of undervoltage and shunt releases (8.4.4);
– additional tests for CBRs to Annex B (8.4.5);
– dielectric tests (see note) (8.4.6);
– verification of clearances (8.4.7).

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NOTE If by the control of materials and manufacturing processes, the integrity of the dielectric properties has been proven, these tests can be replaced by sampling tests according to a recognized sampling plan (see IEC 60410).[1]

However, operation of the circuit-breaker during manufacture and/or other routine test may take the place of the tests listed above provided the same conditions apply and the number of operations is not less than that specified.

The tests of 8.4.3, 8.4.4 and 8.4.5 shall be made with the releases fitted to the circuit-breaker or to an appropriate test equipment simulating the behaviour of the circuit-breaker.

In the context of the tests of 8.4.2, 8.4.3, 8.4.4, 8.4.6 and 8.4.7, the term "circuit-breakers" covers CBRs, where applicable.

8.4.2 Mechanical operation tests

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

The following tests shall be made on manually-operated circuit-breakers:

– two close-open operations;
– two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

The following tests shall be made on power-operated circuit-breakers at 110 % of the maximum rated control supply voltage and/or of the rated supply pressure, and at 85 % of the minimum rated control supply voltage and/or of the rated supply pressure:

– two close-open operations;
– two trip-free operations;
– for automatic reclosing circuit-breakers, two automatic reclosing operations.

8.4.3 Verification of the calibration of overcurrent releases

8.4.3.1 Inverse time-delay releases

The verification of the calibration of inverse time-delay releases shall be made at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curve provided by the manufacturer.

This verification may be made at any convenient temperature, correction being made for any difference from the reference temperature (see 4.7.3).

8.4.3.2 Instantaneous and definite time-delay releases

The verification of the calibration of instantaneous and definite time-delay releases shall check the non-operation and operation of the releases at the values of current given in 8.3.3.2.2 or 8.3.3.2.3, item a), as applicable, without measurement of break time being required.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

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[1] This publication was withdrawn.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the circuit-breaker occurs. Tripping shall occur between the lower and upper limits of test current.

8.4.4 Verification of the operation of undervoltage and shunt releases

8.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 7.2.1.3 of IEC 60947-1:2007 as follows:

a) Hold-in voltage

The release shall close on to a voltage corresponding to 85 % of the minimum rated control supply voltage.

b) Drop-out voltage

The release shall open when the voltage is reduced to a value within the range corresponding to the limits of 70 % and 35 % of the rated control supply voltage, adjusted to take account of the need to operate under the conditions specified in 8.3.3.4.2.3 i). In the case of releases having a range of rated control supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

8.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 7.2.1.4 of IEC 60947-1:2007/AMD2:2014. The test may be made at any convenient temperature provided the test voltage is reduced to take account of the need for the release to operate under the conditions specified in 8.3.3.4.2.4. In the case of a release having a range of rated control supply voltages, the test voltage shall be related to 70 % of the minimum rated control supply voltage.

8.4.5 Additional tests for CBRs

The following additional tests shall be made on CBRs or r.c. units.

a) Operation of the test device

The CBR shall be subjected to two close-trip operations or, in the case of r.c. units, to two reset-trip operations, tripping by the manual operation of the test device with the CBR supplied at the lowest rated operational voltage.

b) Verification of the calibration of the residual current tripping device of the CBR

Using an alternating sinusoidal residual current, it shall be verified that

– the CBR does not trip with a residual current of 0,5 times $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable;

– the CBR trips with a residual current of $I_{\Delta n}$ in each pole separately, at the minimum setting of $I_{\Delta n}$, if adjustable.

8.4.6 Dielectric tests

The test conditions shall be in accordance with 8.3.3.4.1, item 1), of IEC 60947-1:2007/AMD1:2010/AMD2:2014, except that the use of metal foil is not required. The test voltage shall be applied as follows:

– with the circuit-breaker in the open position, between each pair of terminals which are electrically connected together when the circuit-breaker is closed;

– for circuit-breakers not incorporating electronic circuits connected to the main poles, with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable;

– for circuit-breakers incorporating electronic circuits connected to the main poles, with the circuit-breaker in the open position, between each pole and the adjacent pole(s), and

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between each pole and the frame, if applicable, either on the incoming side or on the outgoing side, depending on the position of the electronic components.

Alternatively, disconnection of electronic circuits connected to the main poles is permitted, in which case the test voltage shall be applied with the circuit-breaker in the closed position, between each pole and the adjacent pole(s), and between each pole and the frame, if applicable.

The method of test shall be as in a) or b) or c) below at the manufacturer's discretion:

a) Two tests shall be made:

1) Impulse withstand voltage

The test voltage shall not be less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or the peak value corresponding to 2 U_i whichever is the greater, and

2) Power frequency withstand voltage

The test apparatus shall be as stated in 8.3.3.4.1, item 3) b), of IEC 60947-1:2007/AMD1:2010, except that the overcurrent trip shall be set to 25 mA. However, at the discretion of the manufacturer, for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the trip setting of the overcurrent relay; for example, for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

The value of the test voltage shall be 2 U_e max, with a minimum of 1 000 V r.m.s., applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of U_{imp}, 2 U_i, 2 U_e max or 1 000 V r.m.s.

c) An insulation resistance test at 500 V d.c. The insulation resistance shall be not less than 1 MΩ at any point.

If dielectric properties are tested according to a sampling plan in accordance with the note to 8.4.1, a power frequency withstand test shall be made according to 8.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 12A of IEC 60947-1:2007/AMD2:2010. Circuit-breakers having a rated insulation voltage greater than 1 000 V a.c. shall be tested at a voltage of U_i + 1 200 V a.c. r.m.s. or 2 U_i whichever is the greater.

8.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2007

Subclause 8.3.3.4.3 of IEC 60947-1:2007 applies, except that for the purposes of this standard this test shall be a routine test.

NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:2007 is covered by the tests of 8.4.6.

8.5 Special tests – Damp heat, salt mist, vibration and shock

The following special tests shall be made either at the discretion of the manufacturer or according to agreement between the manufacturer and user (see 2.6.4 of IEC 60947-1:2007). As special tests, unless specifically called for, these additional tests are not mandatory, and it is not necessary for a circuit-breaker to satisfy any of these tests to conform to this standard.

Annex Q of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies.

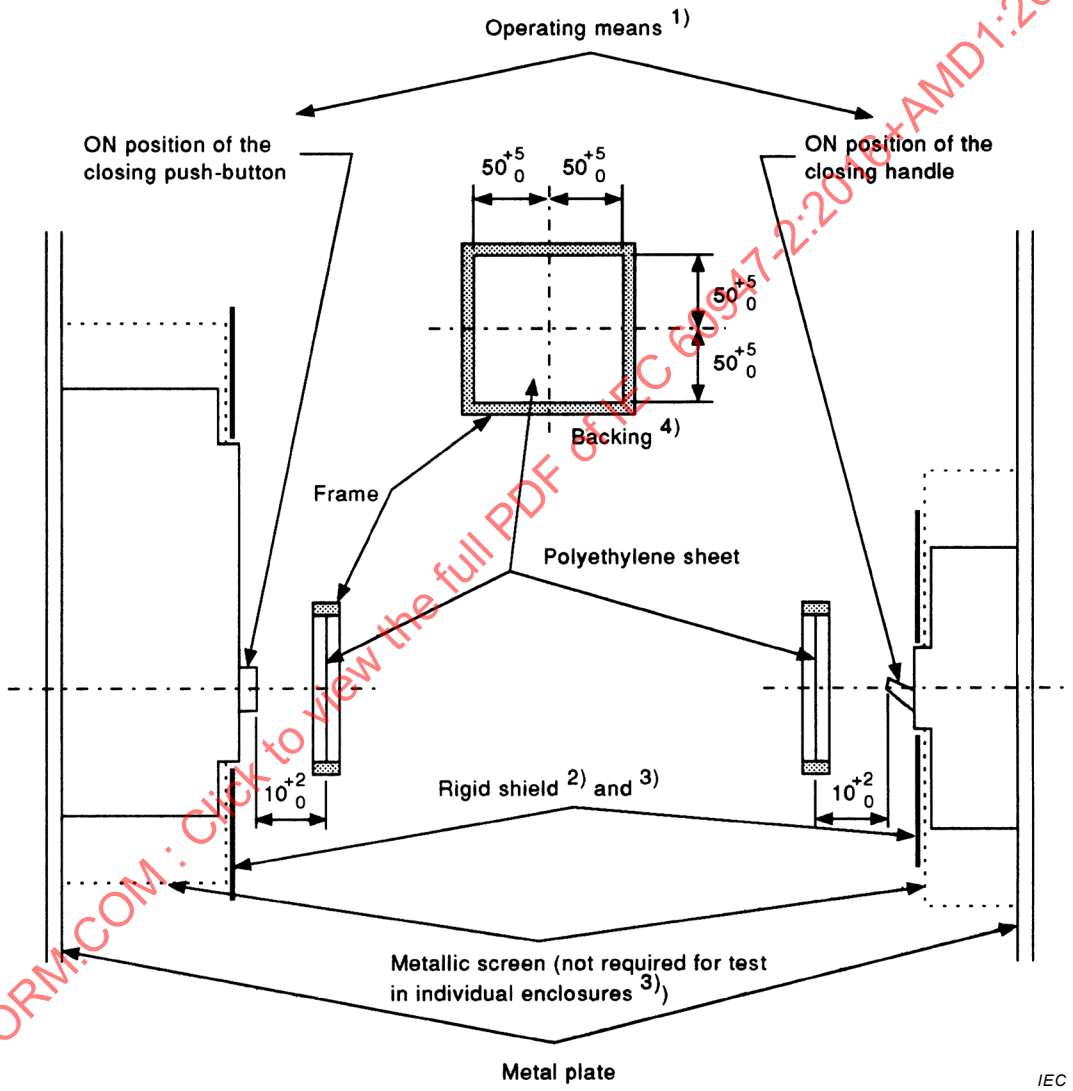
During the test sequences according to Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 8.4 of

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this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote e) of Table Q.1 of IEC 60947-1:2007, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energised with rated voltage. The circuit-breaker shall be operated according to 8.4.2 during the last hour of the test.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.



Case of circuit-breaker with closing push-button — Case of circuit-breaker with a closing handle

Dimensions in millimetres

1) The operating means includes any extension which is normally fitted for the closing operation.

2) The purpose of the rigid shield is to prevent emissions from areas other than those of the handle or push-button from reaching the polyethylene sheet (not required for tests in individual enclosures).

3) The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

4) Made of any suitable rigid material to obviate tearing of the polyethylene sheet.

Figure 1 – Test arrangement (connecting cables not shown) for short-circuit tests

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Annex A
(normative)

Co-ordination between a circuit-breaker and another short-circuit protective device associated in the same circuit

A.1 General

To ensure co-ordination between a circuit-breaker (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their dynamic behaviour as an association.

NOTE An SCPD can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure A.1 – or of another circuit-breaker (C_2) (see Figure A.2 and Figure A.3).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. It is recommended that this should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time. Preferred templates for the representation of cut-off current and let-through energy (I^2t) characteristics are given in Annex K.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances the SCPD may be mounted in locations remote from C_1. The SCPD may be protecting a main feeder supplying a number of circuit-breakers C_1 or just an individual circuit-breaker.

For such applications, the user or specifier may have to decide, on the basis of a desk study, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the circuit-breaker manufacturer should make available.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of selectivity (see 2.5.23 of IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3) as well as consideration of back-up protection (see 2.5.24 of IEC 60947-1:2007).

Consideration of selectivity can either be carried out by desk study or by test (see A.5), whereas the verification of back-up protection normally requires the use of tests (see A.6).

When considering short-circuit breaking capacity, reference may be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

A.2 Scope and object

This annex gives guidance on and requirements for the co-ordination of circuit-breakers with other SCPDs associated in the same circuit, as regards selectivity as well as back-up protection.

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The object of this annex is to state:

– the general requirements for the co-ordination of a circuit-breaker with another SCPD;
– the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

A.3 General requirements for the co-ordination of a circuit-breaker with another SCPD

A.3.1 General considerations

Ideally, the co-ordination should be such that a circuit-breaker (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu}.

NOTE 1 If the value of the prospective fault current at the point of installation is less than the rated ultimate short-circuit breaking capacity of C_1, it can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

a) If the value of the selectivity limit current I_s (see 2.17.4) is too low, there is a risk of unnecessary loss of selectivity.
b) If the value of the prospective fault current at the point of installation exceeds the rated ultimate short-circuit breaking capacity of C_1, the SCPD shall be so selected that the behaviour of C_1 is in accordance with A.3.3 and the take-over current I_B (see 2.17.5), if any, complies with the requirements of A.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1. If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short circuit.

NOTE 2 In the case of interchangeable releases, these considerations apply to each relevant release.

A.3.2 Take-over current

For the purpose of back-up protection the take-over current I_B shall not exceed the rated ultimate short-circuit breaking capacity I_{cu} of C_1 alone (see Figure A.3a)).

A.3.3 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 7.2.1.2.4, item a).

A.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the circuit-breaker shall provide information on the type and the characteristics of the SCPD to be used with C_1, and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (see 2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of this standard, or any other relevant standard.

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If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

A.5 Verification of selectivity

A.5.1 General

Selectivity can normally be considered by the manufacturer by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD (see A.5.2). Selectivity can also be determined by tests (see A.5.3).

In certain cases, tests on the association will show a higher level of I_s than obtained by a desk study, for example:

– when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;

– when the opening time of the SCPD is less than that corresponding to one half-cycle.

To obtain improved selectivity when the associated SCPD is a circuit-breaker, an intentional short-time delay is sometimes provided for C_2.

Selectivity may be partial (see Figure A.3a)) or total up to the rated ultimate short-circuit breaking capacity Icu of C1.

Two illustrations of total selectivity are given in Figure A.2a) and Figure A.2b).

A.5.2 Consideration of selectivity by desk study

A.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by comparison of characteristics

   Selectivity in the time-delayed over-current zone is verified by comparison of the time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this standard.

b) Circuit-breaker (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics

   Selectivity in the overload zone is determined by the comparison of time/current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

A.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time/current characteristics, of selectivity between two circuit-breakers in the fault current (short-circuit) zone (see Figure A.2a)), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

a) Circuit-breakers in series (C_1 and C_2) – selectivity determination by consideration of peak let-through current

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In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2, taking into account the tolerance.

NOTE 1 Example of selectivity calculation

C_2 = 800 A MCCB; I_i = 8 kA r.m.s. – 12 kA r.m.s. (10 kA setting ± 20 %); C_1 = 125 A MCCB.

Minimum tripping level of C_2 is 8 × 1,414 = 11,3 kA peak.

Let-through current of C_1 at 15 kA r.m.s. prospective, due to the current limitation of C_1, is 11 kA peak, from test data.

Therefore the system is selective to at least 15 kA r.m.s. prospective.

NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) Circuit-breaker (C_1) with fuse as SCPD

Selectivity in the fault-current (short-circuit) zone (see Figure A.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

c) Fuse (C_1) with circuit-breaker as SCPD

Selectivity in the instantaneous tripping short-circuit zone is determined from the let-through current of the fuse.

The selectivity limit current I_s is the maximum value at which the peak let-through current of the fuse is lower than the peak value corresponding to the instantaneous tripping level (I_i) of circuit-breaker taking into account the tolerance.

A.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this standard, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream circuit-breaker will give a more precise value for the selectivity limit.

A.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure A.5, where:

– C_1 may be a circuit-breaker in compliance with this standard or another IEC standard or a fuse in accordance with the appropriate IEC standard;

– settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 8.3.2.6.4 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

The test shall consist of an O – t – CO operation, the CO operation being made by closing the downstream device C_1. If the downstream device is a fuse, the operation shall be made by closing C_2.

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The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

– Subclause 8.3.4.1.7 of IEC 60947-1:2007 applies;
– During each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;
– In addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

A.6 Verification of back-up protection

A.6.1 Determination of the take-over current

Compliance with the requirements of A.3.2 can be checked by comparing the operating characteristics of C_1 and the associated SCPD for all settings of C_1 and, if applicable, for all settings of C_2.

A.6.2 Verification of back-up protection

Back-up protection can be verified either by tests, or by comparison of characteristics.

a) Verification by tests

Compliance with the requirements of A.3.3 is normally verified by tests in accordance with A.6.3. In this case, all the conditions for the tests shall be as specified in 8.3.2.6 with the adjustable resistors and inductors for the short-circuit tests on the supply side of the association.

b) Verification by comparison of characteristics

In some practical cases and where the SCPD is a circuit-breaker (see Figure A.3a) and Figure A.3b)), it may be possible for the manufacturer to compare the operating characteristics of C_1 and of the associated SCPD, special attention being paid to the following:

– the Joule integral value of C_1 at its I_{cu} and that of the SCPD at the prospective current of association;
– the effects on C_1 (e.g. by arc energy, by maximum peak current, cut-off current) at the peak operating current of the SCPD.

The suitability of the association may be evaluated by considering the maximum total operating I^2t characteristic of the SCPD, over the range from the rated short-circuit breaking capacity I_{cu} of C_1 up to the prospective short-circuit current of the application, but not exceeding the maximum let-through I^2t of C_1 at its rated short-circuit breaking capacity or other lower limiting value stated by the manufacturer.

NOTE Where the associated SCPD is a fuse, the validity of the desk study is limited up to I_{cu} of C_1.

A.6.3 Tests for verification of back-up protection

If C_1 is fitted with adjustable over-current opening releases, the operating characteristics shall be those corresponding to the minimum time and current settings.

If C_1 can be fitted with instantaneous over-current opening releases, the operating characteristics to be used shall be those corresponding to C_1 fitted with such releases.

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If the associated SCPD is a circuit-breaker (C_2) fitted with adjustable over-current opening releases, the operating characteristics to be used shall be those corresponding to the maximum time and current settings.

If the associated SCPD consists of a set of fuses, each test shall be made using a new set of fuses, even if some of the fuses used during a previous test have not blown.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the associated SCPD is a circuit-breaker (C_2), the full length of cable (75 cm) associated with this circuit-breaker may be on the supply side (see Figure A.4).

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5, the CO operation being made on C1.

A test is made with the maximum prospective current for the proposed application. This shall not exceed the rated conditional short-circuit (see 4.3.6.4 of IEC 60947-1:2007/AMD2:2014).

A further test shall be made at a value of prospective current equal to the rated short-circuit breaking capacity I_{cu} (or I_{cs}) of C_1, for which test a new sample C_1 may be used, and also, if the associated SCPD is a circuit-breaker, a new sample C_2.

During each operation

a) If the associated SCPD is a circuit-breaker (C_2):
   - either both C_1 and C_2 shall trip at both test currents, no further tests then being required.

     This is the general case and provides back-up protection only.
   - or C_1 shall trip and C_2 shall be in the closed position at the end of each operation, at both test currents, no further tests then being required.

     The contacts of C_2 are allowed to separate momentarily during each operation. In this case restoration of the supply is provided, in addition to back-up protection (see Note 1 to Figure A.3a)). The duration of contact separation of C_2, if any, shall be recorded during these tests.
   - or C_1 shall trip at the lower test current, and both C_1 and C_2 shall trip at the higher test current.

     The contacts of C_2 are allowed to separate momentarily at the lower test current. Additional tests shall be made at intermediate currents to determine the lowest current at which both C_1 and C_2 trip, up to which current restoration of supply is provided. The duration of contact separation of C_2, if any, shall be recorded during these tests.

b) If the associated SCPD is a fuse (or a set of fuses):
   - in the case of a single-phase circuit at least one fuse shall blow;
   - in the case of a multi-phase circuit either two or more fuses shall blow, or one fuse shall blow and C_1 shall trip.

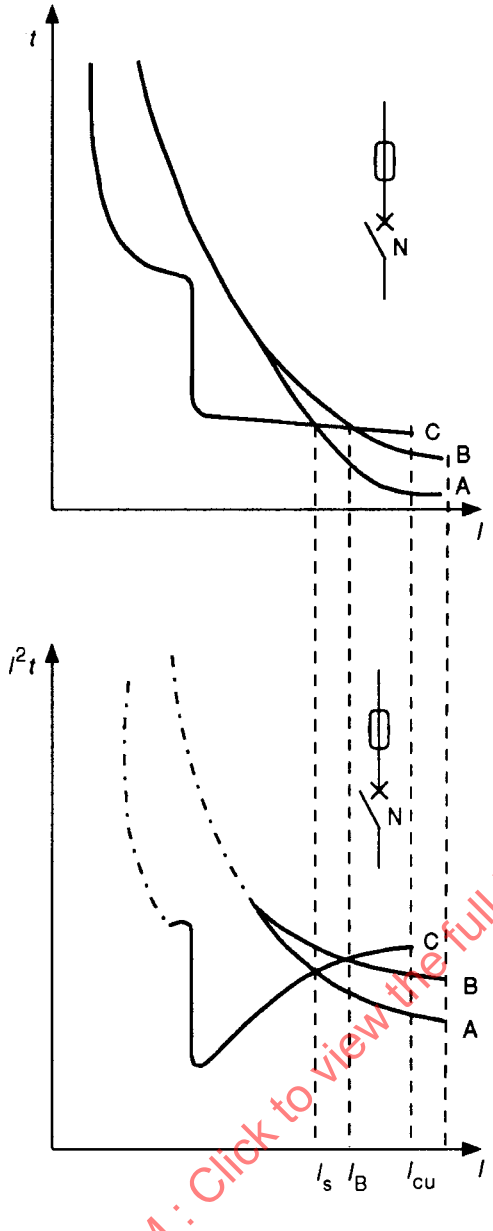
A.6.4 Results to be obtained

Subclause 8.3.4.1.7 of IEC 60947-1:2007 and 8.3.2.6.7 first paragraph of this standard apply, with the following addition:

Following the tests, if C_1 is a circuit-breaker, it shall comply with 8.3.5.4 and 8.3.5.5; if C_1 is a fuse, it shall comply with the applicable requirements of IEC 60269-1.

In addition, if the associated SPCD is a circuit-breaker (C_2), it shall be verified, by manual operation or other appropriate means, that the contacts of C_2 have not welded.

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I = Prospective short-circuit current

I_{cu} = Rated ultimate short-circuit breaking capacity (4.3.6.2.2)

I_s = Selectivity limit current (2.17.4)

I_B = Take-over current (2.17.5)

A = Pre-arcing characteristic of the fuse

B = Operating characteristic of the fuse

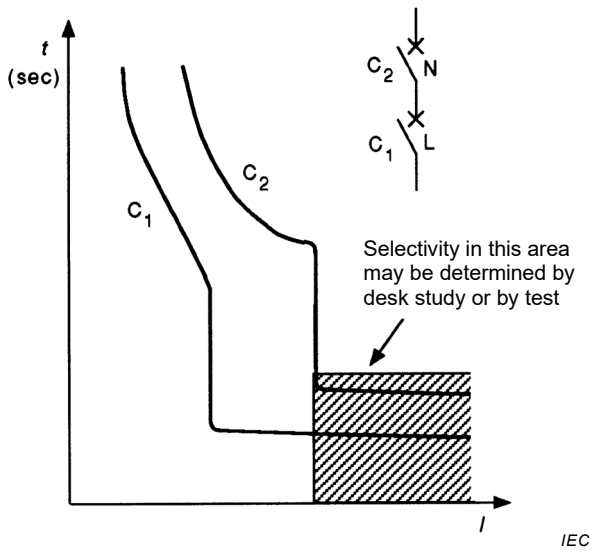
C = Operating characteristic of the circuit-breaker, non-current-limiting (N) (break-time/current and I^2t /current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure A.1 – Over-current co-ordination between a circuit-breaker and a fuse or back-up protection by a fuse: operating characteristics

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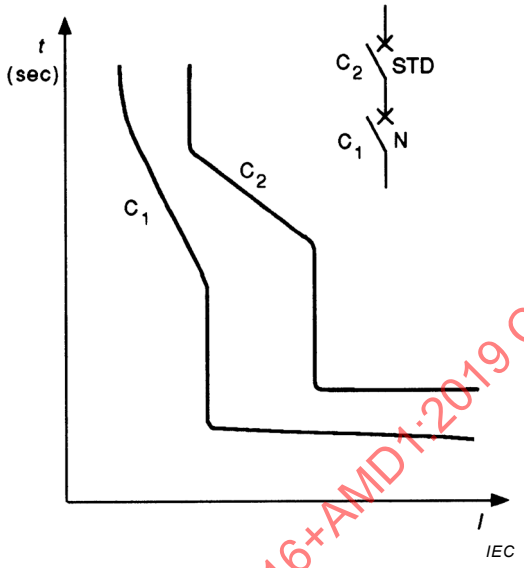


C_1 = Current-limiting circuit-breaker (L) (break-time characteristic)

C_2 = Current-limiting circuit breaker or non current-limiting circuit-breaker (N) (tripping characteristic)

Values of I_{cu} are not shown.

Figure A.2a) – Current-limiting CB downstream



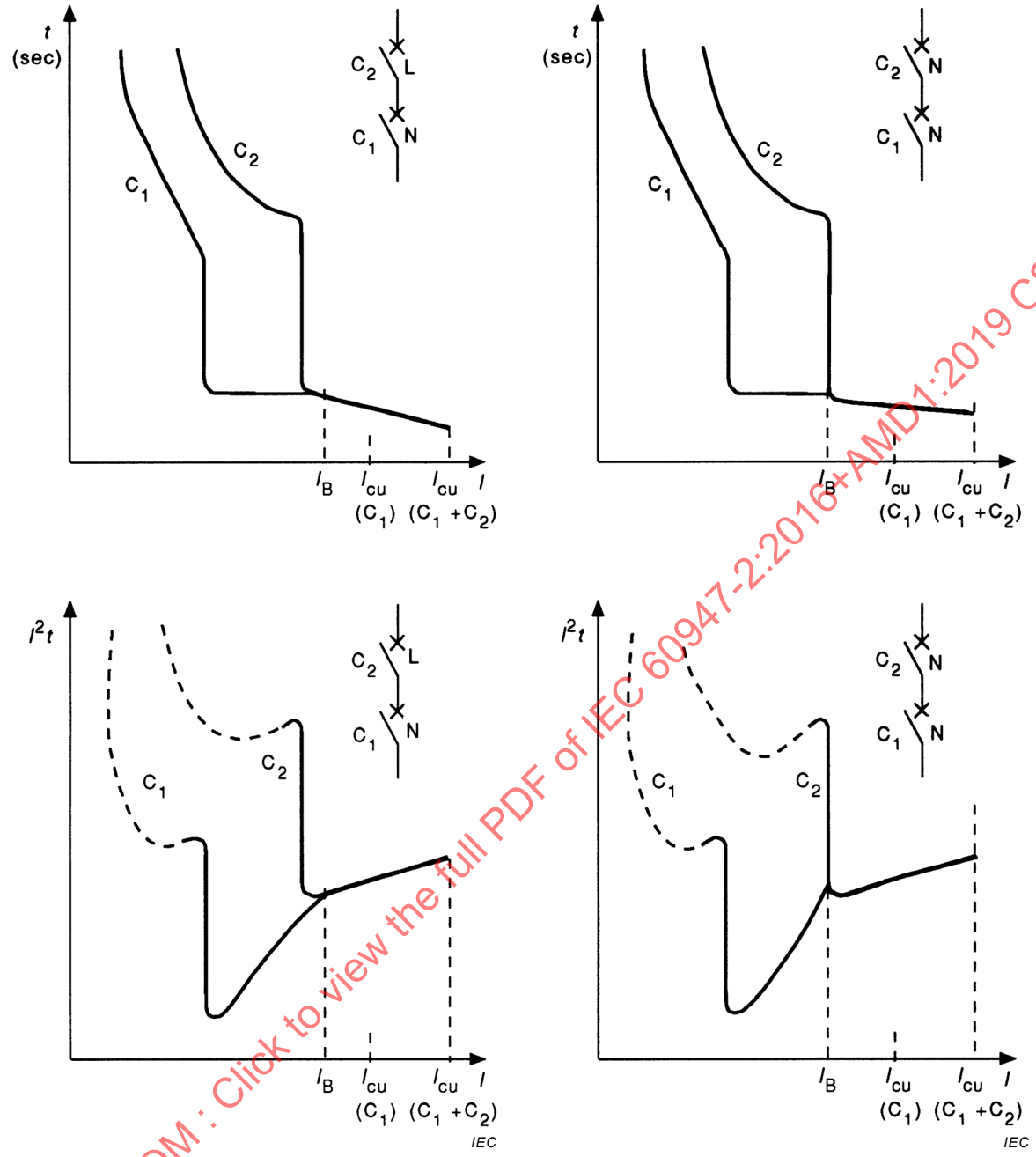
C_1 = Non-current-limiting circuit-breaker (N) (break-time characteristic)

C_2 = Circuit-breaker with intentional short-time delay (STD) (tripping characteristic)

Figure A.2b) – Non current-limiting CB downstream

Figure A.2 – Total selectivity between two circuit-breakers

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C_1 = Non current-limiting circuit-breaker (N)

C_2 = Current-limiting circuit-breaker (L)

Figure A.3a) – Current-limiting CB upstream

C_1, C_2 = Non current-limiting circuit-breaker (N)

Figure A.3b) – Non current-limiting CB upstream

I_B = Take-over current

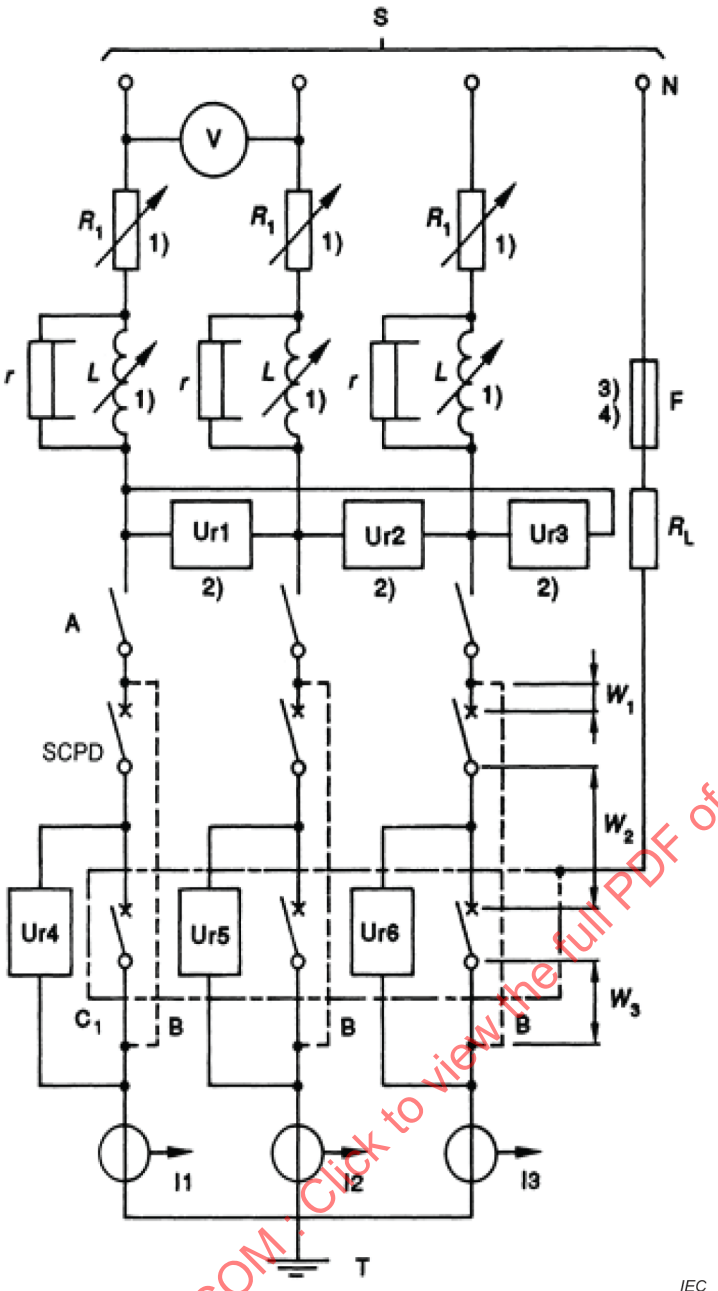
NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 I_{cu} (C_1 + C_2) ≤ I_{cu} (C_2)

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

Figure A.3 – Back-up protection by a circuit-breaker – Operating characteristics

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S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N neutral)	=	Neutral of supply (or artificial
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
B calibration	=	Temporary connections for
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for SCPD
W_2	=	50 cm of cable rated for C_1
W_3	=	25 cm of cable rated for C_1
SCPD	=	Circuit-breaker C_2 or set of 3 fuses
C_1	=	Circuit-breaker under test

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Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

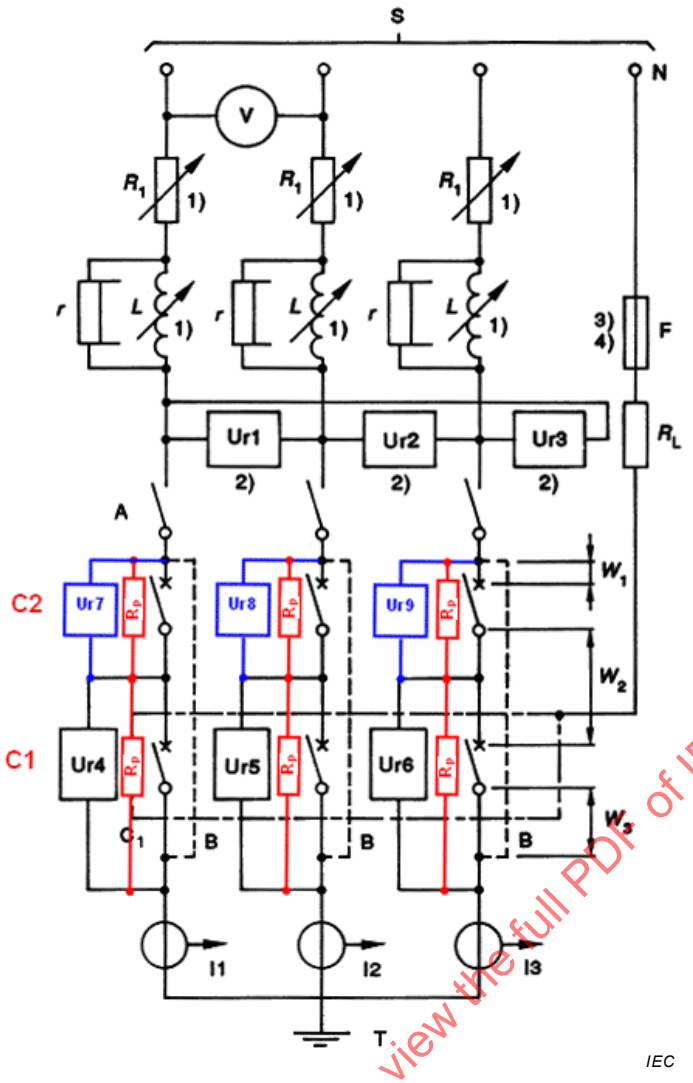
In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

In the USA and Canada (see notes to 4.3.2.1), F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

Figure A.4 – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C_1)



S	=	Supply
Ur1, Ur2, Ur3 Ur4, Ur5, Ur6 Ur7, Ur8, Ur9	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (8.3.4.1.2, item d) of IEC 60947-1:2007)
L	=	Adjustable reactors
R_L	=	Fault current limiting resistor
R_p	=	Optional polarising resistors
B	=	Temporary connections for calibration
I1, I2, I3	=	Current sensing devices
T	=	Earth: one earthing point only (load side or supply side)
r	=	Shunting resistor (8.3.4.1.2, item b) of IEC 60947-1:2007)
W_1	=	75 cm of cable rated for C_2
$W_2 + W_3$	=	75 cm of cable rated for C_1 (see A.5.2)
C_1, C_2	=	Circuit-breakers under test

Adjustable loads L and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit.

Ur1, Ur2, Ur3 may, alternatively, be connected between phase and neutral.

In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

NOTE 1 In the USA and Canada (see notes to 4.3.2.1), F is connected:

– to one phase of the supply for equipment marked with a single value of U_e;

– to the neutral for equipment marked with a twin voltage.

NOTE 2 Polarizing resistors allow determination of contact opening time for the two devices in series, the value being high enough not to influence the devices under test.

Figure A.5 – Example of test circuit for the verification of selectivity

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Annex B
(normative)

Circuit-breakers incorporating residual current protection

B.1 General

B.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of a circuit-breaker to achieve a two-fold goal, i.e.:

– providing protection of installations against overloads and short-circuit currents;
– providing protection of persons against indirect contact, i.e. hazardous increases of ground potential due to defective insulation.

NOTE 1 In IEC 61140:2016, the term “protection of persons against indirect contact” is replaced by “fault protection”.

Residual current devices may also provide additional protection against fire and other hazards, which may develop as a result of an earth fault of a lasting nature that cannot be detected by the over-current protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as a means for additional protection against direct contact in the event of failure of the relevant protective means.

NOTE 2 In IEC 61140:2016, the term “protection of persons against direct contact” is replaced by “basic protection”.

The requirements for the installation of such devices are specified in various sections of IEC 60364 series.

This annex includes definitions, additional requirements and tests for circuit-breakers incorporating residual current protection of type B to cover the use of new electronic technology in equipment which can result in particular residual currents not covered by the characteristics of type AC or type A.

NOTE 3 This annex complies with the relevant requirements of IEC 60755.

B.1.2 Scope and object

This annex applies to circuit-breakers providing residual current protection (CBRs). It covers the requirements for units that concurrently perform residual current detection, compare such measurements with a preset value and cause the protected circuit to be switched off when this value is exceeded.

This annex applies to:

- circuit-breakers in accordance with this document, which incorporate the residual current function as an integrated feature (hereinafter called integral CBRs);
- CBRs consisting of a combination of a residual current device (hereinafter referred to as r.c. units) and a circuit-breaker in accordance with this document; their combination both mechanically and electrically, may be carried out either at the factory or in the field by the user in accordance with the manufacturer's instructions.

This annex covers CBRs of type AC, type A and type B (see B.4.4).

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This annex applies only to CBRs intended for use in a.c. circuits.

NOTE The neutral current sensing means, if any, can be external to the circuit-breaker or the combination, depending on the case.

The residual current function of CBRs covered by this annex may or may not be functionally dependent on line voltage. CBRs depending on an alternative supply source are not covered by this annex.

This annex does not apply to equipment where the current sensing means (except the neutral current sensing means) or the processing device are mounted separately from the circuit-breaker. The requirements for such devices are given in Annex M.

The object of this annex is to state:

a) the specific features of the residual current function;

b) the specific requirements that shall be complied with by the CBR
   – under normal circuit conditions;
   – under abnormal circuit conditions, whether of a residual current nature or not;

c) the tests that shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures, including tests for electromagnetic compatibility;

d) the relevant product information.

B.2 Terms and definitions

As a complement to Clause 2 of this document, the following terms and definitions apply:

B.2.1 Terms and definitions relating to currents flowing from live parts to earth

B.2.1.1
earth fault current
current flowing to earth due to an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-23]

B.2.1.2
earth leakage current
current flowing from the live parts of the installation to earth in the absence of an insulation fault

[SOURCE: IEC 60050-442:1998, 442-01-24]

B.2.2 Terms and definitions relating to the energization of a CBR

B.2.2.1
energizing quantity
electrical energizing quantity that, alone or in combination with other such quantities, shall be applied to a CBR to enable it to accomplish its function under specified conditions

B.2.2.2
energizing input-quantity
energizing quantity by which the CBR is activated when it is applied under specified conditions

Note 1 to entry: These conditions can involve, e.g., the energizing of certain auxiliary elements.

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[SOURCE: IEC 60050-442:1998, 442-05-58, modified – In the definition, "residual current device" has been replaced with "CBR".]

B.2.2.3
residual current
I_{Δ}
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an r.m.s. value

[SOURCE: IEC 60050-442:1998, 442-05-19, modified – The definition has been adapted to apply to CBRs.]

B.2.2.4
residual operating current
$I_{\Delta n}$
value of the residual current which causes the CBR to operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-20, modified – In the definition, "residual current device" has been replaced with "CBR".]

B.2.2.5
residual non-operating current
$I_{\Delta no}$
value of the residual current at which (and below which) the CBR does not operate under specified conditions

[SOURCE: IEC 60050-442:1998, 442-05-21, modified – Symbol introduced and, in the definition, "residual current device" has been replaced with "CBR".]

B.2.3 Terms and definitions relating to the operation and the functions of a CBR

B.2.3.1
circuit-breaker incorporating residual current protection
CBR
circuit-breaker (see 2.1) designed to cause the opening of the contacts when the residual current attains a given value under specified conditions

B.2.3.2
CBR functionally independent of line voltage
CBR for which the functions of detection and evaluation, and the actuating means of interruption (see B.2.3.6) do not depend on the line voltage

B.2.3.3
CBR functionally dependent on line voltage
CBR for which the functions of detection and/or evaluation, and/or the actuating means of interruption (see B.2.3.6) depend on the line voltage

Note 1 to entry: It is understood that the line voltage for detection, evaluation or interruption is applied to the CBR.

B.2.3.4
detection (of a residual current)
function consisting in sensing the presence of a residual current

Note 1 to entry: This function can be performed, for example, by a transformer integrating the vector sum of the currents.

[SOURCE: IEC 60050-442:1998, 442-05-24]

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B.2.3.5
evaluation
function consisting in giving to the CBR the possibility to operate when the detected residual current exceeds a specified reference value

[SOURCE: IEC 60050-442:1998, 442-05-25, modified – In the term, "(for a residual current)" has been deleted and in the definition, "residual current device" has been replaced with "CBR".]

B.2.3.6
interruption
function consisting in bringing automatically the main contacts of the CBR from the closed position into the open position, thereby interrupting the current(s) flowing through them

[SOURCE: IEC 60050-442:1998, 442-05-26, modified – In the term, "(for a residual current device)" has been deleted and in the definition, "residual current device" has been replaced with "CBR".]

B.2.3.7
limiting non-actuating time
maximum delay during which a value of residual current higher than the rated residual non-operating current can be applied to the CBR without bringing it actually to operate

[SOURCE: IEC 60050-442:1998, 442-05-23, modified – In the definition, "residual current device" has been replaced with "CBR" and "rated" has been added.]

B.2.3.8
time-delay CBR
CBR specially designed to attain a predetermined value of limiting non-actuating time, corresponding to a given value of residual current

[SOURCE: IEC 60050-442:1998, 442-05-05, modified – In the definition and the term, "residual current device" has been replaced with "CBR".]

B.2.3.9
reset-CBR
CBR with an r.c. unit that shall be intentionally reset by a means different from the operating means of the CBR, following the occurrence of a residual current, before it can be reclosed

B.2.3.10
test device
device simulating a residual current for checking that the CBR operates

B.2.4 Terms and definitions relating to values and ranges of energizing quantities

B.2.4.1
limiting value of the non-operating over-current in the case of a single-phase load
maximum value of a single-phase over-current which, in the absence of a residual current, can flow through a CBR (whatever the number of poles) without causing it to operate

Note 1 to entry: See B.7.2.7.

B.2.4.2
residual short-circuit making and breaking capacity
value of the a.c. component of a residual prospective short-circuit current which a CBR can make, carry for its opening time and break under specified conditions of use and behaviour

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B.3 Classification

B.3.1 Classification according to the method of operation of the residual current function

B.3.1.1 CBR functionally independent of line voltage (see B.2.3.2)

B.3.1.2 CBR functionally dependent on line voltage (see B.2.3.3 and B.7.2.12)

B.3.1.2.1 Opening automatically in the case of failure of the line voltage with or without delay

B.3.1.2.2 Not opening automatically in the case of failure of line voltage

Not opening automatically in the case of failure of the line voltage, but able to trip under specified conditions in the case of an earth fault arising on failure of the line voltage.

NOTE Classification under this subclause includes CBRs unable to open automatically when no hazardous situation exists.

B.3.2 Classification according to the possibility of adjusting the residual operating current

B.3.2.1 CBR with single rated residual operating current

B.3.2.2 CBR with multiple settings of residual operating current

– by fixed steps;
– by continuous variation.

B.3.3 Classification according to time delay of the residual current function

B.3.3.1 CBR without time-delay: non-time-delayed type

B.3.3.2 CBR with time-delay: time-delayed type (see B.2.3.8)

B.3.3.2.1 CBR with non-adjustable time delay

B.3.3.2.2 CBR with adjustable time delay

– by fixed steps;
– by continuous variation.

B.3.4 Classification according to behaviour in presence of a d.c. component

B.3.4.1 CBRs of type AC (see B.4.4.1)

B.3.4.2 CBRs of type A (see B.4.4.2)

B.3.4.3 CBRs of type B (see B.4.4.3)

B.4 Characteristics of CBRs concerning their residual current function

B.4.1 Rated values

B.4.1.1 Rated residual operating current ($I_{\Delta n}$)

The r.m.s. value of a sinusoidal residual operating current (see B.2.2.4) assigned to the CBR by the manufacturer, at which the CBR shall operate under specified conditions.

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For a CBR with multiple settings of residual operating current, the highest setting is used to designate its rating. See, however, Clause B.5 concerning marking.

B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The r.m.s. value of sinusoidal residual non-operating current (see B.2.2.5) assigned to the CBR by the manufacturer at which the CBR does not operate under specified conditions.

B.4.1.3 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of the prospective residual short-circuit current (see B.2.4.2) assigned to the CBR by the manufacturer, which the CBR can make, carry and break under specified conditions.

B.4.2 Preferred and limiting values

B.4.2.1 Preferred values of rated residual operating current ($I_{\Delta n}$)

Preferred values of rated residual operating current are

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A – 1 A – 3 A – 10 A – 30 A

Higher values may be required.

$I_{\Delta n}$ may be expressed as a percentage of the rated current.

B.4.2.2 Minimum value of rated residual non-operating current ($I_{\Delta no}$)

The minimum value of rated residual non-operating current is 0,5 $I_{\Delta n}$.

B.4.2.3 Limiting value of non-operating over-current in the case of a single-phase load

The limiting value of non-operating over-current in the case of a single-phase load shall be in accordance with B.7.2.7.

B.4.2.4 Operating characteristics

B.4.2.4.1 Non-time-delay type

The operating characteristic for a non-time-delay type is given in Table B.1.

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Table B.1 – Operating characteristic in the case of sinusoidal residual current for non-time-delay type

Residual current [c]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	10 $I_{\Delta n}$ [b]
Maximum break times s	0,3	0,15	0,04	0,04
NOTE These values are derived from IEC 60479-1 and are valid for both 50 Hz and 60 Hz.				
[a] For CBRs having $I_{\Delta n} \leq 30$ mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.				
[b] For CBRs having $I_{\Delta n} \leq 30$ mA, 0,5 A may be used as an alternative to 10 $I_{\Delta n}$.				
[c] For CBRs of types A and B, multiplying factors may apply – see B.8.7 and B.8.8.				

CBRs having $I_{\Delta n} \leq 30$ mA shall be of the non-time-delay type.

B.4.2.4.2 Time-delay type

B.4.2.4.2.1 Limiting non-actuating time (see B.2.3.7)

For a time-delay type, the limiting non-actuating time is defined at 2 $I_{\Delta n}$ and shall be declared by the manufacturer.

The minimum limiting non-actuating time is 0,06 s.

The preferred values of limiting non-actuating time are

0,06 s – 0,1 s – 0,2 s – 0,3 s – 0,4 s – 0,5 s – 1 s

B.4.2.4.2.2 Operating characteristics

For CBRs having a limiting non-actuating time of 0,06 s, the operating characteristics is given in Table B.2.

Table B.2 – Operating characteristics in the case of sinusoidal residual currents, for time-delay type having a limiting non-actuating time of 0,06 s

Residual current [a]	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	10 $I_{\Delta n}$
Maximum break time s	0,5	0,2	0,15	0,15
Limiting non actuating time s	-	0,06	-	-
NOTE These values are derived from IEC 60479-1 and are valid for both 50 Hz and 60 Hz.				
[a] For CBRs of types A and B, multiplying factors may apply – see B.8.7 and B.8.8				

For CBRs having a limiting non-actuating time higher than 0,06 s, the manufacturer shall declare the maximum break time at $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, and 10 $I_{\Delta n}$.

In the case of a CBR having an inverse current/time characteristic, the manufacturer shall state the residual current/break time characteristic.

B.4.3 Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

The minimum value of $I_{\Delta m}$ is 25 % of I_{cu}.

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Higher values may be tested and declared by the manufacturer.

B.4.4 Operating characteristics in the case of an earth fault current in the presence or absence of a d.c. component

B.4.4.1 CBR of type AC

A CBR for which tripping is ensured for residual sinusoidal alternating currents, in the absence of a d.c. component whether suddenly applied or slowly rising.

B.4.4.2 CBR of type A

A CBR for which tripping is ensured for residual sinusoidal alternating currents in the presence of specified residual pulsating direct currents with or without a specified level of superimposed d.c. (± 6 mA), whether suddenly applied or slowly rising.

B.4.4.3 CBR of type B

A CBR for which tripping is ensured as for type A, and in addition:

– for residual sinusoidal alternating currents up to 1 000 Hz,
– for composite residual currents, whether suddenly applied or slowly rising intended for circuits supplied between phase and neutral or phase and earthed middle conductor,
– for residual alternating currents superimposed by a smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value,
– for residual pulsating direct currents superimposed by a smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value,
– for residual direct currents which can result from rectifying circuits, i.e.:
  - two-pulse bridge connection line to line for 2-, 3- and 4-pole CBRs,
  - three-pulse star connection or six-pulse bridge connection for 3- and 4-pole CBRs,
– for residual smooth direct currents.

B.5 Marking

Each CBR shall be marked as specified in 5.2 and, in addition, in accordance with Table B.3

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Table B.3 – Product information

Item	Information	Marking location	
		Integral CBR	r. c. unit
B1.1	the operating means of the test device by the letter T (see also B.7.2.6)	Visible	Visible
B1.2	operating characteristic in the case of residual currents in the presence or absence of a d.c. component: – for CBRs of type AC with the symbol  (IEC 60417-6148:2012-01) – for CBRs of type A with the symbol  (IEC 60417-6149:2012-01) – for CBRs of type B with the symbol  (IEC 60417-6398:2017-12) or  (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	Visible
B1.3	rated residual operating current $I_{\Delta n}$	Visible	Visible
B2.1	settings of residual operating current, when applicable	Marked	Marked
B2.2	limiting non-actuating time at 2 $I_{\Delta n}$, for time-delay type, by the symbol Δt followed by the limiting non-actuating time	Marked	Marked
B2.3	suitability for use with a 3-phase supply only, with the symbol  (IEC 60417-6364:2016-07)	Marked	Marked
B2.4	rated voltage(s) if different from the rated voltage(s) of the circuit-breaker	-	Marked
B2.5	value (or range) of the rated frequency if different from that of the circuit-breaker	-	Marked
B2.6	the indication I_n ≤ ...A (I_n being the maximum current rating of the circuit-breaker with which the r.c. unit may be combined)	-	Marked
B2.7	manufacturer's name or trade mark	-	Marked
B2.8	type designation or catalog reference	-	Marked
B2.9	identification of the circuit-breaker(s) with which the r.c. unit may be assembled, unless incorrect assembly (such as to render the protection ineffective) is made impossible by the design;	-	Marked
B2.10	IEC 60947-2	-	Marked
B3.1	rated residual short-circuit making and breaking capacity $I_{\Delta m}$ if higher than 25 % of I_{cu} (see B.4.3)	Literature	Literature
B3.2	diagram of connections, including those of the test circuit and, if applicable, those to the line, for CBRs dependent on the line voltage	Literature	Literature
B3.3	value of rated residual non-operating current $I_{\Delta no}$ if greater than 0,5 $I_{\Delta n}$	Literature	Literature
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked:marked on the product Literature:provided in the manufacturer's literature			

B.6 Normal service, mounting and transport conditions

Clause 6 applies.

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B.7 Design and operating requirements

B.7.1 Design requirements

It shall not be possible to modify the operating characteristic of a CBR except by means which are specifically provided for setting the rated residual operating current or the definite time delay.

Changing from one setting to another shall only be possible through a deliberate action, such as the use of a tool, a password or equivalent means.

CBRs combining an r.c. unit device and a circuit-breaker shall be so designed and built that:

– the coupling system of the r.c. unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that may adversely affect the installation or result in injury to the user;
– the addition of the r.c. unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;
– the r.c. unit does not sustain any permanent damage due to the short-circuit currents during test sequences.

B.7.2 Operating requirements

B.7.2.1 Operation in the case of a residual current

CBRs shall open automatically in response to any earth leakage current or earth fault current equal to or exceeding the rated residual operating current for a time exceeding the non-actuating time.

The operation of CBRs shall be in compliance with the time requirements specified in B.4.2.4. Compliance shall be checked by the tests of B.8.1.2.

B.7.2.2 Rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

CBRs shall meet the test requirements of B.8.11.

B.7.2.3 Operational performance capability

CBRs shall comply with the tests of B.8.1.2.1.

B.7.2.4 Effects of environmental conditions

CBRs shall operate satisfactorily, taking into account the effects of environmental conditions.

Compliance is checked by the test of B.8.12.

B.7.2.5 Dielectric properties

CBRs shall withstand the tests of B.8.3.

B.7.2.6 Test device

CBRs shall be provided with a test device causing the passing through the detecting device of a current simulating a residual current, in order to allow periodic testing of the ability of the CBRs to operate.

The test device shall satisfy the tests of B.8.4.

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The protective conductor, if any, shall not become live when the test device is operated.

It shall not be possible to energize the protected circuit by operating the test device when the CBR is in the open position.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; a light colour should preferably be used.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

B.7.2.7 Value of the non-operating over-current in the case of a single-phase load

CBRs shall withstand the smaller of the following two over-current values without tripping:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

Compliance is checked by the test of B.8.5.

However this test is not necessary in the case of CBRs of selectivity category B since the requirements of this subclause are verified during test sequence IV (or test sequence VI).

NOTE Polyphase balanced load tests are considered to be covered by the requirements of this subclause.

B.7.2.8 Resistance of CBRs to unwanted tripping due to surge currents resulting from impulse voltages

B.7.2.8.1 Resistance to unwanted tripping in the case of loading of the network capacitance

CBRs shall withstand the test of B.8.6.2.

B.7.2.8.2 Resistance to unwanted tripping in the case of flashover without follow-on current

CBRs shall withstand the test of B.8.6.3.

B.7.2.9 Behaviour of CBRs of type A in the case of an earth fault comprising a d.c. component

The behaviour of CBRs in the case of an earth fault current comprising a d.c. component shall be such that the maximum break times stated in Table B.1 and Table B.2, as applicable, shall also be valid, the test current values specified being, however, increased:

– by the factor 1,4 for CBRs having $I_{\Delta n} \geq 0{,}030$ A;
– by the factor 2 for CBRs having $I_{\Delta n} < 0{,}030$ A.

Compliance is checked by the tests of B.8.7.

B.7.2.10 Behaviour of CBRs of type B in response to the type of residual current

B.7.2.10.1 Composite residual currents

Type B RCDs shall operate in response to a steady increase of composite residual currents, including a 10 Hz component and a 1 kHz component, as defined in Table B.7.

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The residual operating current shall be within the limits given in Table B.8.

Compliance is checked by the tests of B.8.8.1.

Type B CBRs shall operate in response to a sudden appearance of a composite residual current equal to 7 $I_{\Delta n}$, within the maximum break-time specified in B.4.2.4 for 5 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.2.

B.7.2.10.2 Residual sinusoidal alternating currents up to 1 000 Hz

Type B RCDs shall operate in response to residual currents of any frequency up to 1 000 Hz, in accordance with Table B.9.

Compliance is checked by the tests of B.8.8.3.

B.7.2.10.3 Residual alternating current superimposed by a residual smooth direct current

Type B CBRs shall operate in the case of residual alternating currents of the rated frequency superimposed by a residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value.

The alternating tripping current shall be equal or lower than $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.4.

B.7.2.10.4 Residual pulsating direct current superimposed by a residual smooth direct current

Type B CBRs shall operate in the case of residual pulsating direct currents superimposed by a residual smooth direct current of 0,4 times the rated residual current ($I_{\Delta n}$) or 10 mA whichever is the highest value.

The tripping current shall not be higher than 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ > 0,01 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≤ 0,01 A.

NOTE The tripping current 1,4 $I_{\Delta n}$ or 2 $I_{\Delta n}$, as applicable, is the RMS value due to the half-wave pulsating direct current.

Compliance is checked by the tests of B.8.8.5.

B.7.2.10.5 Residual pulsating direct currents that can result from rectifying circuits supplied from two phases

Type B CBRs shall operate in response to a steady increase of residual pulsating direct currents resulting from rectifying circuits within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.6 a).

Type B CBRs shall operate in response to a sudden appearance of residual pulsating direct currents resulting from rectifying circuits according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.6 b).

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B.7.2.10.6 Residual pulsating direct currents that can result from rectifying circuits supplied from three phases

Type B CBRs shall operate in response to a steady increase of residual pulsating direct currents resulting from rectifying circuits within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.7 a).

Type B CBRs shall operate in response to a sudden appearance of residual pulsating direct currents resulting from rectifying circuits according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.7 b).

B.7.2.10.7 Residual smooth direct current

Type B CBRs shall operate in response to a steady increase of a smooth direct residual current within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

Compliance is checked by the tests of B.8.8.8.1 a) and B.8.8.8.2.

Type B CBRs shall operate in response to a sudden appearance of a smooth direct residual current according to the limits specified in B.4.2.4, the test current values specified being, however, increased by a factor 2.

Compliance is checked by the tests of B.8.8.8.1 b).

B.7.2.11 Conditions of operation for reset-CBRs

It shall not be possible to reclose reset-CBRs (see B.2.3.9) after tripping due to a residual current, if they have not been reset.

Compliance is checked during the test of 8.3.3.4.4 in accordance with B.8.1.2.1.

B.7.2.12 Additional requirements for CBRs functionally dependent on line voltage

CBRs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times its rated value.

Compliance is checked by the tests of B.8.2.3.

Where a CBR has more than one rated frequency or a range of rated frequencies, the CBR shall be capable of operating in accordance with this subclause at all frequencies.

Compliance is verified by carrying out the tests of B.8.2 and B.8.4.

According to their classification CBRs functionally dependent on line voltage shall comply with the requirements given in Table B.4.

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Table B.4 – Requirements for CBRs functionally dependent on line voltage

Classification of the device according to B.3.1		Behaviour in the case of failure of line voltage
CBRs opening automatically in the case of failure of the line voltage (B.3.1.2.1)	Without delay	Opening without delay according to item a) of B.8.9.3
	With delay	Opening with delay according to item b) of B.8.9.3
CBRs not opening automatically in the case of failure of the line voltage but able to open in the case of a hazardous situation arising (B.3.1.2.2)		Operating according to B.8.10

B.7.3 Electromagnetic compatibility

The requirements of Annex J apply.

Additional test specifications are given in B.8.13.

Immunity to voltage variations is covered by the requirements of B.7.2.12.

B.8 Tests

B.8.1 Test sequences

B.8.1.1 General

This clause specifies tests for CBRs having a rated residual operating current $I_{\Delta n}$ up to and including 30 A.

The applicability of the tests specified in this clause when $I_{\Delta n} > 30$ A is subject to agreement between manufacturer and user.

The instruments for the measurement of the residual current shall show (or permit to determine) the true r.m.s. value.

Tests specified in this annex are supplementary to the tests of Clause 8.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 8. For the dielectric withstand verifications during these test sequences (see 8.3.3.6), the control circuit of residual current devices functionally dependent on line voltage shall be disconnected from the main circuit.

The tests shall be carried out with substantially sinusoidal currents.

For CBRs comprising a separate r.c. unit and a circuit-breaker, the assembly shall be performed in compliance with the manufacturer's instructions.

In the case of CBRs with multiple settings of residual operating current, the tests shall be carried out at the lowest setting, unless otherwise stated.

In the case of CBRs with adjustable time delays (see B.3.3.2.2), the time delay shall be set at maximum, unless otherwise stated.

In the case of CBRs with adjustable instantaneous tripping, the instantaneous trip shall be set at maximum, unless otherwise stated.

b) Routine tests

Subclause 8.4.5 applies.

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B.8.1.2 Tests to be carried out during the test sequences of Clause 8

B.8.1.2.1 General performance characteristics (test sequence I)

To avoid unintentional operation of the residual current function, the verification of tripping limits and characteristics (8.3.3.2) shall be amended as follows:

– for the verification of the short-circuit releases of electronic overcurrent releases, the pole under test shall be tested in series with one other pole chosen at random; for the verification of the short-circuit releases of electromagnetic overcurrent releases, the additional verification in single pole need not be carried out; for the verification of the overload release of the neutral pole, this pole shall be tested in series with 2 other poles connected in parallel;

– alternatively, when feasible and with the agreement of the manufacturer, the residual current function may be rendered inoperative;

– the test conditions shall be stated in the test report.

During the operating cycles with current (see 8.3.3.4.4) specified in Table 8 (see 7.2.4.2), a third of the breaking operations shall be performed by actuating the test device, and a further third by applying a residual current of value $I_{\Delta n}$ (or, if applicable, of the lowest setting of the residual operating current) to any one pole.

In the case of a reset-CBR, it shall be verified that it is not possible to reclose the CBR after tripping without the intentional resetting action. This verification shall take place at the beginning and at the end of the operational performance capability test with current (8.3.3.4.4).

No failure to trip shall be admitted.

B.8.1.2.2 Verification of the withstand capability to short-circuit currents

B.8.1.2.2.1 Rated service short-circuit breaking capacity (test sequence II)

Following the tests of 8.3.4, verification of the correct operation of the CBR in the case of residual current shall be performed in accordance with B.8.2.4.2.

B.8.1.2.2.2 Rated ultimate short-circuit breaking capacity (test sequence III)

For the purpose of verifying the correct operation of the overload releases, the single pole tests specified in 8.3.5.2 and 8.3.5.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.5.2 and 8.3.5.5 but applicable to two poles.

Following the tests of 8.3.5, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.3 Rated short-time withstand current (test sequence IV or test sequence VI (combined))

a) Behaviour during rated short-time withstand current test

No tripping shall occur during the test of 8.3.6.3 or 8.3.8.3, as applicable.

b) Verification of overload releases

– for test sequence IV

For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.6.2 and 8.3.6.7, the single pole tests specified in 8.3.5.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

– for the combined test sequence

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For the purpose of verifying the correct operation of the overload releases in accordance with 8.3.8.2, the single pole test specified in 8.3.5.2 shall be replaced by two-pole tests made on all possible combinations of phase poles in turn.

For the purpose of verifying the correct operation of overload releases in accordance with 8.3.8.7, the test specified in 8.3.3.8 shall be carried out using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 8.3.6 or 8.3.8, as applicable, verification of the residual current tripping device shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.4 Integrally fused circuit-breakers (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 8.3.7.5 and 8.3.7.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 8.3.7.5 and 8.3.7.9 but applicable to two poles.

Following the tests of 8.3.7, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.5 Test sequence VI (combined)

Following the tests of 8.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.3 Additional test sequences

Additional test sequences shall be performed on CBRs in accordance with Table B.5.

Table B.5 – Additional test sequences

Sequences	Test	Subclause
B I	Verification of the operating characteristics	B.8.2
	Verification of dielectric properties	B.8.3
	Verification of the operation of the test device at the limits of rated voltage	B.8.4
	Verification of the limiting value of the non-operating current under over-current conditions	B.8.5
	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Additional verifications for CBRs of types A and B	B.8.7
	Additional verifications for CBRs of type B	B.8.8
	Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1	B.8.9
	Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.2	B.8.10
B II	Verification of the residual short-circuit making and breaking capacity ($I_{\Delta m}$)	B.8.11
B III	Verification of the effects of environmental conditions	B.8.12
B IV	Verification of electromagnetic compatibility	B.8.13
	Immunity tests	B.8.13.1
	Emission tests	B.8.13.2

For CBRs having variants with different number of poles, tests shall be carried out on the variant with the greatest number of poles. For a variant where there is no construction break

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from the tested variant, no additional tests are required. If the variants' construction is not identical to the variant tested, then those variants shall also be tested.

One sample shall be tested for each of the test sequences B I, B II and B III.

For test sequence B IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

B.8.2 Verification of the operating characteristics

B.8.2.1 Test circuit

The CBR shall be installed as in normal use.

The test circuit shall be in accordance with Figure B.1.

B.8.2.2 Test voltage for CBRs functionally independent of line voltage

Tests may be carried out at any convenient voltage.

B.8.2.3 Test voltage for CBRs functionally dependent on line voltage

Tests shall be carried out at the following values of voltage applied to the relevant terminals:

– 0,85 times the minimum rated voltage for the tests specified in B.8.2.4 and B.8.2.5.2;
– 1,1 times the maximum rated voltage for the tests specified in B.8.2.5.3.

For CBRs having functions which do not depend on line voltage, tests of those functions may be carried out at any convenient voltage.

CBRs with more than one rated frequency or a range of rated frequencies shall be tested in each case at the highest and lowest rated frequency. However, for CBRs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover the requirements.

For tests where the poles are loaded with rated current or above (see for example B.8.2.5.3, B.8.7.2.3, B.8.8.8.2 and B.8.8.9), for practical reasons, it is acceptable to use a sample where the voltage pick-up conductors have been separated from the phase poles, to allow the use of a low-power source for the loading with current. The details of the modification shall be agreed between the manufacturer and the testing station, and shall be stated in the test report.

B.8.2.4 Off-load test at 20 °C ± 5 °C

B.8.2.4.1 General

The connections being as in Figure B.1, the CBR shall perform the tests of B.8.2.4.2, B.8.2.4.3 and B.8.2.4.4 and also, where applicable, B.8.2.4.5, all made on one pole only chosen at random. Each test shall comprise three measurements or verifications, as applicable.

Unless otherwise specified, for CBRs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the lowest and highest settings, and at one intermediate setting.

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B.8.2.4.2 Verification of the correct operation in the case of a steady increase of the residual current

For CBRs with adjustable time delays, the tests shall be performed at the lowest setting. The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$ so as to attain the value $I_{\Delta n}$ in approximately 30 s, the tripping current being measured each time. The three measured values shall be greater than $I_{\Delta no}$ and less than or equal to $I_{\Delta n}$.

B.8.2.4.3 Verification of the correct operation in the case of closing on residual current

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or the specific settings of the residual operating current if applicable, see B.8.2.4), and the switches S_1 and S_2 being closed, the CBR is closed onto the circuit so as to simulate service conditions as closely as possible. The break time measurement test shall be repeated three times.

No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

B.8.2.4.4 Verification of the correct operation in the case of sudden appearance of residual current

The test circuit being calibrated at each of the values of the residual operating current I_{Δ} specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable, and the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing switch S_2.

The CBR shall trip during each test.

Three measurements of the break time are made at each value of I_{Δ}. No value shall exceed the relevant limiting value.

B.8.2.4.5 Verification of the limiting non-actuating time of CBRs of the time-delayed type

The test circuit being calibrated at the value of 2 $I_{\Delta n}$, the switch S_1 and the CBR being in the closed position, the residual current is established by closing the switch S_2 and applied for a time equal to the limiting non-actuating time declared by the manufacturer, in accordance with B.4.2.4.2.1.

During each of the three verifications, the CBR shall not trip. If the CBR has an adjustable residual operating current setting and/or an adjustable time delay, the test shall be made, as applicable, at the lowest setting of residual operating current and at the maximum setting of time delay.

B.8.2.5 Tests at the temperature limits

B.8.2.5.1 General

NOTE The upper temperature limit can be the reference temperature.

The temperature limits of this subclause may be extended by agreement between manufacturer and user, in which case tests shall be performed at the agreed temperature limits.

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B.8.2.5.2 Off-load test at –5 °C

The CBR shall be placed in a chamber having a stabilized internal temperature within the limits of –7 °C and –5 °C. After reaching thermal steady-state conditions, the CBR is submitted to the tests of B.8.2.4.4 and, if applicable, B.8.2.4.5.

B.8.2.5.3 On-load test at the reference temperature or at +40 °C

The CBR, connected in accordance with Figure B.1, shall be placed in a chamber having a stabilized internal temperature equal to the reference temperature (see 4.7.3) or, in the absence of a reference temperature, equal to 40 °C ± 2 °C. A load current equal to I_n (not indicated on Figure B.1) shall be applied on all phase poles.

After reaching thermal steady-state conditions, the CBR shall be submitted to the tests of B.8.2.4.4 and, where applicable, B.8.2.4.5.

B.8.3 Verification of dielectric properties

CBRs shall comply with 8.3.3.3.

B.8.4 Verification of the operation of the test device at the limits of rated voltage

The verification consists of the following tests:

a) The CBR being supplied with a voltage equal to 1,1 times the highest rated voltage, the test device shall be momentarily actuated 25 times, the CBR being closed again before each operation.

b) Test a) shall be then repeated at 0,85 times the lowest rated voltage, the test device being actuated 3 times instead of 25 times.

c) The CBR being in the closed position and supplied with a voltage equal to 1,1 times the highest rated voltage, the test device shall be actuated and held in the actuated position for 5 s.

For these tests:

– in the case of CBRs with identified line and load terminals, the supply connections shall be in accordance with the marking;

– in the case of CBRs with unidentified line and load terminals, the supply shall be connected to each set of terminals in turn, or alternatively to both sets of terminals simultaneously.

At each test, the CBR shall operate.

For CBRs having an adjustable residual operating current:

– the lowest setting shall be used for tests a) and c);

– the highest setting shall be used for test b).

For CBRs having an adjustable time delay, the test shall be made at the maximum setting of the time-delay.

NOTE The verification of the endurance of the test device is considered to be covered by the tests of B.8.1.2.1.

B.8.5 Verification of the limiting value of the non-operating current under over-current conditions

The test shall be carried out with a single-phase load, the connections being made in accordance with Figure B.2.

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The impedance Z shall be adjusted so as to let a current equal to the lower of the following two values flow in the circuit:

– 6 I_n;
– 80 % of the maximum short-circuit release current setting.

NOTE 1 For the purpose of this current adjustment, the CBR D (see Figure B.2) can be replaced by connections of negligible impedance.

For CBRs with an adjustable residual current setting, the test shall be made at the lowest setting.

CBRs functionally independent of line voltage are tested at any convenient voltage.

CBRs functionally dependent on line voltage are supplied on the line side with their rated voltage (or, if relevant, with a voltage having any value within the range of rated voltages).

The test shall be made at a power factor of 0,5.

The switch S_1, being open, shall be closed and reopened after 2 s. The test shall be repeated three times for each possible combination of the current paths, the interval between successive closing operations being at least 1 min.

The CBR shall not trip.

NOTE 2 The time of 2 s can be reduced (but to not less than the minimum break time) to avoid the risk of tripping by action of the overload release(s) of the CBR.

B.8.6 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

B.8.6.1 General

For CBRs with adjustable time delays (see B.3.3.2.2), the time delay shall be set at minimum.

B.8.6.2 Verification of resistance to unwanted tripping in the case of loading of the network capacitance

The CBR shall be tested using a surge current generator capable of delivering a damped oscillatory current as shown in Figure B.4.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.5.

One pole of the CBR chosen at random shall be subjected to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be approximately 30 s. The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

- peak value: 200 A $^{+10}_{0}$ %;
- virtual front time: 0,5 µs ± 30 %;
- period of the following oscillatory wave: 10 µs ± 20 %;
- each successive peak: about 60 % of the preceding peak.

During the tests the CBR shall not trip.

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B.8.6.3 Verification of resistance to unwanted tripping in the case of flashover without follow-on current

The CBR shall be tested using a surge current generator capable of delivering an 8/20 µs surge current wave, without reverse polarity, as shown in Figure B.6.

An example of the circuit diagram for the connection of the CBR is shown in Figure B.7

One pole of the CBR, chosen at random, shall be submitted to 10 applications of each of the surge currents listed below. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications of surge current shall be approximately 30 s.

The current impulse shall be measured by appropriate means and adjusted, using an additional sample CBR of the same type (see B.3.4), to meet the following requirements:

– peak value: 250 A $^{+10}_{0}$ %, with no tripping and

– 3 000 A $^{+10}_{0}$ %, with tripping allowed;

– virtual front time (T_1): 8 µs ± 10 %;

– virtual time to half value (T_2): 20 µs ± 10 %.

B.8.6.4 Verification after the tests

After the tests of B.8.6.2 and B.8.6.3, the operation of the CBR shall be verified in accordance with B.8.2.4.4, with one measurement of break time, at $I_{\Delta n}$ only.

B.8.7 Additional verifications for CBRs of types A and B

B.8.7.1 Test conditions

The test conditions of B.8 and B.8.2.1, B.8.2.2 and B.8.2.3 apply, except that the test circuits shall be those shown in Figure B.8 and Figure B.9, as applicable.

B.8.7.2 Verifications

B.8.7.2.1 Verification of the correct operation in the case of a continuous rise of residual pulsating direct current

The test circuit shall be according to Figure B.8. In the case of a CBR with an adjustable time delay (see B.3.3.2.2), the time delay shall be set to minimum.

The auxiliary switches S_1 and S_2 and the CBR D shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the CBR shall be tested at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S_3.

At every test, the current, starting from zero, shall be steadily increased at an approximate rate of:

– 1,4 $I_{\Delta n}$ / 30 s for CBRs of $I_{\Delta n}$ ≥ 0,030 A;

– 2 $I_{\Delta n}$ / 30 s for CBRs of $I_{\Delta n}$ < 0,030 A.

The tripping current shall be in accordance with Table B.6.

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Table B.6 – Tripping current range for CBRs in the case of an earth fault comprising a d.c. component

Angle α	Tripping current A	
	Lower limit	Upper limit
0° 90° 135°	0,35 $I_{\Delta n}$ 0,25 $I_{\Delta n}$ 0,11 $I_{\Delta n}$	2 $I_{\Delta n}$ for $I_{\Delta n}$ < 0,030 A or 1,4 $I_{\Delta n}$ for $I_{\Delta n}$ ≥ 0,030 A

B.8.7.2.2 Verification of the correct operation in the case of a suddenly appearing residual pulsating direct current

The test shall be performed according to Figure B.8.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the CBR being in the closed position, the residual current is suddenly established by the closing switch S_2.

NOTE In the case of a CBR functionally dependent on line voltage, classified according to B.3.1.2.2, the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the CBR. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the CBR under test and S_2 being previously closed.

Four measurements are made at each value of test current at a current delay angle α = 0°, two with the auxiliary switch in position I and two in position II.

For CBRs with $I_{\Delta n}$ ≥ 0,030 A, the test shall be carried out at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 1,4.

For CBRs with $I_{\Delta n}$ < 0,030 A, the test shall be carried out at each value of $I_{\Delta n}$ specified in Table B.1, multiplied by the factor 2.

No value shall exceed the specified limiting values (see B.7.2.9).

B.8.7.2.3 Verification of the correct operation with load at the reference temperature

The tests of B.8.7.2.1 and B.8.7.2.2 shall be repeated, the pole under test and one other pole of the CBR being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure B.8.

B.8.7.2.4 Verification of the correct operation in the case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

This test need not be applied to CBRs of type B since it is covered by the test of B.8.8.5.

The CBR shall be tested according to Figure B.9, with a half-wave rectified residual current (current delay angle α = 0°) superimposed by a smooth direct current of 0,006 A.

Each pole of the CBR shall be tested in turn, twice at each of the positions I and II.

For CBRs of $I_{\Delta n}$ ≥ 0,030 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 1,4 $I_{\Delta n}$ / 30 s, tripping shall occur before the current exceeds a value of 1,4 $I_{\Delta n}$ + 0,006 A.

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For CBRs of $I_{\Delta n}$ < 0,030 A, the half-wave current, starting from zero, being steadily increased at an approximate rate of 2 $I_{\Delta n}$ / 30 s, tripping shall occur before the current exceeds a value of 2 $I_{\Delta n}$ + 0,006 A.

B.8.8 Additional verifications for CBRs of type B

B.8.8.1 Verification of the correct operation in the case of a steady increase of composite residual current

The operation of the CBR shall be verified with a composite residual current in accordance with Table B.7. The test set up shall comply with Figure B.14.

The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from the value given in Table B.7, so as to attain the upper limit of residual operating current given in Table B.8 within approximately 30 s.

The ratio of the different frequencies shall be maintained from the initial value up to the operating value.

The test shall be repeated three times through one pole chosen at random. Operating values shall be within the limits of Table B.8.

The test frequency has a tolerance of ± 2 %.

Table B.7 – Composite test current definition and starting current value

Frequency component values of composite starting current			Resulting composite current starting value (r.m.s.)
I at rated frequency	I 1 kHz	I F motor (10 Hz)	I_Δ
0,138 $I_{\Delta n}$	0,138 $I_{\Delta n}$	0,035 $I_{\Delta n}$	0,2 $I_{\Delta n}$
NOTE 1 $I_{\Delta n}$ corresponds to the rated residual operating current of the device at the rated frequency. NOTE 2 For the test purposes, the values of 10 Hz and 1 kHz have been used for the output and clock frequency, respectively, representing the most severe condition.			

Table B.8 – Operating current range for composite residual current

Operating current (r.m.s.)	
Lower limit	Upper limit
0,5 $I_{\Delta n}$	1,4 $I_{\Delta n}$

B.8.8.2 Verification of the correct operation in the case of sudden appearance of composite residual current

Tests are carried out to verify the break time of the CBR, the test current being calibrated at 5 times the upper limit value given in Table B.8.

The test shall be performed according to Figure B.14.

The switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

Three measurements of the break time are made.

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For non-time-delayed type CBRs, the break times shall be less than 0,04 s.

For time-delayed type the break time shall comply with Table B.2 or the value declared by the manufacturer for 5 $I_{\Delta n}$, as applicable.

Time-delayed CBRs shall additionally be tested to verify the non-actuating time, the test current being suddenly established by closing the switch S_2 for a duration of 0,06 s or the value of the non-actuating time declared by the manufacturer, as applicable, with a tolerance of $^{0}_{-5}$ %.

Three tests are made, at an interval of at least 1 min. The CBR shall not trip during any of the tests.

B.8.8.3 Verification of the correct operation in the case of residual sinusoidal alternating currents up to 1 000 Hz

The test shall be performed according to Figure B.14.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of residual operating current given in Table B.9 within approximately 30 s, the tripping current being measured.

   The test shall be carried out on one pole taken at random at each frequency given in Table B.9 and repeated five times; the tripping values shall be in compliance with Table B.9.

b) The test circuit being calibrated at the residual operating current corresponding to 1 000 Hz according to Table B.9, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

   Two measurements of the break time are made on one pole chosen at random.

   For the non-time-delay type, the maximum break time shall not exceed 0,3 s.

   For the time delayed type, the maximum break time shall not exceed 0,5 s or the value declared by the manufacturer for $I_{\Delta n}$, as applicable.

Table B.9 – Operating limits for residual sinusoidal alternating currents up to 1 000 Hz

Frequency Hz	Residual non-operating current	Residual operating current
150	0,5 $I_{\Delta n}$	2,4 $I_{\Delta n}$ [a]
400	0,5 $I_{\Delta n}$	6 $I_{\Delta n}$ [a]
1 000	$I_{\Delta n}$	14 $I_{\Delta n}$ [a b]

[a] These values are derived from ventricular fibrillation protection according to IEC 60479-1 in combination with the frequency factor for ventricular fibrillation according to IEC 60479-2.

[b] IEC 60479-2 gives no factors for frequencies above 1 kHz.

B.8.8.4 Verification of the correct operation in the case of a residual alternating current superimposed by a residual smooth direct current

The test shall be performed according to Figure B.10.

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The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current shall be applied through one pole chosen at random and shall be adjusted to 0,4 $I_{\Delta n}$ or 10 mA, whichever is the highest value.

The residual alternating current of the rated frequency shall be applied to another pole chosen at random and is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

The CBR shall be tested twice at each of the positions I and II of S_3.

The alternating tripping current shall be equal or lower than $I_{\Delta n}$.

B.8.8.5 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a residual smooth direct current

The test shall be performed in accordance with Figure B.9.

The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current shall be applied through one pole chosen at random and shall be adjusted to 0,4 $I_{\Delta n}$ or 10 mA whichever is the highest value.

The residual pulsating direct current shall be applied to another pole chosen at random with a current delay angle α of 0° and is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≥ 0,030 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ < 0,030 A within approximately 30 s, the tripping current being measured.

The CBR shall be tested twice at each of the positions I and II of S_3.

The CBR shall trip before the residual pulsating direct current exceeds a value of 1,4 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≥ 0,030 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ < 0,030 A.

B.8.8.6 Verification of the correct operation in the case of residual direct currents that can result from rectifying circuits supplied from two phases

The test shall be performed in accordance with Figure B.11.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 2 $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

   The CBR shall be connected to the test circuit at two line terminals chosen at random.

   The CBR shall be tested five times at each of the positions I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

   With the CBR connected at two line terminals chosen at random, five measurements of the break time are made at each of these values of residual current given in Table B.1 at each position I and II of S_3.

   The break times shall be in compliance with B.4.2.4.

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B.8.8.7 Verification of the correct operation in the case of residual direct currents that can result from rectifying circuits supplied from three phases

This test does not apply to 2-pole type B CBRs.

The test shall be performed in accordance with Figure B.12.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, so as to attain the value of 2 $I_{\Delta n}$ within approximately 30 s, the tripping current being measured.

   The CBR shall be tested five times at each of the positions I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2.

   Five measurements of the break time are made at each of these values of residual current at each position I and II of S_3.

   The break times shall be in compliance with B.4.2.4.

B.8.8.8 Verification of the correct operation in the case of residual smooth direct current

B.8.8.8.1 Verification of the correct operation in the case of residual smooth direct current without load

The test shall be performed according to Figure B.13.

The test is run in two steps; a first step a) to verify the tripping current, and a second step b) to verify the break time.

a) The switches S_1 and S_2 and the CBR being in the closed position, the residual smooth direct current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, trying to attain the value of 2 $I_{\Delta n}$ within 30 s, the tripping current being measured.

   One pole of the CBR, chosen at random and exemplified in Figure B.14, shall be tested twice at each position I and II of S_3.

   The CBR shall trip within the limits of 0,5 $I_{\Delta n}$ to 2 $I_{\Delta n}$.

b) The test circuit being successively calibrated at 2 times each residual operating current value given in Table B.1, the switch S_1 and the CBR being in the closed position, the residual current is suddenly established by closing the switch S_2. The switch S_3 shall be in position I or II chosen at random.

   Two measurements of the break time are made on one pole chosen at random at each test current.

   The break times shall be in compliance with B.4.2.4.

B.8.8.8.2 Verification of the correct operation in the case of residual smooth direct current with load

The test of B.8.8.8.1 a) shall be repeated, the CBR being loaded with the rated current as in normal service for a sufficient time so as to reach thermal steady-state conditions.

NOTE The loading with rated current is not shown in Figure B.13.

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B.8.8.9 Tests at the temperature limits

The CBR shall perform the tests specified in B.8.8.6 b), B.8.8.7 b) and B.8.8.8.1 b) under the following conditions, successively:

a) ambient air temperature: −5 °C, without load;

b) ambient air temperature: +40 °C, the CBR having been previously loaded with the rated current, until it has attained thermal steady-state conditions. In practice these conditions are reached when the variation of temperature-rise, measured at one of the main terminals, does not exceed 1 K per hour. The loading of the main circuit may be carried out at reduced voltage but the power supply of the residual current function, for a CBR functionally dependent on line voltage, shall be connected to its maximum rated voltage – see also B.8.2.3.

In the case of CBRs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

B.8.8.10 Test of three- and four-pole CBRs supplied between two phase poles only

Additionally, the tests of B.8.8.3 and B.8.8.8.1 are repeated, the CBR being supplied between two phase poles chosen at random.

B.8.9 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1

B.8.9.1 General

For CBRs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For CBRs with an adjustable time delay, the test shall be carried out at any one of the time-delay settings.

B.8.9.2 Determination of the limiting value of the line voltage

A voltage equal to the rated voltage shall be applied to the line terminals of the CBR and shall be then progressively lowered to zero over a time period corresponding to the longer of the two values given hereinafter until automatic opening occurs:

– about 30 s;

– a period long enough with respect to the delayed opening of the CBR, if any (see B.7.2.12).

The corresponding voltage is measured.

Three measurements are made. All the values shall be less than 0,85 times the minimum rated voltage of the CBR.

Following these measurements, it shall be verified that the CBR trips when a residual current equal to $I_{\Delta n}$ is applied, the applied voltage being just above the highest value measured.

It shall then be verified that, for any value of voltage less than the lowest value measured, it is not possible to close the CBR by manual operating means.

B.8.9.3 Verification of the automatic opening in the case of failure of the line voltage

The CBR being closed, a voltage equal to its rated voltage, or, in the case of a range of rated voltages, any one of the rated voltages shall be applied to its line terminals. The voltage is

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then switched off. The CBR shall trip. The time interval between the switching off and the opening of the main contacts is measured.

Three measurements are made:

a) for CBRs opening without a delay (see B.7.2.12), no value shall exceed 0,2 s;

b) for CBRs opening with a delay, the maximum and minimum values shall be situated within the range stated by the manufacturer.

B.8.10 Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.2

B.8.10.1 General

For CBRs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For CBRs having an adjustable time-delay, the test shall be carried out at any one of the time-delay settings.

B.8.10.2 Case of loss of one phase in a 3-phase system (for 3-pole and 4-pole CBRs)

The CBR shall be connected according to Figure B.3 and shall be supplied on the line side at 0,85 times the rated voltage, or, in the case of a range of rated voltages, at 0,85 times the lowest value of rated voltage.

One phase is then switched off by opening switch S_4; the CBR shall be then submitted to the test of B.8.2.4.4. The switch S_4 being closed again, a further test shall be made by opening switch S_5; the CBR shall be then submitted to the test of B.8.2.4.4.

This test procedure shall be repeated by connecting the adjustable resistor *R* to each of the other two phases in turn.

B.8.10.3 Case of voltage drop due to an overcurrent resulting from a low-impedance fault to earth

The CBR shall be connected in accordance with Figure B.3 and shall be supplied on the line side with the rated voltage or, in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_1. The CBR shall not trip.

S_1 is then reclosed and the voltage is reduced as follows:

a) for CBRs for use with a three-phase supply: to 70 % of the lowest rated voltage;

b) for CBRs for use with a single-phase supply: to 85 V applied as follows:

- for single-pole and two-pole CBRs: between poles;
- for three-pole and four-pole CBRs, declared as suitable for use with a single-phase supply (see B.5): between each combination of two poles, connected according to the manufacturer's specifications.

NOTE For the purpose of this annex, a single-pole CBR is a device with one overcurrent protected pole and an uninterrupted neutral (two current paths).

A current of value $I_{\Delta n}$ shall be then applied to a) and/or b), as applicable. The CBR shall trip.

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B.8.11 Verification of the residual short-circuit making and breaking capacity

B.8.11.1 General

This test is intended to verify the ability of the CBR to make, to carry for a specified time and to break residual short-circuit currents.

B.8.11.2 Test conditions

The CBR shall be tested according to the general test conditions specified in 8.3.2.6, using Figure 9 of IEC 60947-1:2007/AMD1:2010, but connected in such a manner that the short-circuit current is a residual current.

The test shall be carried out at phase to neutral voltage on one pole only which shall not be the neutral pole. The current paths that do not have to carry the residual short-circuit current are connected to the supply voltage at their line terminals.

Where applicable, the CBR shall be adjusted at the lowest setting of residual operating current and at the maximum setting of the time delay.

If the CBR has more than one value of I_{cu}, each one having a corresponding value of $I_{\Delta m}$, the test shall be made at the maximum value of $I_{\Delta m}$, at the corresponding phase-to-neutral voltage.

B.8.11.3 Test procedure

The sequence of operations to be performed is:

O – *t* – CO

B.8.11.4 Conditions of the CBR after test

Following the test of B.8.11.3, the CBR shall comply with the following requirements:

a) the CBR shall show no damage likely to impair its further use and shall be capable, without maintenance, of:
   - withstanding a voltage equal to twice its maximum rated operational voltage, under the conditions of 8.3.3.4.1 item 4) of IEC 60947-1:2007. For the purposes of this document, circuits incorporating solid-state devices shall be disconnected for the tests;
   - making and breaking its rated current at its maximum rated operational voltage.

b) the CBR shall be capable of performing satisfactorily the tests specified in B.8.2.4.4, but at a value of 1,25 $I_{\Delta n}$ and without measurement of break time. The test shall be made on any one pole, taken at random.

   If the CBR has an adjustable residual operating current, the test shall be made at the lowest setting, at a current of a value of 1,25 times that setting.

c) where applicable, the CBR shall also be submitted to the test of B.8.2.4.5.

d) CBRs functionally dependent on line voltage shall also satisfy the tests of B.8.9 or B.8.10, as applicable.

e) CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

B.8.12 Verification of the effects of environmental conditions

The test shall be carried out in accordance with IEC 60068-2-30.

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The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be:

– 6 for $I_{\Delta n} > 1$ A;

– 28 for $I_{\Delta n} \leq 1$ A.

The 28 cycles test shall be applied to CBRs having multiple settings of residual operating current when one of the possible settings is ≤ 1 A.

At the end of the cycles, the CBR shall be capable of complying with the tests of B.8.2.4.4, but with a residual test current of 1,25 $I_{\Delta n}$ and without measurement of break time. Only one verification needs to be carried out.

Where applicable, the CBR shall also comply with the test of B.8.2.4.5. Only one verification needs to be carried out.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

B.8.13 Verification of electromagnetic compatibility

B.8.13.1 Immunity tests

B.8.13.1.1 General

Annex J applies with the following additional requirements.

For CBRs with adjustable settings of residual operating current and/or time delay, the tests shall be carried out at the lowest of these settings.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

The tests are performed without load current but with the residual current, when specified.

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1, with the following specifications:

Performance criterion A:

For step 1, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, shall correctly indicate the status.

For step 2, the CBR shall trip at each test frequency, when loaded at 1,25 $I_{\Delta n}$; the dwell time at each frequency shall be not less than the maximum break time specified for $I_{\Delta n}$ in B.4.2.4.1 or B.4.2.4.2, as applicable.

Following these tests, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, in accordance with B.8.2.4.4, but at $I_{\Delta n}$ only.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

Performance criterion B:

During the test, the CBR shall not trip, when loaded at 0,3 $I_{\Delta n}$ on one pole chosen at random; the monitoring functions, if any, may be temporarily affected.

Following the test, the correct operation of the CBR shall be verified in the case of the sudden appearance of a residual current, according to B.8.2.4.4, but at $I_{\Delta n}$ only.

CBRs of type B shall trip with a test current of 2,5 $I_{\Delta n}$ with smooth direct current. One test only is made without measurement of break time.

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B.8.13.1.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

The test set-up shall be in accordance with Figure J.1 and Figure J.3.

Performance criterion B applies except that during the test, the CBR can trip. If this is the case, a further test shall be carried out at the immediate lower level, and the CBR shall not trip.

B.8.13.1.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test set-up shall be in accordance with Figure J.4.

The test connections shall be in accordance with Figure 5 or Figure 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer's instructions for installation. The type of cable used shall be stated in the test report.

Performance criterion A applies.

B.8.13.1.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figure 4 of IEC 61000-4-4:2012.

The test set-up shall be in accordance with Figure J.5 for testing power lines and with Figure J.6 for testing signal lines, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

B.8.13.1.5 Surges

Annex J applies, in particular J.2.5.

The test conditions of 7.2 of IEC 61000-4-5:2014 apply.

For convenience, the mounting specified in B.8.13.1.4 may be used but the use of the ground reference plane is optional.

The test connections shall be in accordance with Figures 6, 7, 8 or 9 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

B.8.13.1.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

Performance criterion A applies.

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B.8.13.2 Emission tests

B.8.13.2.1 General

Annex J applies with the following additional requirements.

The CBR shall be supplied at the rated operational voltage, or, in the case of a range of rated operational voltages, at any convenient voltage within this range.

Tests shall be carried out without load current and without residual current.

B.8.13.2.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

B.8.13.2.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

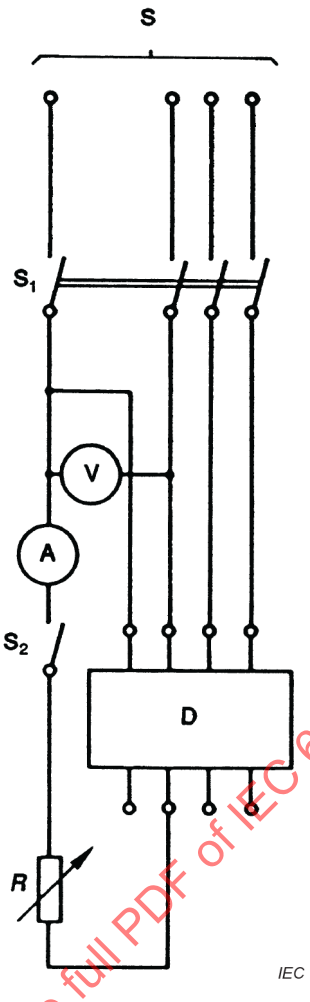
B.8.14 Test for variations or interruptions of voltage and for voltage dips

NOTE For definition of voltage dips, see IEC 61000-4-11.

The relevant tests of B.8.8 and B.8.10 are considered adequate to cover the EMC requirements.

No additional tests are therefore required.

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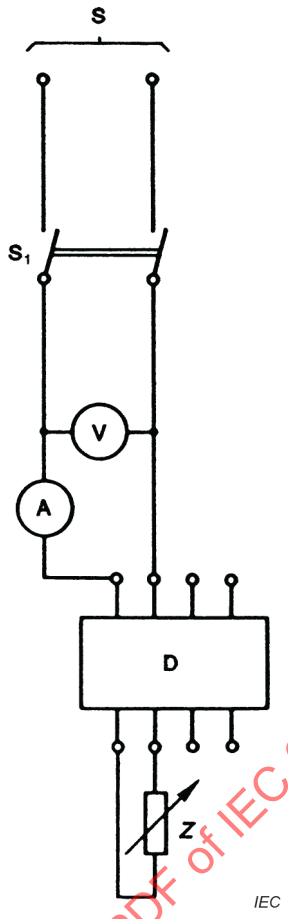


Key

S supply
V voltmeter
A ammeter
S_1 multi-pole switch
S_2 single-pole switch
D CBR under test
R adjustable resistor

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)

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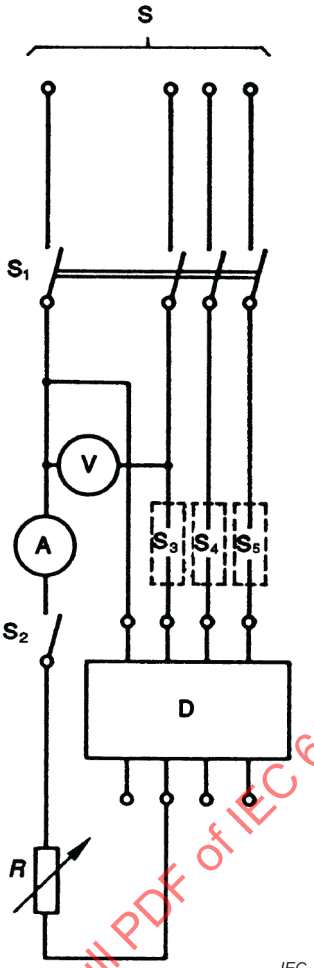


Key

S	supply	D	CBR under test
V	voltmeter	*Z*	adjustable impedance
A	ammeter	S_1	two-pole switch

Figure B.2 – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5)

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Key

S	supply	S_2	single-pole switch
V	voltmeter	S_3, S_4, S_5	single-pole switches opening one phase in turn
A	ammeter	D	CBR under test
S_1	multi-pole switch	*R*	adjustable resistor

Figure B.3 – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.10)

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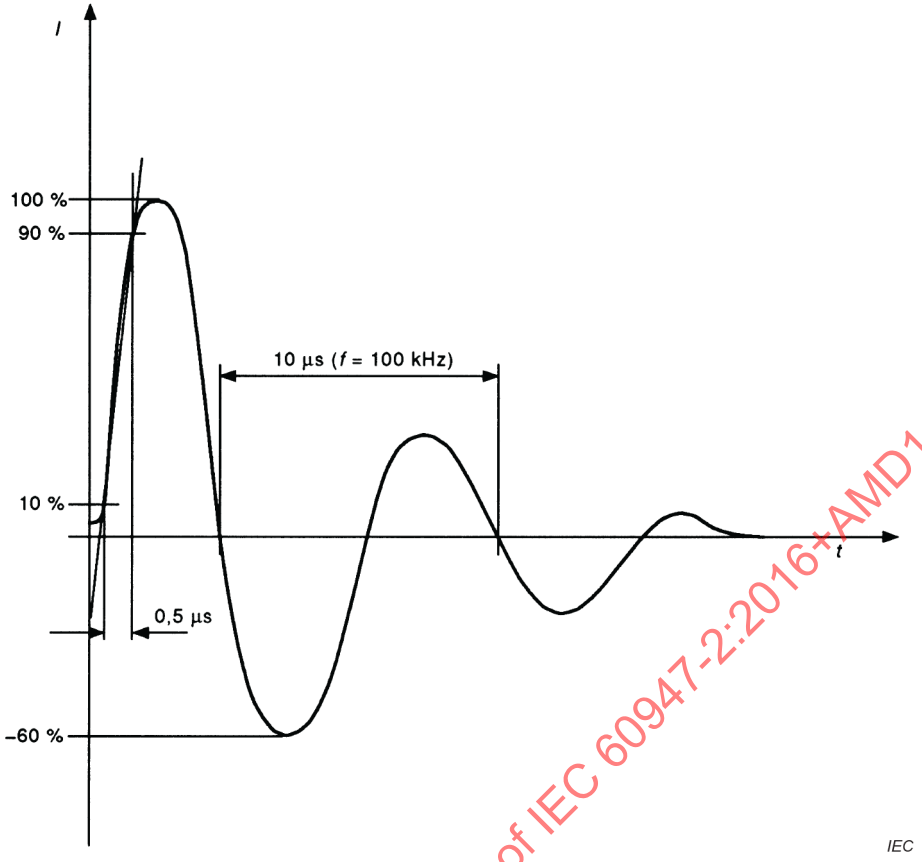
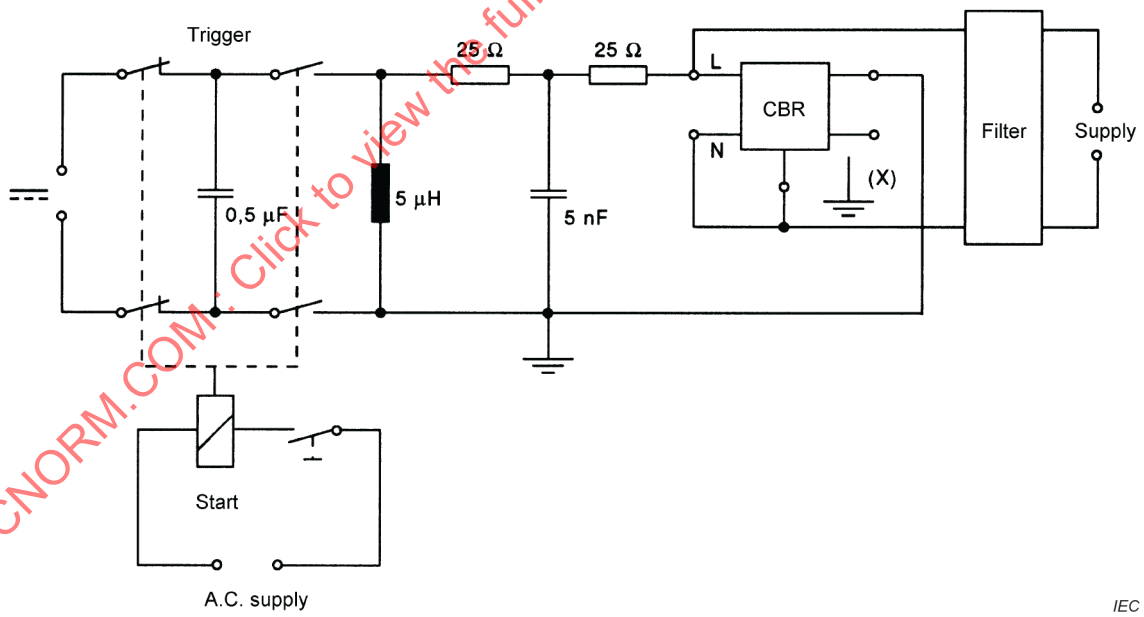


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

The circuit component values are given for guidance only and may require adjustment to comply with the wave shape requirements of Figure B.4.

Figure B.5 – Example of a test circuit for the verification of resistance to unwanted tripping

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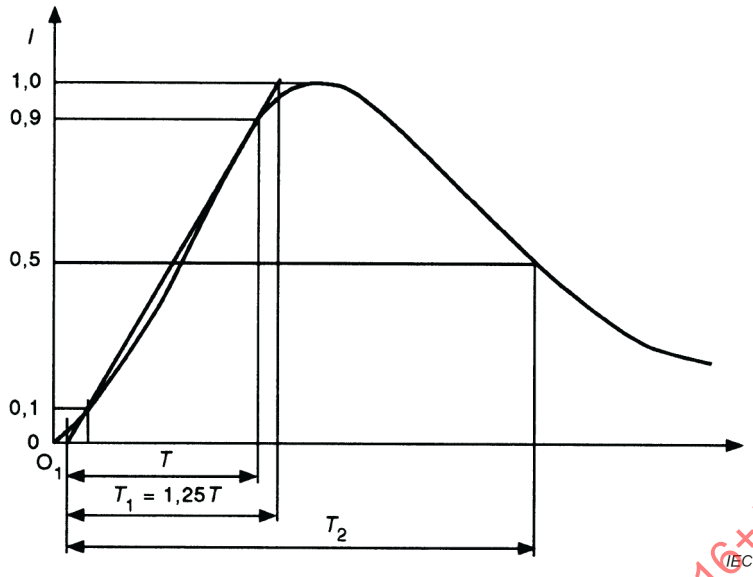
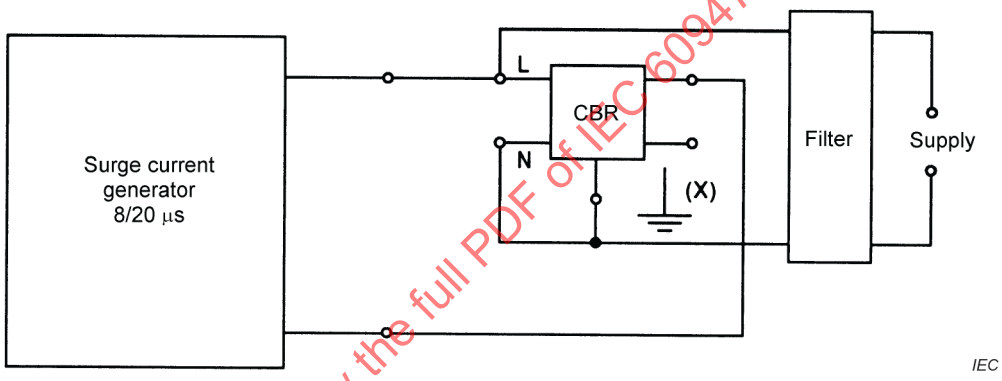


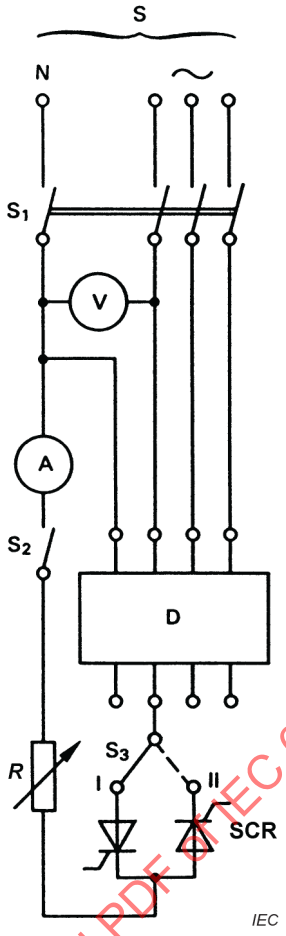
Figure B.6 – Surge current wave 8/20 µs



(X) Earthing terminal, if provided, to be connected to the neutral terminal, if so marked or in the absence of such marking, to any phase terminal.

Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in the case of flashover without follow-on current

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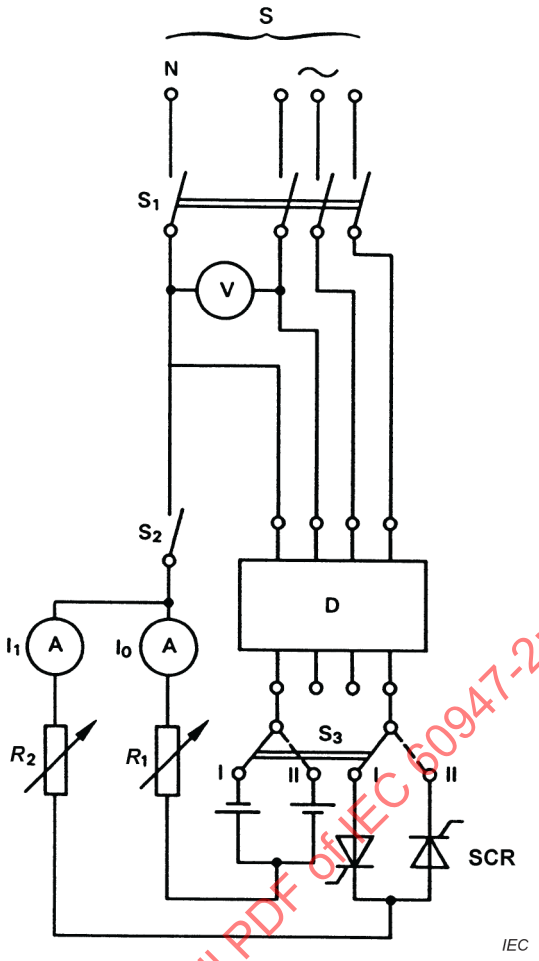


Key

S	supply	*R*	adjustable resistor
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch
SCR	thyristors		

Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents

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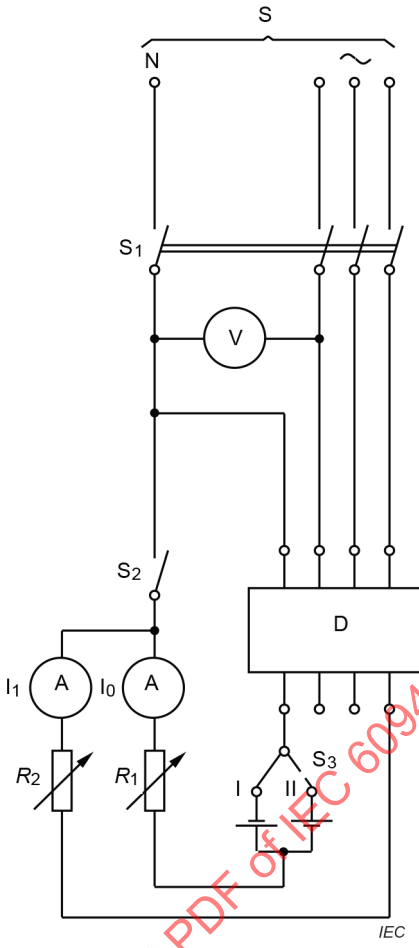


Key

S	supply	R_1, R_2	adjustable resistors
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch
SCR	thyristors		

Figure B.9 – Test circuit for residual pulsating direct current superimposed by a smooth direct current

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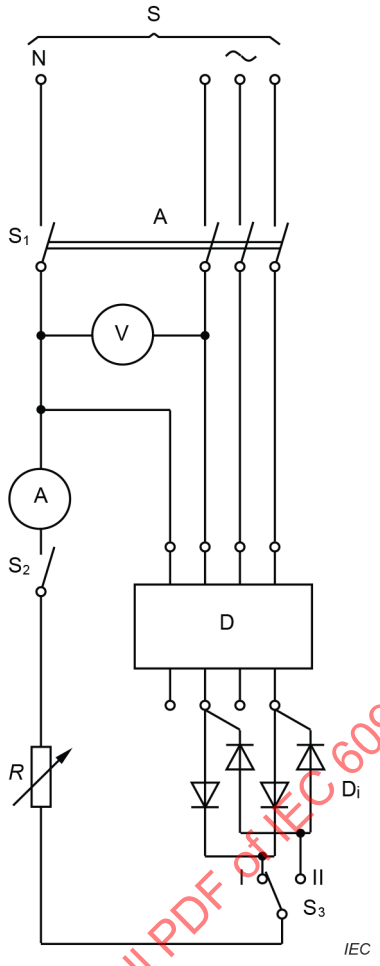


Key

S	supply	R_1, R_2	adjustable resistors
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch

Figure B.10 – Test circuit for residual alternating currents superimposed by a smooth direct current

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Key

Point A supply by 2 phases chosen at random

S supply

V voltmeter

A ammeter

D CBR under test

D_i diodes

R adjustable resistor

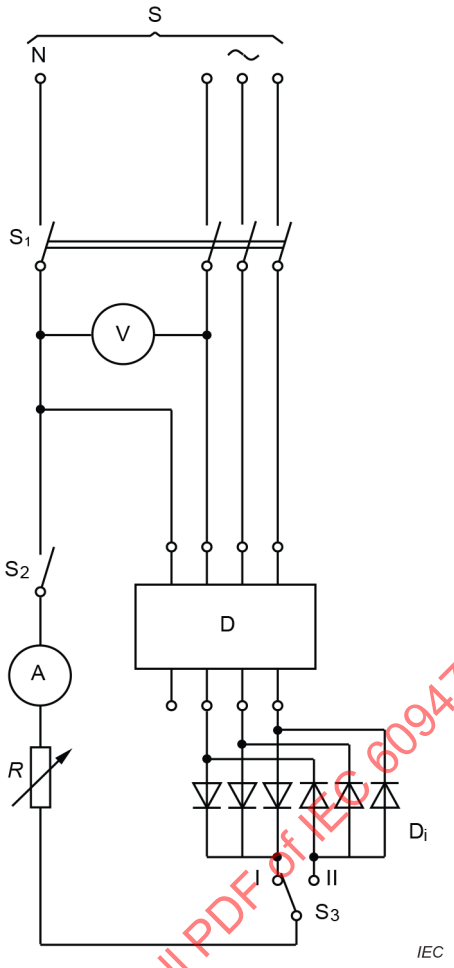
S_1 multi-pole switch

S_2 single-pole switch

S_3 two-way switch

Figure B.11 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from two phases

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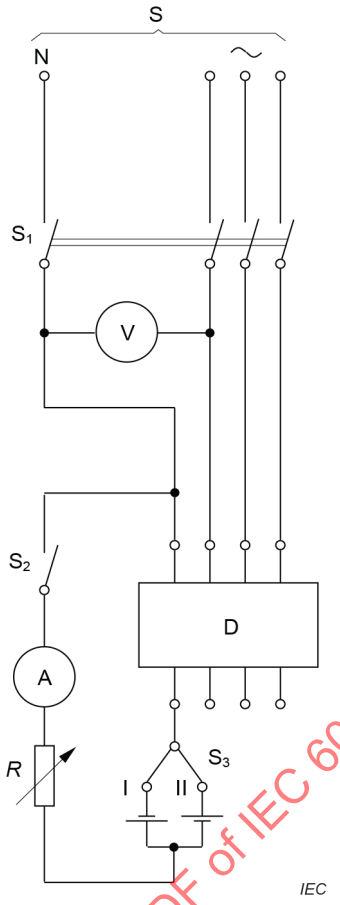


Key

S	supply	*R*	adjustable resistors
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch
D_i	diodes		

Figure B.12 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from three phases

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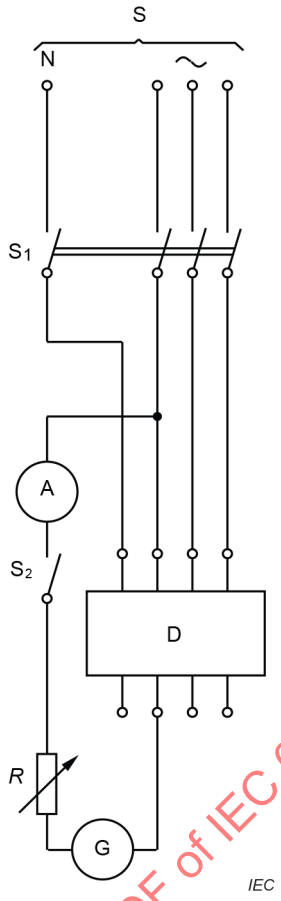


Key

S	supply	*R*	adjustable resistor
V	voltmeter	S_1	multi-pole switch
A	ammeter	S_2	single-pole switch
D	CBR under test	S_3	two-way switch

Figure B.13 – Test circuit for residual smooth direct current

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Key

S	supply	*R*	adjustable resistor
A	ammeter	S_1	multi-pole switch
D	CBR under test	S_2	single-pole switch
G	generator		

Figure B.14 – Test circuit for composite residual currents, and residual sinusoidal alternating current up to 1 000 Hz

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Annex C
(normative)

Individual pole short-circuit test sequence

C.1 General

This test sequence applies to multipole circuit-breakers intended for use on phase-earthed systems and identified in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit breaking capacity (I_{su})	C.2
Verification of dielectric withstand	C.3
Verification of overload releases	C.4

C.2 Test of individual pole short-circuit breaking capacity

A short-circuit test is made under the general conditions of 8.3.2, with a value of prospective current I_{su} equal to 25 % of the ultimate rated short-circuit breaking capacity I_{cu}.

NOTE Values higher than 25 % of I_{cu} can be tested and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on phase-earthed systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with
Table 10. The power factor shall be according to Table 11, appropriate to the test current.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

$$O - t - CO$$

and shall be made on each pole separately, in turn.

C.3 Verification of dielectric withstand

Following the test according to Clause C.2, the dielectric withstand shall be verified according to 8.3.5.4.

C.4 Verification of overload releases

Following the test according to Clause C.3, the operation of the overload releases shall be verified in accordance with 8.3.5.5.

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Annex D
(normative)

Additional requirements for circuit-breakers intended for connection of aluminium conductors

D.1 General

The purpose of this annex is to address the need of connecting aluminium conductors, as an alternative to copper, by specifying appropriate tests and other requirements while maintaining safety and performance.

This annex specifies the requirements for use of solid and stranded aluminium conductors and aluminium busbars with circuit-breakers within the scope of this document, as follows:

a) aluminium test conductors that are equivalent to, and can be used as an alternative to, the copper conductors given in Tables 9, 10 and 11 of IEC 60947-1:2007 for terminals as depicted in Figures D.1, D.2, D.3, D.4, D.5 (including busbars) and D.6 of IEC 60947-1:2007/AMD1:2010 or similar clamping units;

b) method for verifying the means of connecting aluminium conductors, as used in normal service for terminals as depicted in Figures D.1, D.2, D.3, D.4 and D.6 of IEC 60947-1:2007/AMD1:2010 or similar clamping units. Testing of lug terminals depicted in Figure D.5 of IEC 60947-1:2007/AMD1:2010 is covered by IEC 61238-1 (all parts).

Terminals covered by this annex may be an integral part of the circuit-breaker or may be provided as an accessory.

NOTE The term “terminal” used in this annex is equivalent to the term “clamping unit” used in IEC 60947-1.

Screwless terminals as depicted in Figure D.7 of IEC 60947-1:2007/AMD1:2010 and connection of flexible aluminium conductors are not covered by this annex. Terminating aluminium and copper conductors in one clamping unit at the same time is not covered by this annex.

D.2 Terms and definitions

Clause 2 applies with the following additions:

D.2.1
reference conductor
continuous length of the same type and size conductor as that used in the terminal unit under test and connected in the same series circuit to enable the reference temperature and, if required, reference resistance to be determined

D.2.2
equalizer
arrangement used in the test loop to ensure an equipotential point and a uniform current density in a stranded conductor, without adversely affecting the temperature of the conductor(s)

D.2.3
stability factor
Sf
measure of temperature stability of a terminal unit during the current cycling test

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Note 1 to entry: Definitions for different types of terminals can be found in Annex D of IEC 60947-1:2007/AMD1:2010.

D.3 Classification

Clause 3 applies with the following additions:

According to the conductor connection:

– for use with copper only, or
– for use with either copper or aluminium, or
– for use with aluminium only.

D.4 Characteristics

Clause 4 applies.

D.5 Product information

D.5.1 Nature of information

Subclause 5.1 applies.

D.5.2 Marking

Subclause 5.2 applies with the following addition:

The suitability of the terminal for use with aluminium conductors only (Al) or copper and aluminium conductors (Cu/Al) shall be marked on the circuit-breaker or the circuit-breaker terminals, or in the manufacturer's literature, as appropriate. When the marking is on the circuit-breaker or terminals, the abbreviations ‘AL’ and ‘CU/AL’ may also be used.

If the rated current of the terminals is lower than the rated current of the circuit-breaker, it shall be marked on the circuit-breaker or the circuit-breaker terminals, or in the manufacturer literature, as appropriate.

D.5.3 Instructions for installation, operation and maintenance

Subclause 5.3 applies with the following addition:

Manufacturer’s literature may include recommended installation practices, such as:

(i) after removal of the conductor insulation and prior to termination, the aluminium conductor shall be cleaned by wire brushing the aluminium followed by application of an anti-oxidant compound to limit oxidization of the aluminium;

(ii) treatment of the busbar at the termination points, by wire brushing the aluminium followed by the application of an anti-oxidant compound or by use of an electrically conductive coating such as tin.;

(iii) use of specific hardware for termination.

D.6 Normal service, mounting and transport conditions

Clause 6 applies.

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D.7 Constructional and performance requirements

Clause 7 applies with the following addition:

Clamping units intended for use with aluminum conductor(s) shall be treated with an electrically conductive coating such as tin, or alternative means that will inhibit corrosion due to difference in electrochemical series.

The manufacturer shall specify whether the terminals are suitable for stranded, solid or both types of conductors. Performance tests shall be carried out with all conductor types specified by the manufacturer.

Aluminium conductor sizes for different currents given in Table D.7 and in Table D.8 correspond to copper conductor sizes given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007.

NOTE The conductor sizes have been derived from IEC 60898-1, UL 486E and IS 13947-1.

D.8 Tests

D.8.1 General

The tests shall be performed with aluminium conductors having a cross-section as given in Table D.7, corresponding to the lower of either the rated current of the device or the rated current of the terminals.

The aluminium cable to be used shall be single core, with black insulation, with electrical and mechanical properties complying with IEC 60228.

Class A aluminium alloy grade 1350, as referred to in IEC 61545, shall be used for testing purposes.

NOTE 1 Grade 1350 aluminium is generally considered to be the worst case and its use for testing is consistent with UL 486 standards.

NOTE 2 Requirements for terminals acceptable for use with sector-shaped conductors are under consideration.

The following tests shall be carried out on either the product or the terminal specimen to be used in the final product as specified in Table D.1 below. Each specimen comprises a pair of terminals and a conductor part.

Table D.1 – List of tests for terminal connections[a] with aluminium cables

Test		Subclause	Tested on	Number of units
Current cycling test		D.8.2	Terminal specimen	4 specimens
Mechanical properties of terminals	Flexion test	D.8.3.1	Circuit-breaker	As per 8.2.4.3 of IEC 60947-1: 2007/AMD1:2010
	Pull-out test	D.8.3.2		As per 8.2.4.4 of IEC 60947-1: 2007/AMD1:2010
Insertion test		D.8.4	Circuit-breaker	As per 8.2.4.5 of IEC 60947-1: 2007/AMD1:2010

[a] Type of connection limited to clamping unit types of Figure D.1, D.2, D.3, D.4 and D.6 as per Annex D of IEC 60947-1:2007/AMD1:2010.

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D.8.2 Current cycling test

D.8.2.1 General

The intent of this test is to verify the stability of the terminal by comparing the temperature performance with that of the reference conductor under current cycling conditions. This test shall be carried out on terminals alone, not on the circuit-breaker.

D.8.2.2 Preparation

The test shall be performed on four specimens, each one made by a couple of terminals, assembled in a manner which represents the use of the terminals in the circuit-breaker. The terminals that have been removed from the product shall be attached to conducting parts of the same cross-section, shape, metal and finish as those on which they are mounted on the product. The conducting part shall not exceed:

(i) three times the length of the terminal,

(ii) the width of the terminal

as shown in Figure D.2. The terminals shall be fixed to the conductor part(s) in the same manner (position, torque, etc.) as on the product.

To avoid excessive oxidation of the conductor and ensure proper connection, a sufficient length of insulation shall be removed immediately prior (without any intentional delay) to installation.

The wire shall be positioned so that 6 mm to 13 mm of the bare conductor is exposed between the wire-entry face of the terminal and the beginning of the insulation. There shall be no mechanical removal or chemical treatment of any oxide on the surface of the conductor entering the terminal, unless it is explicitly required by the manufacturer's instructions, in which case it shall be stated in the test report.

D.8.2.3 Test arrangement

The general arrangement of the samples shall be as shown in Figure D.1.

The test shall be carried out with conductors in accordance with Table D.7, specifying the equivalent cross-section of aluminium conductors.

The length of the test conductor from the point of entry to the terminal specimens to the equalizer shall be as in Table D.2.

Test conductors shall be connected in series with a reference conductor of the same cross-section. The length of the reference conductor shall be approximately twice the length of the test conductor.

90 % of the value of torque stated by the manufacturer or, if not stated, selected in Table 4 of IEC 60947-1:2007/AMD2:2014, shall be used to connect the aluminium cables to the terminal specimens.

Each free-end of the test and reference conductor(s) not connected to a terminal specimen shall be welded or brazed to a short length of equalizer of cross section not greater than that given in Table D.3. All strands of the conductor shall be welded or brazed to make an electrical connection with the equalizer. As an alternative, tool-applied compression type terminations without welding or brazing may be used for the equalizer if acceptable to the manufacturer.

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For a wiring terminal of a piece of equipment intended for paralleling conductors, the hole spacing pattern in the equalizer shall be identical to the hole spacing pattern of the wiring terminal of the piece of equipment.

The distance between the test and reference conductors shall be at least 150 mm.

The test specimen shall be suspended either horizontally or vertically in free air by supporting the equalizer by non-conductive supports so as to minimize the tensile load on the terminals. Thermal barriers shall be installed mid- way between the conductors and shall extend 25 mm ± 5 mm widthways and 150 mm ± 10 mm lengthways beyond the terminals (see Figure D.1). Thermal barriers are not required provided the specimens are separated by at least 450 mm. The specimens shall be located at least 600 mm from the floor, wall or ceiling.

The test specimens shall be located in a substantially vibration-free and draught-free environment and at an ambient air temperature between 15 °C and 35 °C. Once the test is started, the maximum permissible variation is ± 4 K provided the range limitation is not exceeded.

D.8.2.4 Temperature measurements

Temperature measurements are made by means of thermocouples. Positioning of the thermocouples shall not damage the terminal or the reference conductor.

NOTE 1 Drilling of a small hole and subsequent fastening of the thermocouple is an acceptable method, provided that the performance is not affected and that it is agreed by the manufacturer.

For the measurement of the terminal temperature, the thermocouple shall be located on the conductor entry side of the terminal, close to the contact interface.

For the measurement of the temperature of the reference conductor, the thermocouple shall be located midway between the ends of the conductor, and under its insulation.

The ambient air temperature shall be measured with two thermocouples in such a manner as to achieve an average and stable reading in the vicinity of the test loop without undue external influence. The thermocouples shall be located in a horizontal plane intersecting the specimens, at a minimum distance of 600 mm from them.

NOTE 2 A satisfactory method for achieving a stable measurement is, for example, to attach the thermocouple to unplated copper plates of approximately 50 mm × 50 mm, having a thickness of between 6 mm and 10 mm.

D.8.2.5 Test method

The test loop shall be subjected to 500 cycles; each cycle consists of an on-period and an off-period as specified, starting at the test current value given in Table D.4.

The on-time shall be the time it takes for the test specimen terminal to reach stable temperatures. The off-time shall be the time it takes to reach room temperature. These times shall be determined in the first 25 cycles of operation. A test specimen terminal has attained a stable temperature when three readings, taken at not less than 10-minutes intervals, show no more than a 2 °C variation between any two of the readings. The time to temperature stabilization is the first of three readings indicating stable temperature.

Forced-air cooling may be employed to reduce the off-time, if acceptable to the manufacturer. In that case, it shall be applied to the entire test loop and the resulting temperature of the forced air shall not be lower than the ambient air temperature.

Alternatively, for terminals with single conductors, the on- and/or off-times in Table D.4 may be used.

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Near the end of each on-period of the first 24 cycles, the temperature of each terminal shall have attained a minimum of 105 °C. When necessary, the current shall be adjusted to achieve this condition.

If the manufacturer demonstrates that the maximum temperature-rise of the terminals is less than 70 K, the 105 °C temperature may be reduced to this temperature-rise plus 35 °C.This shall be demonstrated by means of a temperature-rise test, in accordance with the general conditions of 8.3.3.3.4 of IEC 60947-1:2007, carried out on the device at the lower of either the rated current of the device or the rated current of the terminals. This test shall be carried out on a new device equipped with the terminals under consideration and the aluminium conductors as specified in Table D.7. The maximum temperature-rise of all terminals shall be used for determining the target temperature for the current cycling test.

At the 25th cycle, the test current shall be adjusted for the last time and the corresponding temperature, when stabilized at the final load current,shall be recorded as the first measurement. There shall be no further adjustment of the test current for the remainder of the test.

Temperatures shall additionally be recorded after approximately 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles. The temperature shall be measured during the last 5 min of the on-period. If the size of the set of test specimens or the speed of the data acquisition system is such that not all measurements can be completed within 5 min, the on-period shall be extended as necessary to complete all the measurements.

D.8.2.6 Acceptance criteria

The evaluation of the performance is based on both the limit of terminal temperature-rise and the temperature variation (stability factor) during the test.

The stability factor *S*f for each of the 11 temperature measurements shall be determined as follows:

– calculate the temperature deviation *d* for the 11 individual temperature measurements by subtracting the associated reference conductor temperature from the terminal temperature;
– calculate the average temperature deviation *D* from the 11 values of *d*;
– calculate *S*f = *d* − *D* for each value of *d*.

See example of stability factor calculation in Table D.5.

NOTE The value of *d* is positive if the terminal temperature is higher than that of the reference conductor and negative if it is lower.

For each terminal:

– the temperature-rise shall not exceed 125 K, and
– the stability factor *S*f shall not exceed ±10 K.

As this is an accelerated aging test, the insulation can be damaged owing to high temperatures, but this is not considered as a failure of the test.

D.8.3 Mechanical properties of terminals

D.8.3.1 Flexion test

Subclause 8.2.4.3 of IEC 60947-1:2007/AMD1:2010 applies with the following modification:

The test values shall be in accordance with Table D.6.

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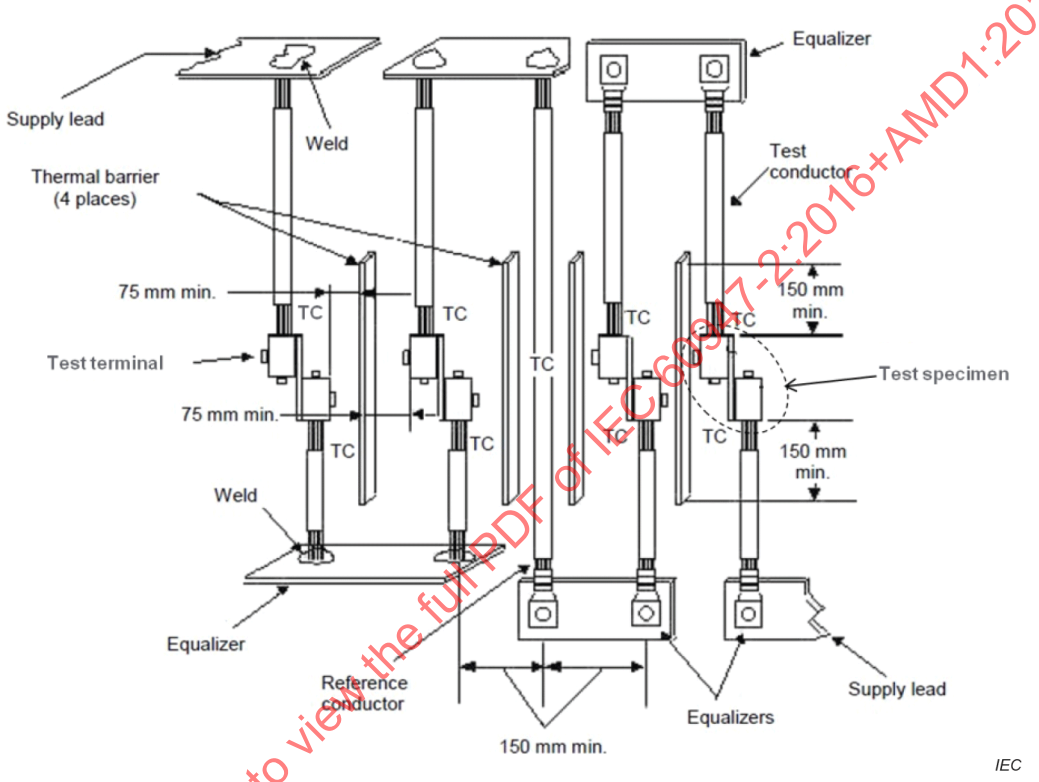
D.8.3.2 Pull-out test

Subclause 8.2.4.4 of IEC 60947-1:2007/AMD1:2010 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.4 Test for insertability of unprepared round aluminium conductors having the maximum cross-section

Subclause 8.2.4.5 of IEC 60947-1:2007/AMD1:2010 applies. Table 7 of IEC 60947-1:2007 applies, except the column relating to flexible conductors.



Key

TC thermocouple

Figure D.1 – General test arrangement

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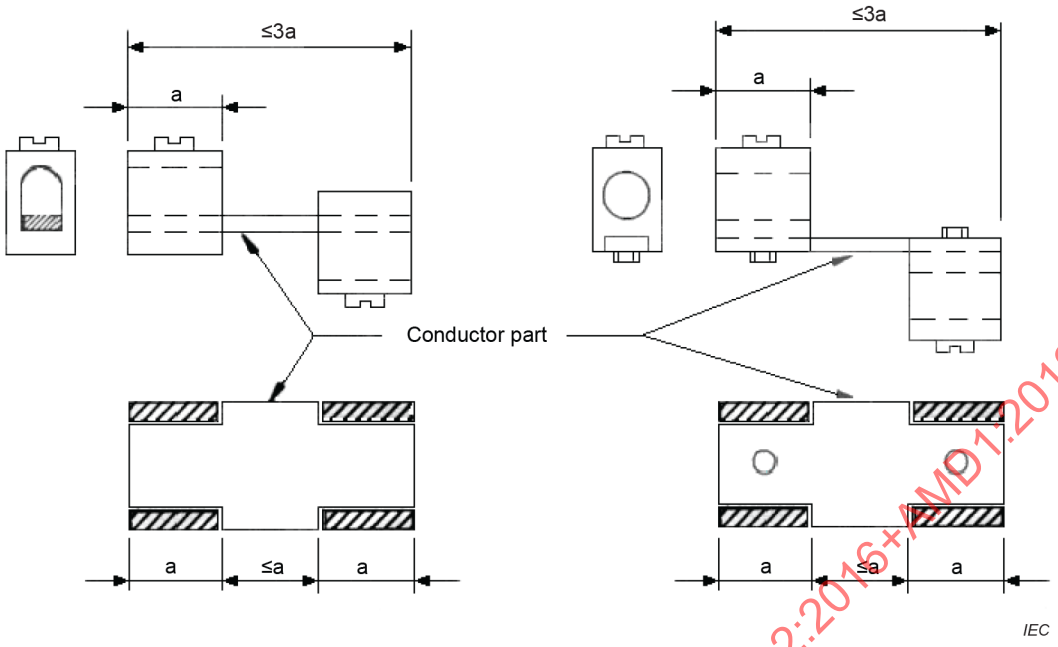


Figure D.2 – Mounting of terminals for the current cycling test

Table D.2 – Conductor length for the current cycling test as per conductor cross-section

Conductor cross-section		Minimum conductor length
mm^2	AWG/kcmil	mm
0 to 10	30 to 8	200
16 to 25	6 to 3	300
35 to 240	2 to 500	460
Larger than 240	Larger than 500	660

Table D.3 – Equalizer dimensions

Range of test current A		Maximum dimensions[a] (thickness × width)			
		Copper		Aluminium	
>	≤	mm	in	mm	in
0	50	3,2 × 12,7	1/8 × 1/2	3,2 × 12,7	1/8 × 1/2
50	125	3,2 × 25	1/8 × 1	3,2 × 32	1/8 × 1-1/4
125	225	3,2 × 48	1/8 × 1-7/8	3,2 × 57	1/8 × 2-1/4
225	400	6,4 × 38	1/4 × 1-1/2	6,4 × 50	1/4 × 2
400	600	6,4 × 50	1/4 × 2	6,4 × 76	1/4 × 3
600	800	6,4 × 76	1/4 × 3	6,4 × 102	1/4 × 4
800	1 000	6,4 × 102	1/4 × 4	9,5 × 89	3/8 × 3-1/2
1 000	1 400	12,7 × 76	1/2 × 3	12,7 × 89	1/2 × 3-1/2
1 400	2 000	12,7 × 102	1/2 × 4	12,7 × 127	1/2 × 5

[a] The equivalence between mm and inches is only approximative; it is acceptable for the equalizer to comply with either millimeters or inches columns. Other dimensions may be used provided the current density for the upper limit of the test current (2nd column) exceeds 1,16 A/mm^2 (750 A/in^2) for an aluminium equalizer or 1,55 A/mm^2 (1 000 A/in^2) for a copper equalizer.

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Table D.4 – Starting test current for the current cycling test

Cable(s) size			Test current	Duration of on- and off-periods
Number	mm^2	AWG/kcmil	A	hours
1	4	12	33	1
1	6	10	45	1
1	10	8	60	1
1	16	6	85	1
1	25	4	110	1
1	35	2	150	1
1	50	0	200	1
1	70	00	230	1
1	95	000	270	1
1	120	250 kcmil	350	1,5
1	150	300 kcmil	390	1,5
1	185	350 kcmil	435	1,5
1	240	500 kcmil	540	2
2	120	250 kcmil	460	-
2	150	300 kcmil	510	-
2	240	500 kcmil	707	-
2	300	600 kcmil	907	-
3	240	500 kcmil	1 060	-

Table D.5 – Example of stability factor calculation

Temperature measurement	Cycle Number	Temperatures		Temperature deviation d = a) – b)	Stability factor $S_f = d - D$ [a]
		a) Terminal [b]	b) Reference conductor		
		°C	°C	K	K
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	-0,82
4	100	76	77	-1	-1,82
5	125	77	77	0	-0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	-1	-1,82
10	425	77	79	-2	-2,82
11	500	81	78	3	2,18

[a] Average temperature deviation $D = \frac{\sum d}{\text{number of measurements}} = \frac{9}{11} = 0{,}82$.

[b] Example applies to a cable terminal with a maximum temperature of 75 °C.

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Table D.6 – Test values for flexion and pull-out test for cables

Conductor cross-section		Diameter of the bushing hole [a, b]	Height H[a]	Mass	Pulling force
mm^2	AWG/kcmil	mm	mm	kg	N
4	12	9,5	280	0,7	44
6	10	9,5	280	0,7	44
10	8	9,5	280	1,4	44
16	6	12,7	300	4	124
25	4	12,7	300	4,5	160
-	3	14,3	320	5,9	187
35	2	14,3	320	6,8	222
-	1	15,8	343	8,6	271
50	0	15,8	343	9,5	320
70	00	19,1	368	10,4	347
95	000	19,1	368	13,6	432
-	0000	19,1	368	13,6	516
120	250 kcmil	22,2	406	13,6	516
150	300 kcmil	22,2	406	15,4	516
185	350 kcmil	25,4	432	17,2	574
-	400 kcmil	25,4	432	17,2	574
240	500 kcmil	28,6	464	20,4	685
300	600 kcmil	28,6	464	20,4	685

NOTE Table D.6 is based on UL 486E.

[a] Tolerances for height *H* is ± 15 mm, tolerance for diameter of the bushing hole is ± 2 mm.

[b] If the bushing hole diameter is not large enough to accommodate the conductor without binding, a bushing having the next larger hole size may be used.

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Table D.7 – Test aluminium cables for test currents up to 800 A[a,d]

Range of test current A		Cable size		
>	≤	Number	mm²	AWG/kcmil
0	8	1	c	c
8	12	1	c	c
12	15	1	4[b]	12[b]
15	20	1	4[b]	12[b]
20	25	1	6[b]	10[b]
25	32	1	10	8
32	50	1	16	6
50	65	1	25	4
65	85	1	35	2
85	100	1	50	0
100	115	1	50	0
115	130	1	70	00
130	150	1	95	000
150	175	1	120	250 kcmil
175	200	1	150	300 kcmil
200	225	1	150	300 kcmil
225	250	1	185	350 kcmil
250	275	1	240	500 kcmil
275	300	2	120	250 kcmil
300	350	2	120	250 kcmil
350	400	2	150	300 kcmil
400	500	2	240	500 kcmil
500	630	2	300	600 kcmil
630	800	3	240	500 kcmil

[a] See 8.3.3.3.4 of IEC 60947-1:2007.

[b] National regulations may require larger sizes. Aluminium cables with cross-sections lower than 10 mm² are not recommended per IEC 60364-5-52.

[c] Aluminium cables with cross-sections lower than 4 mm² are not recommended.

[d] Test cables for currents above 800 A are under consideration.

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Table D.8 – Test aluminium bars for test currents above 400 A[g] and up to 3 150 A[a, f]

Range of test current A		Aluminium bars[b c d]	
>	≤	Number	Dimensions (mm)
400	500	2	25 × 10
500	630	2	30 × 12
630	800	2	40 × 10
800	1 000	2	50 × 10
1 000	1 250	2	80 × 10
1 250	1 600	2	100 × 10
1 600	2 000	3	100 × 10
2 000	2 500	4	100 × 10
2 500	3 150	4	150 × 10[e]

[a] See 8.3.3.3.4 of IEC 60947-1:2007.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] Bars are assumed to be arranged with their long faces vertically. Arrangements with long faces horizontally may be used if specified by the manufacturer.

[d] Where four bars are used they shall be in two sets of two bars with not more than 100 mm between pair centres.

[e] Dimensions given are recommendations only. Different sizes can be used upon agreement between manufacturer and user.

[f] For rated currents greater than 3 150 A, agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc. This information shall form part of the test report.

[g] Aluminium bars for test currents below or equal to 400 A are under consideration.

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Annex E
(informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex

– "agreement" is used in a very wide sense;

– "user" includes testing stations.

Annex J of IEC 60947-1:2007 applies with regard to clauses and subclauses of this standard, with the following additions:

Clause or subclause number of this standard	Item
4.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 2
7.2.1.2.1	Automatic opening operation other than trip-free operation and by stored energy
Table 10	Setting of overload releases at intermediate values for short-circuit tests
8.3.3.5	Method of temperature-rise tests for four-pole circuit-breakers having a conventional thermal current higher than 63 A
8.3.2.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
8.3.3.2.3, item b)	Test current value for the verification of inverse time/current characteristics
8.3.3.5	To increase the severity of the conditions for testing overload performance
8.3.3.8 8.3.4.6	Permissible delay between the verification of temperature-rise and that of overload relays in test sequences I and II
8.4.3	Calibration of releases other than over-current releases, shunt releases and undervoltage releases
8.5	Special tests – Damp heat, salt mist, vibration and shock
B.8	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.5	Extension of the test ambient temperature limits

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Annex F
(normative)

Additional tests for circuit-breakers with electronic over-current protection

F.1 General

This annex applies to circuit-breakers intended to be installed on a.c. circuits and providing over-current protection by electronic means, incorporated in the circuit-breaker and independent of the line voltage or any auxiliary supply.

The tests verify the performance of the circuit-breaker under the environmental conditions stated in this annex.

Specific tests for electronic means intended for functions other than over-current protection are not covered by this annex. However, the tests of this annex shall be performed to ensure that these electronic means do not impair the performance of the over-current protective functions.

F.2 List of tests

F.2.1 General

Tests specified in this annex are type tests and are supplementary to the tests of Clause 8.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this standard, if relevant.

F.2.2 Electromagnetic compatibility (EMC) tests

F.2.2.1 General

Circuit-breakers with electronic overcurrent protection shall be tested according to Table J.1 and Figure J.3.

F.2.2.2 Performance criteria

The results of immunity tests shall be evaluated on the basis of the performance criteria given in J.2.1 with the following specifications:

Performance criterion A:

For step 1, the circuit-breaker when loaded at 0,9 times the current setting shall not trip and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

For step 2, when loaded at 2,0 times the current setting, the circuit-breaker shall trip within 0,9 times the minimum value and 1,1 times the maximum value of the manufacturer's time current characteristic, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

Performance criterion B:

During the test, the circuit-breaker when loaded at 0,9 times the current setting shall not trip. After the test, the circuit-breaker shall comply with the manufacturer's time current characteristic when loaded at 2,0 times the current setting and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker.

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F.2.3 Suitability for multiple frequencies

The test shall be performed in accordance with F.6.

F.2.4 Dry heat test

The test shall be performed in accordance with F.7.

F.2.5 Damp heat test

The test shall be performed in accordance with F.8.

F.2.6 Temperature variation cycles at a specified rate of change

The test shall be performed in accordance with F.9.

F.3 General test conditions

F.3.1 General

Tests according to this annex may be performed separately from the tests of Clause 8.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

F.3.2 Electromagnetic compatibility tests

For immunity tests (F.4) one circuit-breaker per frame size and per type of current sensor design shall be tested; a change of winding turns is not considered as a different design in this context. In the case of withdrawable circuit-breaker, the device shall be mounted inside the enclosure in accordance with the manufacturer's instructions, the test set-up being modified accordingly.

The current setting I_r shall be adjusted to the minimum value.

Short-time and instantaneous release settings shall each, if applicable, be adjusted to the minimum value but to not less than 2,5 times I_r.

The tests shall be performed with the appropriate test circuit, as specified in the following subclauses, taking into account any phase-loss sensitive features.

For circuit-breakers having electronic overcurrent protection, it may be assumed that the tripping characteristics are the same, whether tests are performed:

– on individual poles of multipole circuit-breakers;
– on two or three phase poles in series;
– by three-phase connection.

NOTE This enables comparisons to be made between test results obtained on different phase pole combinations as required by the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M):

– in the cases of F.4.4, F.4.5 and F.4.6, tests are made on pairs of phase poles for multipole circuit-breakers, to avoid unintentional tripping by residual current;
– in the cases of F.4.1 and F.4.7, tests may be made on any combination of phase poles, as long as unintentional tripping by residual current is avoided.

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F.4 Immunity tests

F.4.1 Harmonic currents

F.4.1.1 General

These tests apply to circuit-breakers for which the electronic current sensing means are stated by the manufacturer to be r.m.s. responsive.

This shall be indicated either by marking “r.m.s.” on the circuit-breaker or given in the manufacturer's literature, or both.

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including the dimensions of the enclosure shall be stated in the test report.

Where applicable, the tests shall be performed at the rated frequency.

NOTE The test currents can be generated by a source of power based on the use of thyristors (see Figure F.1), saturated cores, programmable power supplies, or other appropriate sources.

F.4.1.2 Test currents

The test current waveform shall consist of one of the following two options:

– option a): two waveforms applied successively:
  - a waveform consisting of a fundamental and a third harmonic component;
  - a waveform consisting of a fundamental and a fifth harmonic component.
– option b): a waveform consisting of a fundamental and a third, fifth and seventh harmonic component.

Test currents shall be

– for option a):

  test of the third harmonic and peak factor
  - 72 % of fundamental component ≤ third harmonic ≤ 88 % of fundamental component;
  - peak factor: 2,0 ± 0,2;

  test of the fifth harmonic and peak factor
  - 45 % of fundamental component ≤ fifth harmonic ≤ 55 % of fundamental component;
  - peak factor: 1,9 ± 0,2;
– for option b):

  the test current, for each period, consists of two equal opposite half-waves defined as follows:
  - current conduction time, for each half-wave is ≤ 21 % of the period;
  - peak factor: ≥ 2,1.

NOTE 1 The peak factor is the peak value of the current divided by the r.m.s. value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 This test current for option b) has at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;
– fifth harmonic > 14 %;
– seventh harmonic > 7 %;
– twenty-first harmonic > 1 %.

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Other harmonics can also be present.

NOTE 3 The test current waveform for option b) can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 4 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the r.m.s. values of the composite waveforms.

F.4.1.3 Test procedure

The tests shall be performed on two-phase poles, chosen at random in accordance with item b) of 7.2.1.2.4 carrying the test current at any convenient voltage, connections being in accordance with Figure F.2. For releases with a phase loss sensitive feature, connections shall be made in accordance with Figure F.3 or Figure F.4, as applicable.

Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The duration of the test to verify the immunity to unwanted tripping (at 0,9 times the current setting) shall be 10 times the tripping time, which corresponds to twice the current setting.

F.4.1.4 Test results

Performance criterion A of F.2.2.2 shall apply.

F.4.2 Electrostatic discharges

Annex J, in particular J.2.2, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure J.3.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

The busbar routing shown in Figure F.2, Figure F.3 and Figure F.4 may be varied providing the 0,1 m distances, with a tolerance of $^{+10}_{0}$ %, to the enclosure are maintained. The actual configuration used shall be shown in the test report.

Performance criterion B of F.2.2.2 applies.

F.4.3 Radiated RF electromagnetic fields

Annex J, in particular J.2.3, applies with the following additions.

The test set-up shall be in accordance with Figure F.16 and Figure F.17.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.4 Electrical fast transient/burst (EFT/B)

Annex J, in particular J.2.4, applies with the following additions.

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The test set-up shall be in accordance with Figure F.16 and Figure F.18 for testing power lines and with Figure F.16 and Figure F.19 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.6.

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.7 for the three phase poles in series connection or as shown in Figure F.8 on a phase pole chosen at random for the three-phase connection.

Performance criterion A of F.2.2.2 applies. However, temporary changes to the monitoring functions (e.g. unwanted LED illumination) during the tests are acceptable, in which case the correct functioning of the monitoring shall be verified after the tests. For step 2, the disturbance shall be applied until the circuit-breaker trips.

F.4.5 Surges

Annex J, in particular J.2.5, applies with the following additions.

On a.c. mains ports, the disturbance shall be applied on one phase pole chosen at random, the EUT being supplied from the other two phase poles, in accordance with Figure F.9 (line-to-earth) and Figure F.12 (line-to-line).

For releases which have a phase-loss sensitive feature, the test shall be performed as shown in Figure F.10 (line-to-earth) and Figure F.13 (line-to-line) for the three phase poles in series connection or as shown in Figure F.11 (line-to-earth) and Figure F.14 (line-to-line) on a phase pole chosen at random for the three-phase connection.

Performance criterion B of F.2.2.2 applies.

F.4.6 Conducted disturbances induced by RF fields (common mode)

Annex J, in particular J.2.6, applies with the following additions.

The test set-up shall be in accordance with Figure F.16, Figure F.20 and Figure F.21, Figure F.22 or Figure F.23 for testing power lines and with Figure F.16 for testing signal lines.

On the a.c. mains port, the disturbance shall be applied on one phase pole chosen at random, the circuit-breaker being supplied from the other phase poles, in accordance with Figure F.2.

For releases which have a phase-loss sensitive feature the test circuit shall be in accordance with Figure F.3 or Figure F.4 as applicable.

Performance criterion A of F.2.2.2 applies.

F.4.7 Current dips

F.4.7.1 Test procedure

The EUT shall be tested in free air unless it is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details including the dimensions of the enclosure shall be stated in the test report.

The test circuit shall be in accordance with Figure F.2 on two-phase poles chosen at random. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

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The tests shall be performed with a sinusoidal current at any convenient voltage. The current applied shall be according to Figure F.5 and to Table F.1 below where I_r is the setting current, I_D is the dip test current and T is the period of the sinusoidal current.

The duration of each test shall be between three and four times the maximum tripping time corresponding to twice the current setting or 10 min, whichever is the lower.

Table F.1 – Test parameters for current dips and interruptions

Test No.	I_D	Δt
1	0	0,5 T
2		1 T
3		5 T
4		25 T
5		50 T
6	0,4 I_r	10 T
7		25 T
8		50 T
9	0,7 I_r	10 T
10		25 T
11		50 T

F.4.7.2 Test results

Performance criterion B of F.2.2.2 shall apply, except that the after-test verification is not required.

F.5 Emission tests

F.5.1 Harmonics

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.2 Voltage fluctuations

The electronic control circuits operate at very low power and hence create negligible disturbances; therefore no tests are required.

F.5.3 Conducted RF disturbances (150 kHz to 30 MHz)

Circuit-breakers covered by this annex are independent of line voltage or of any auxiliary supply. Electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to 1 GHz)

Annex J, in particular J.3.3, applies with the following additions.

The test circuit shall be in accordance with Figure F.2. For releases with a phase-loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

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Undervoltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The limits of Table J.3 apply.

F.6 Suitability for multiple frequencies

F.6.1 General

The test verifies the tripping characteristics of circuit-breakers declared as suitable for multiple frequencies. It does not apply to circuit-breakers rated at 50 Hz to 60 Hz only.

F.6.2 Test conditions

The tests shall be performed at each rated frequency or, when a range of rated frequencies is declared, at the lowest and the highest rated frequencies.

F.6.3 Test procedure

Tests shall be performed on any pair of phase-poles chosen at random at any convenient voltage.

The test circuit shall be in accordance with Figure F.2. For releases with a phase loss sensitive feature, the test circuit shall be in accordance with Figure F.3 or Figure F.4, as applicable.

Under-voltage releases, if any, shall either be energized or disabled. All other auxiliaries shall be disconnected during the test.

The short-time and instantaneous trip current settings shall each, if relevant, be adjusted to 2,5 times the current setting. If this setting is not available, the next closest higher setting shall be used.

Tests shall be performed as follows:

a) A current of 0,95 times the conventional non-tripping current (see Table 6) is applied for a time equal to 10 times the tripping time which corresponds to 2,0 times the current setting.

b) Immediately following the test of a), a current of 1,05 times the conventional tripping current (see Table 6) is applied.

c) A further test starting from the cold state is made at 2,0 times the current setting.

F.6.4 Test results

For each test frequency, the overload tripping characteristics shall comply with the following requirements:

– for test a) no tripping shall occur;

– for test b) tripping shall occur within the conventional time (see Table 6);

– for test c) tripping shall occur within 1,1 times the maximum and 0,9 times the minimum values of the manufacturer's stated time-current characteristic.

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F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 7.2.2 at the maximum rated current for a given frame size, on all phase poles, at an ambient temperature of 40 °C. The duration of the test, once temperature equilibrium is reached, shall be 168 h.

The tightening torques to be applied to the terminal screws shall be in accordance with the manufacturer's instructions (see Table 13, item 3.11).

As an alternative, the test may be performed as follows:

– measure and record the highest temperature rise of the air surrounding the electronic components, during the temperature rise verification of test sequence I;
– install the electronic controls in the test chamber;
– supply the electronic controls with their input energizing value;
– adjust the temperature of the test chamber to a value of 40 K above the temperature rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

F.7.2 Test results

The circuit-breaker and the electronic controls shall meet the following requirements:

– no tripping of the circuit-breaker shall occur;
– no operation of the electronic controls which would cause the circuit-breaker to trip shall occur.

F.7.3 Verification of overload releases

Following the test of F.7.1, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.8 Damp heat test

F.8.1 Test procedure

The test shall be performed according to IEC 60068-2-30.

The upper temperature shall be 55 °C ± 2 °C (variant 1) and the number of cycles shall be six.

The test may be performed with only the electronic controls in the test chamber.

F.8.2 Verification of overload releases

Following the test of F.8.1 the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

F.9 Temperature variation cycles at a specified rate of change

F.9.1 Test conditions

Each design of electronic controls shall be submitted to temperature variation cycles in accordance with Figure F.15.

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The rise and fall of temperature during the rate of variation shall be 1 K/min ± 0,2 K/min. The temperature, once reached, shall be maintained for at least 2 h.

The number of cycles shall be 28.

F.9.2 Test procedure

The test shall be carried out according to IEC 60068-2-14.

For these tests, the electronic controls may be mounted inside the circuit-breaker or separately.

The electronic controls shall be energized to simulate service conditions.

Where the electronic controls are mounted inside the circuit-breaker, the main circuit shall not be energized.

F.9.3 Test results

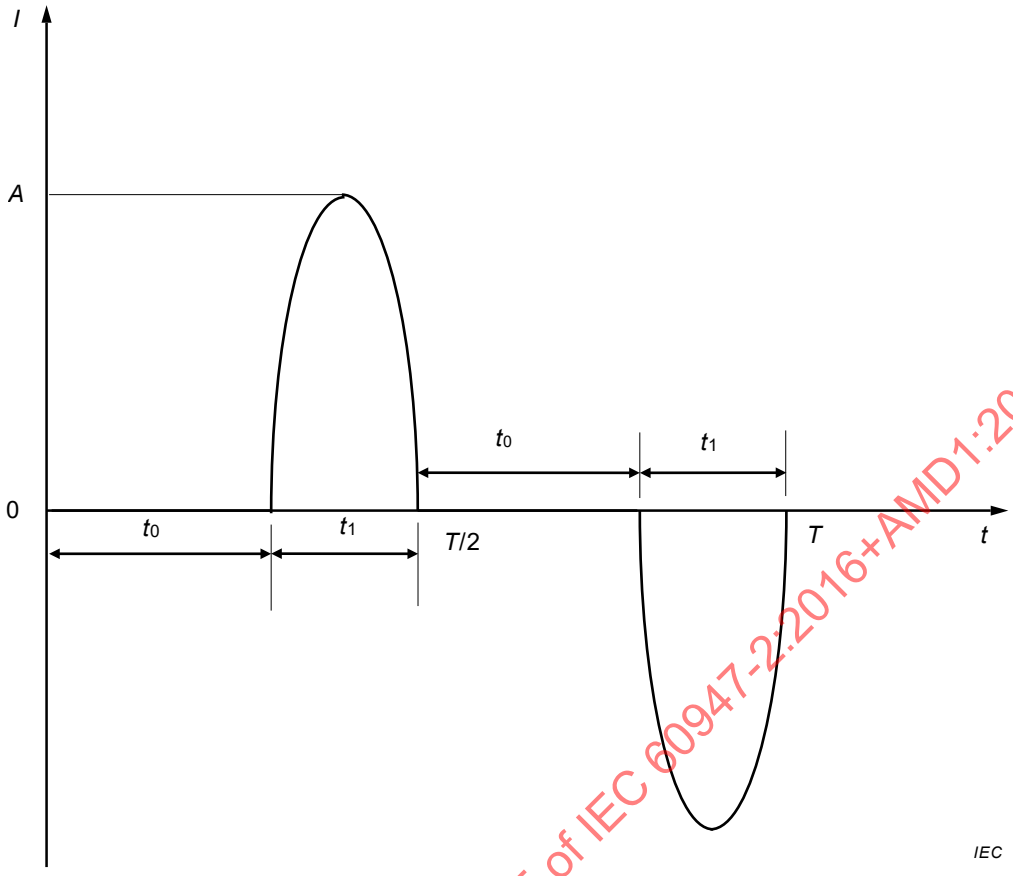
The electronic controls shall meet the following requirement.

No operation of the electronic controls which would cause the circuit-breaker to trip during the 28 cycles shall occur.

F.9.4 Verification of overload releases

Following the test of F.9.2, the operation of the overload releases of the circuit-breaker shall be verified in accordance with 7.2.1.2.4, item b).

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Key

A peak current

T period

t_1 conducting time during each half-cycle

t_0 delay time

$$\text{Peak factor} = \frac{A}{\sqrt{\frac{2}{T}\int_0^{T/2} i^2(t)\,dt}}$$

Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1

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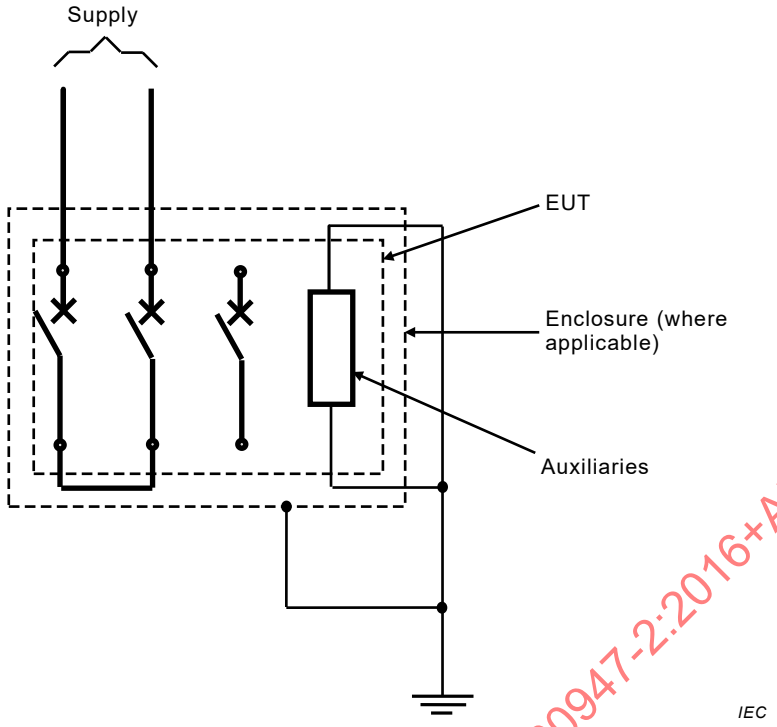


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

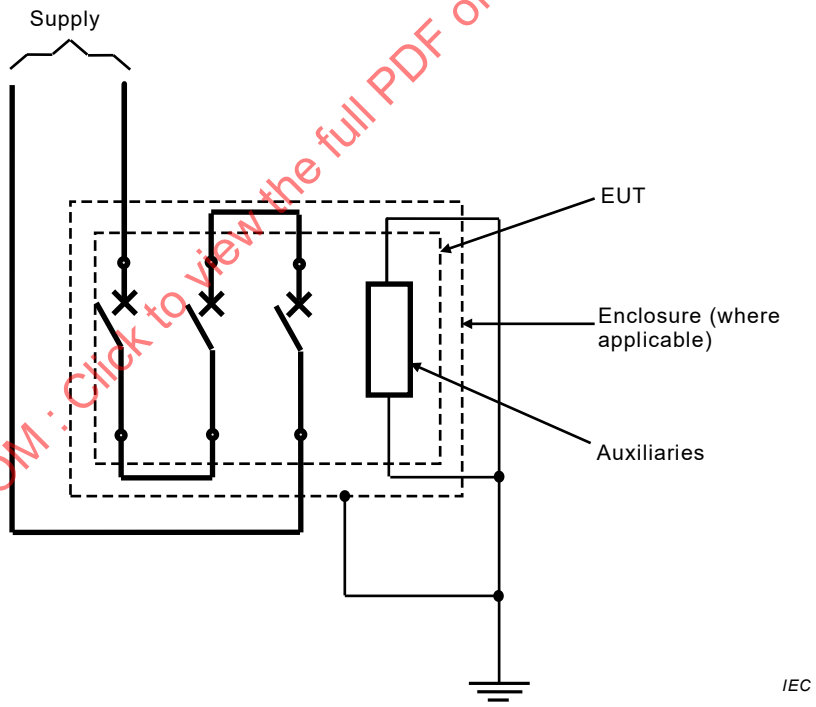
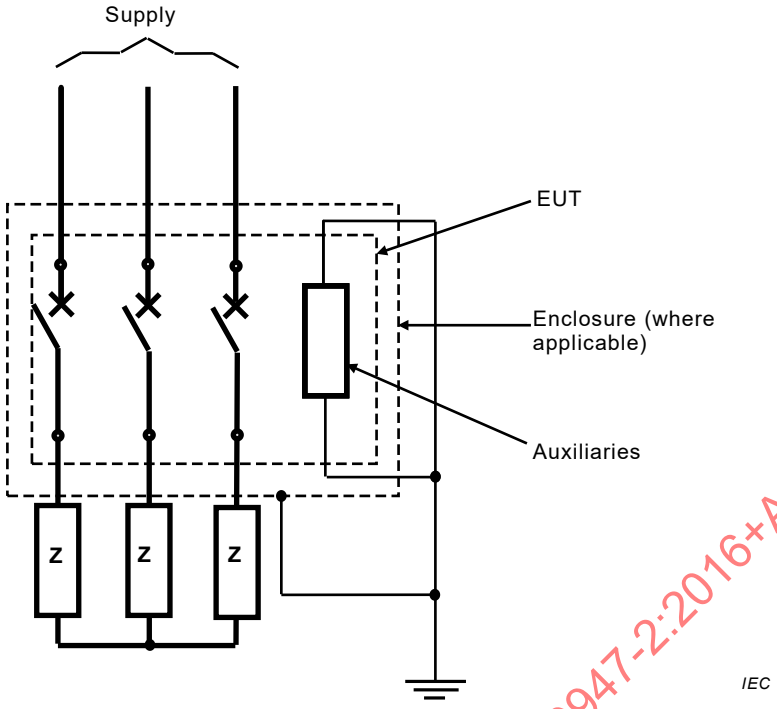


Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series

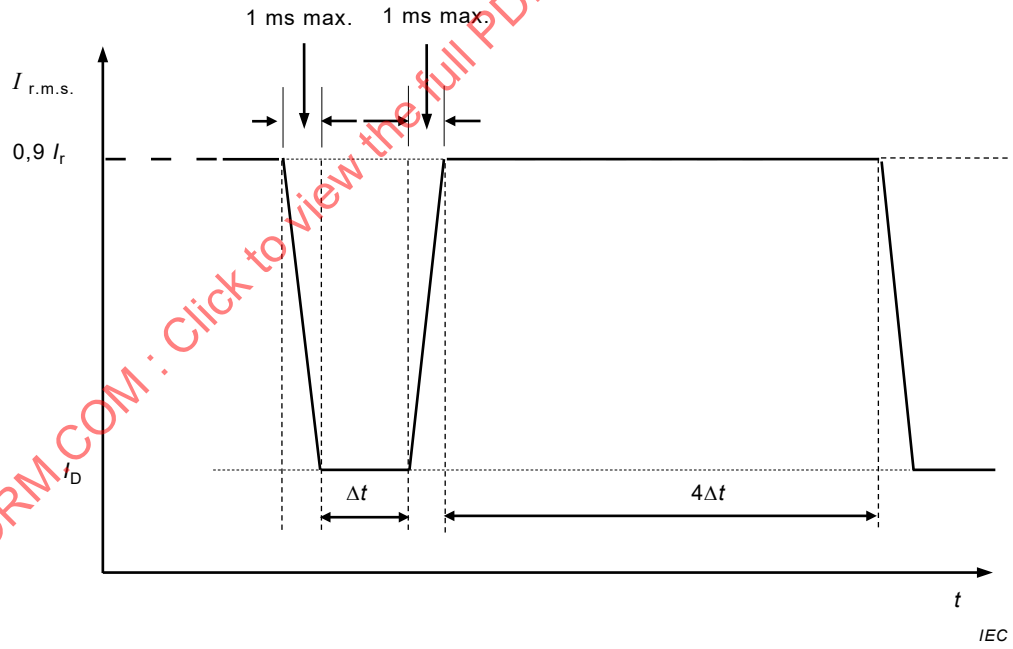
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Key

Z impedance for adjusting the current (where required)

Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection



Key

I_r setting current

I_D dip test current

Δt dip time

$4\Delta t$ dwell time

Figure F.5 – Test current for the verification of the influence of the current dips and interruptions in accordance with F.4.7.1

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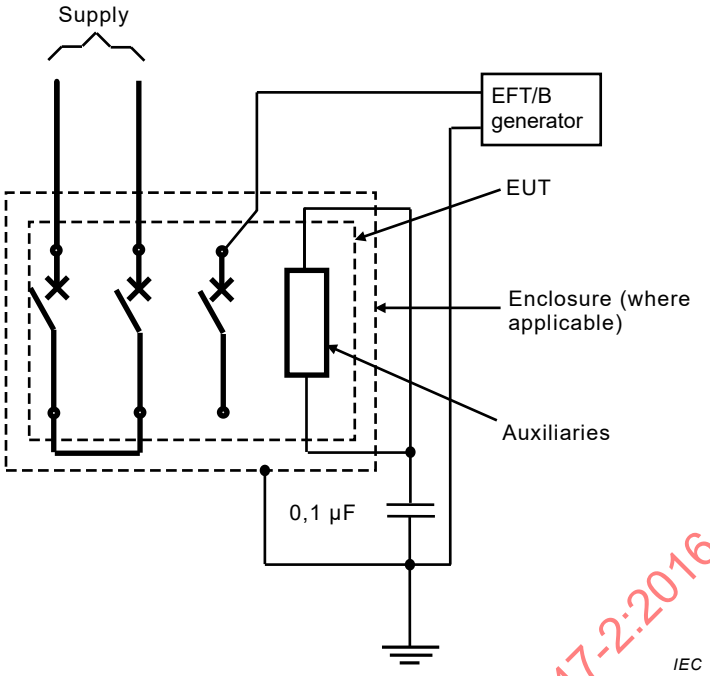


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

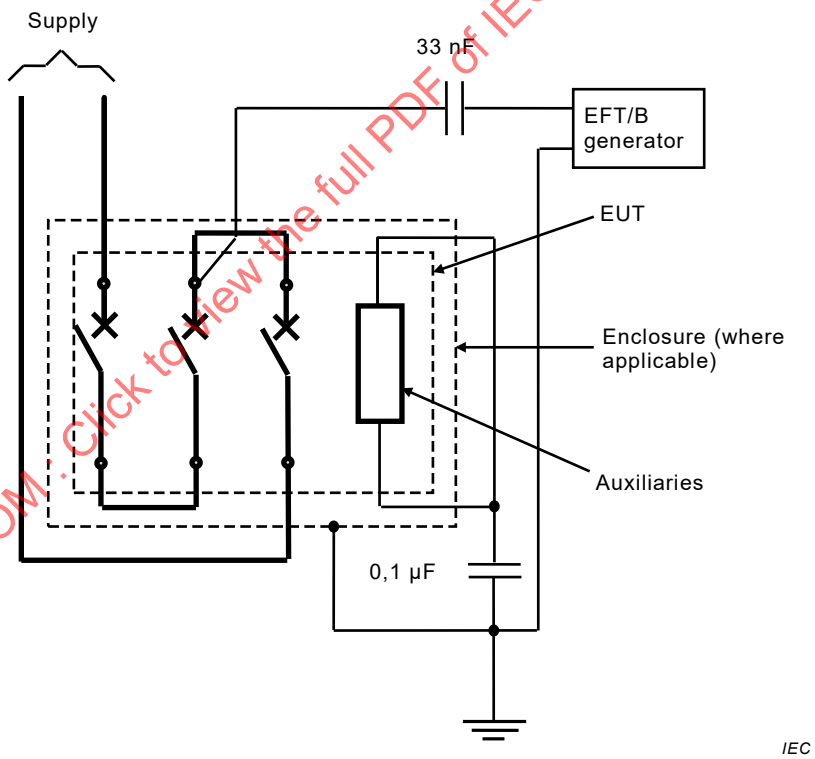
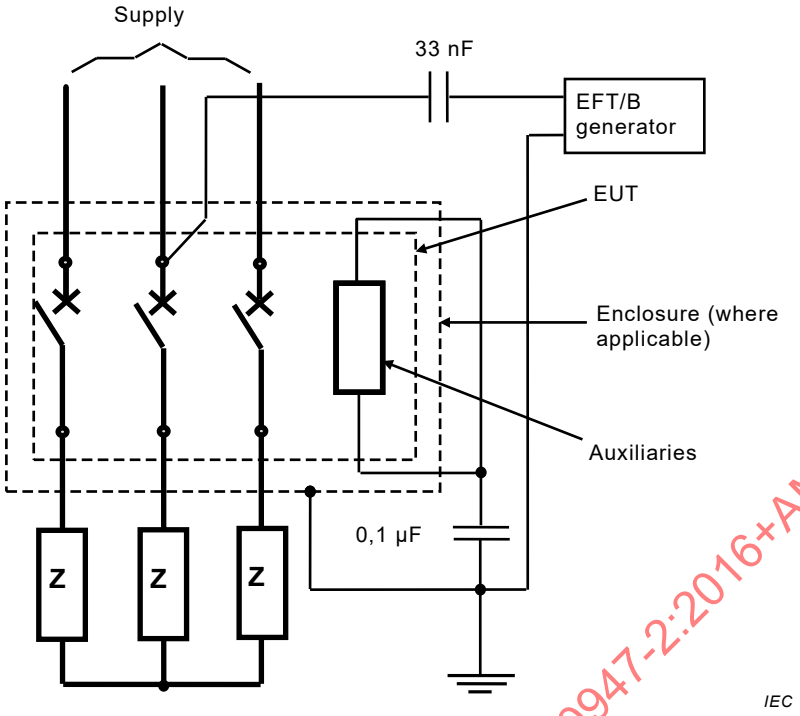


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series

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Key

Z impedance for adjusting the current (where required)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

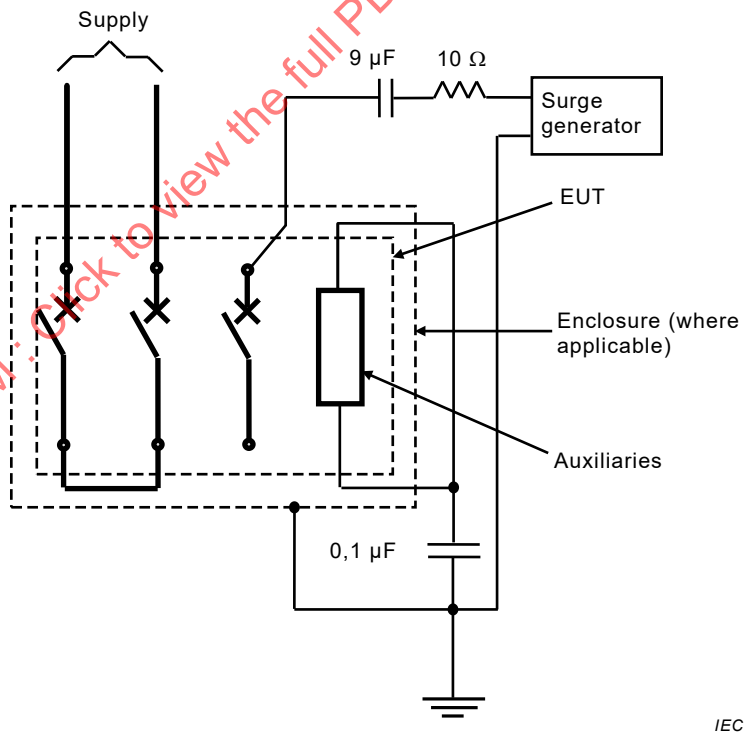


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

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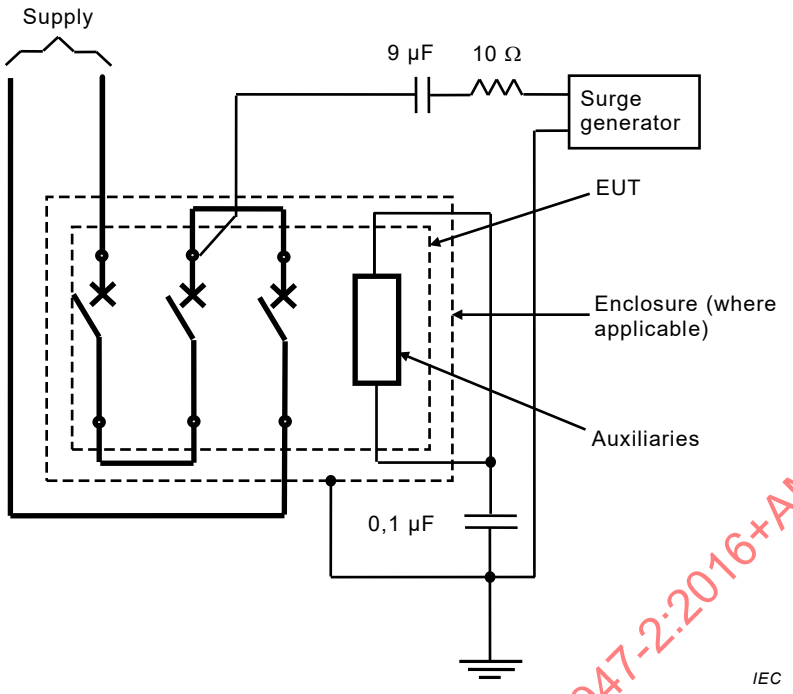
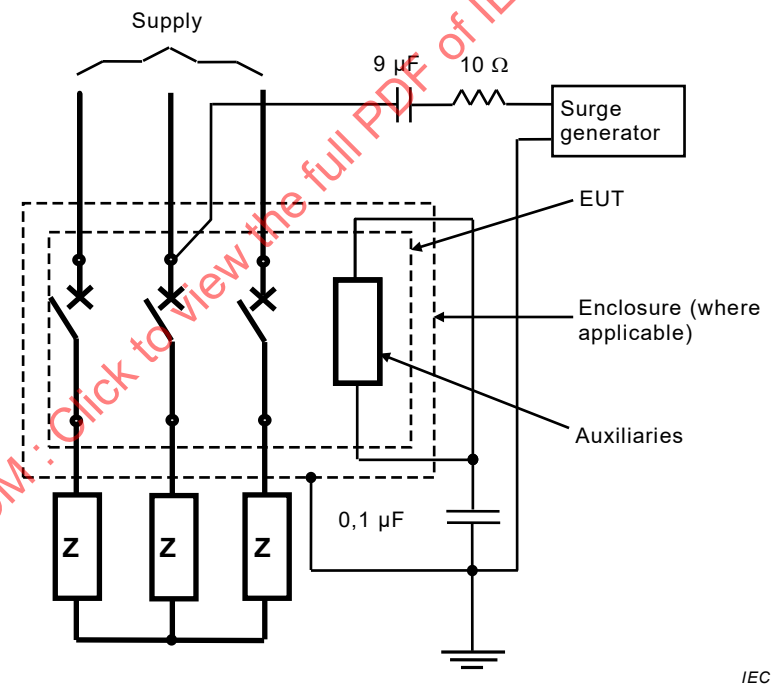


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where required)

Figure F.11 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection

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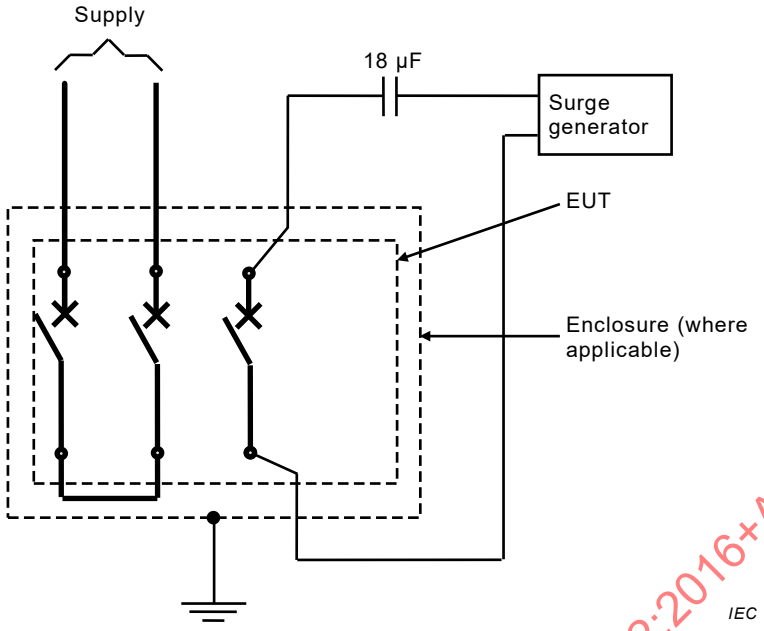


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

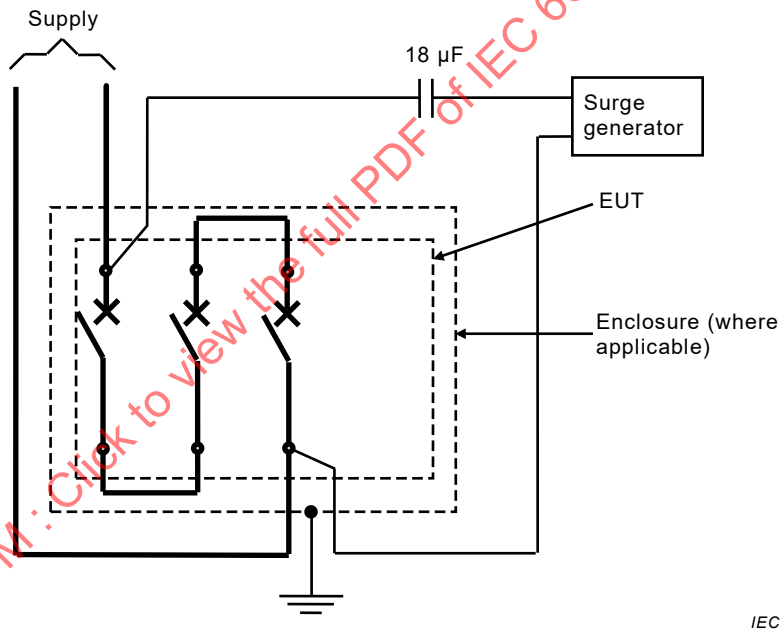
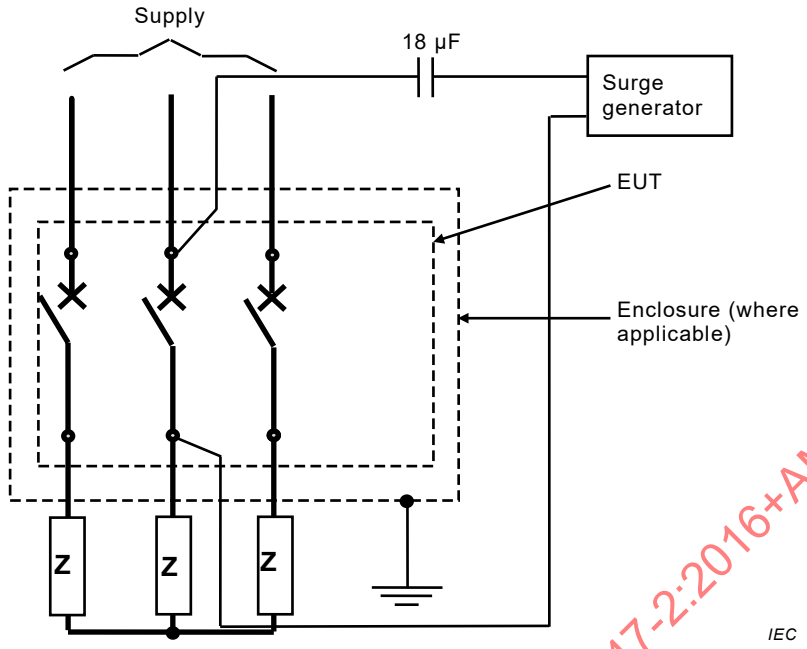


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series

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Key

Z impedance for adjusting the current (where required)

Figure F.14 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three-phase connection

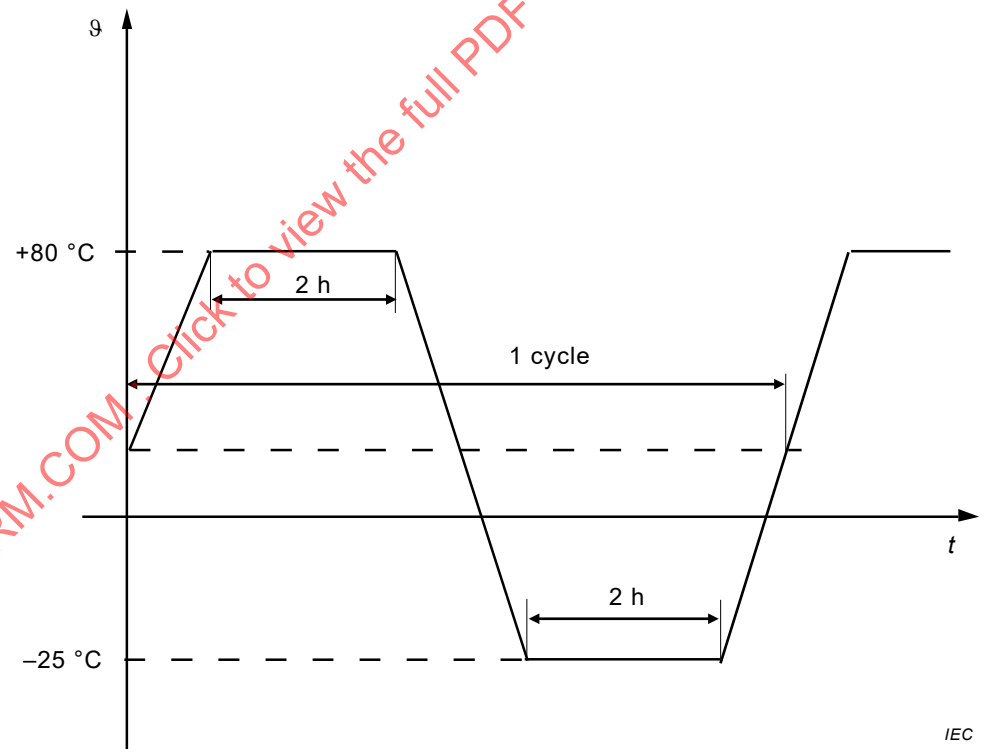
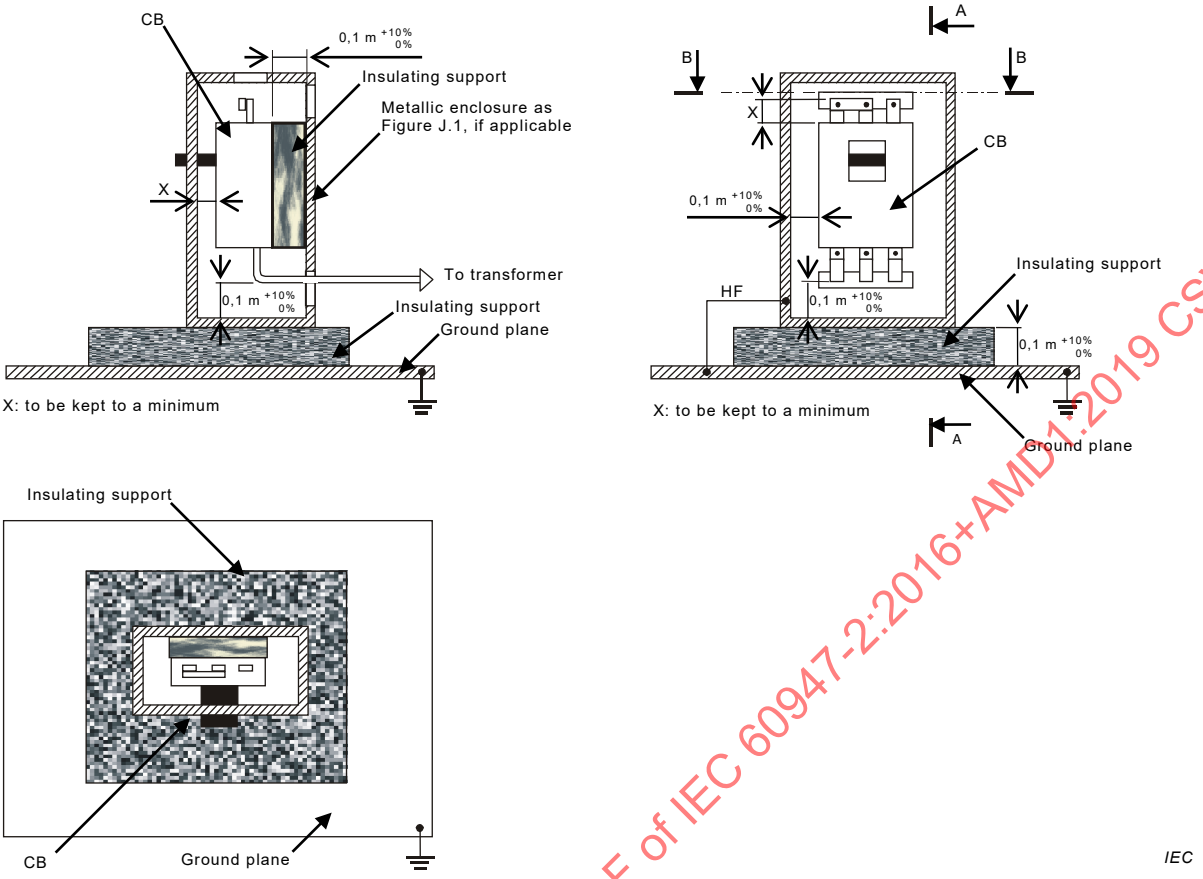


Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1

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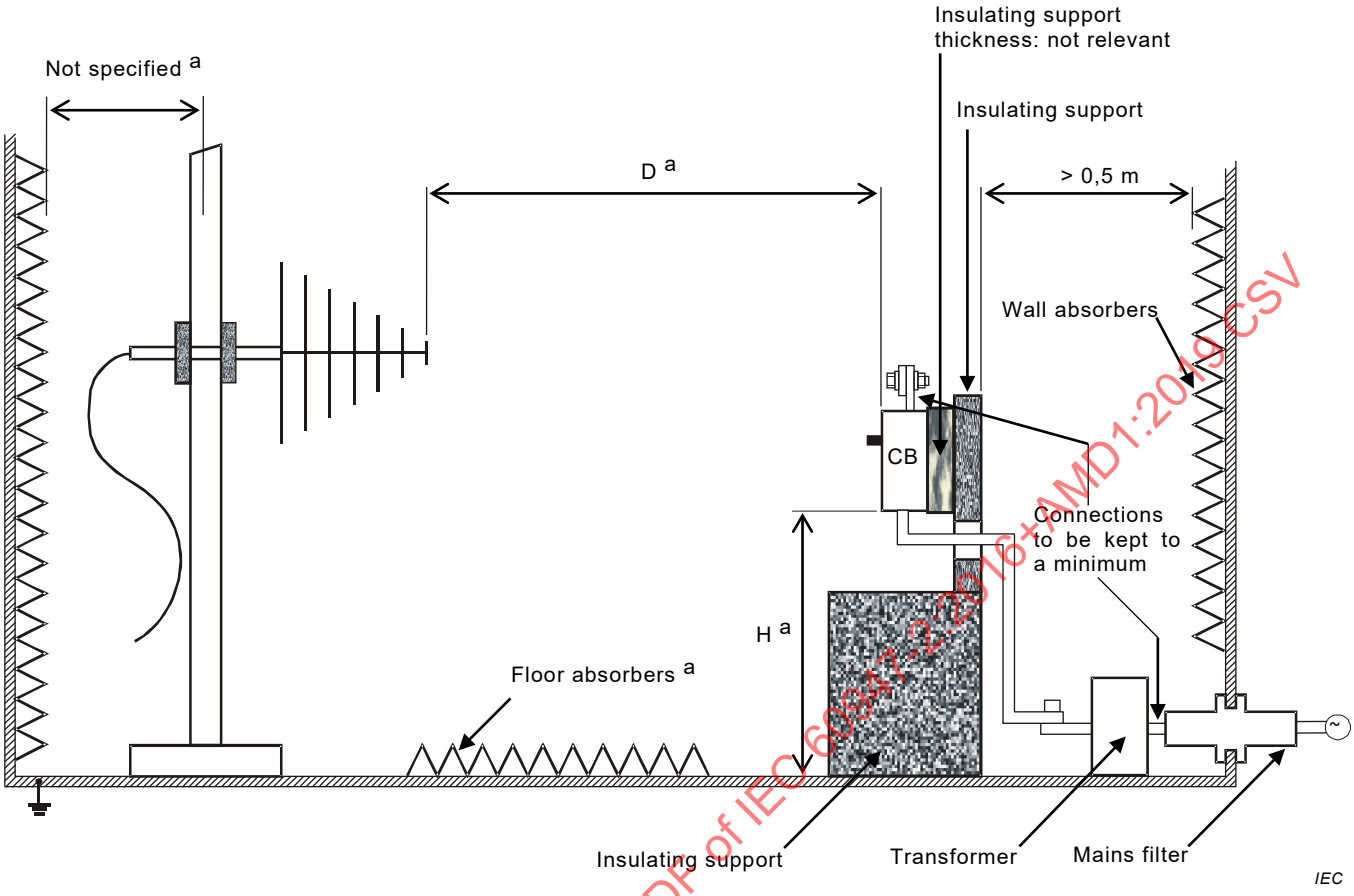
Key

CB circuit-breaker

NOTE The terminal arrangement can vary according to the type of circuit-breaker tested.

Figure F.16 – General test set-up for immunity tests

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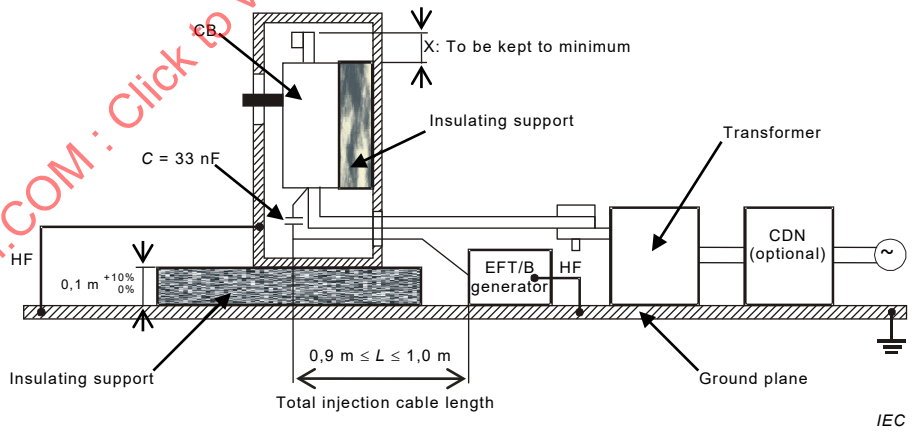


Key

CB circuit-breaker

a See IEC 61000-4-3

Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields



Key

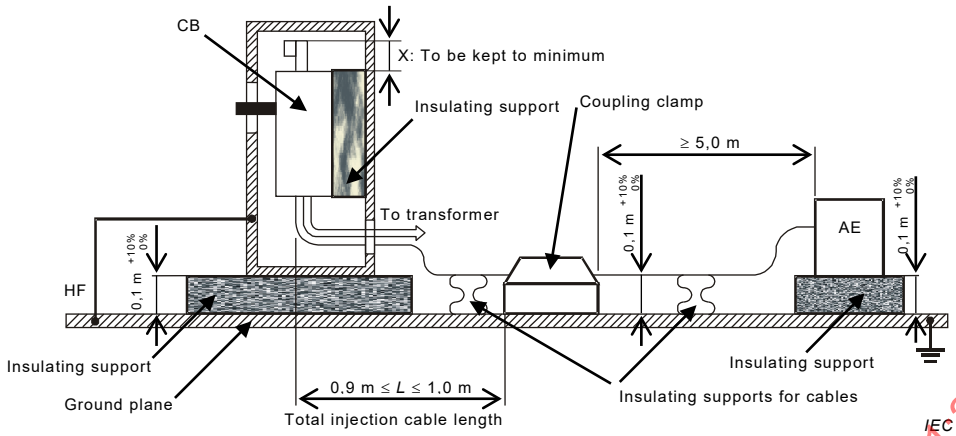
CB circuit-breaker

CDN coupling-decoupling network

HF high frequency connection

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines

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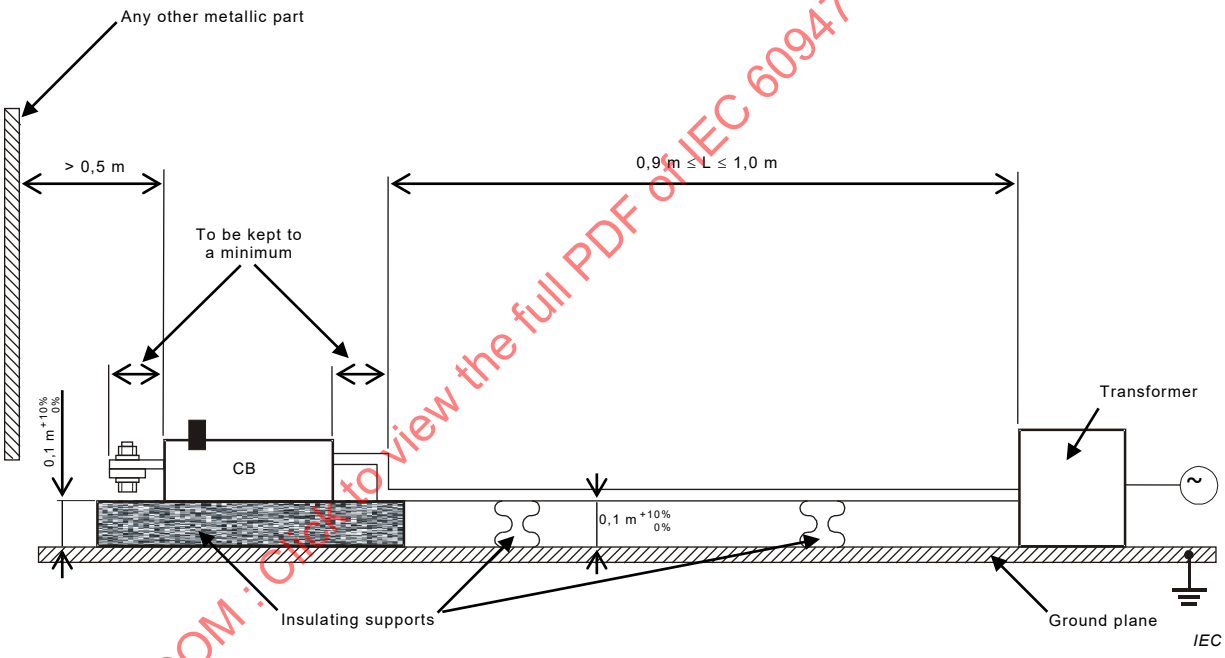
Key

AE auxiliary equipment

CB circuit-breaker

HF high frequency connection

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines



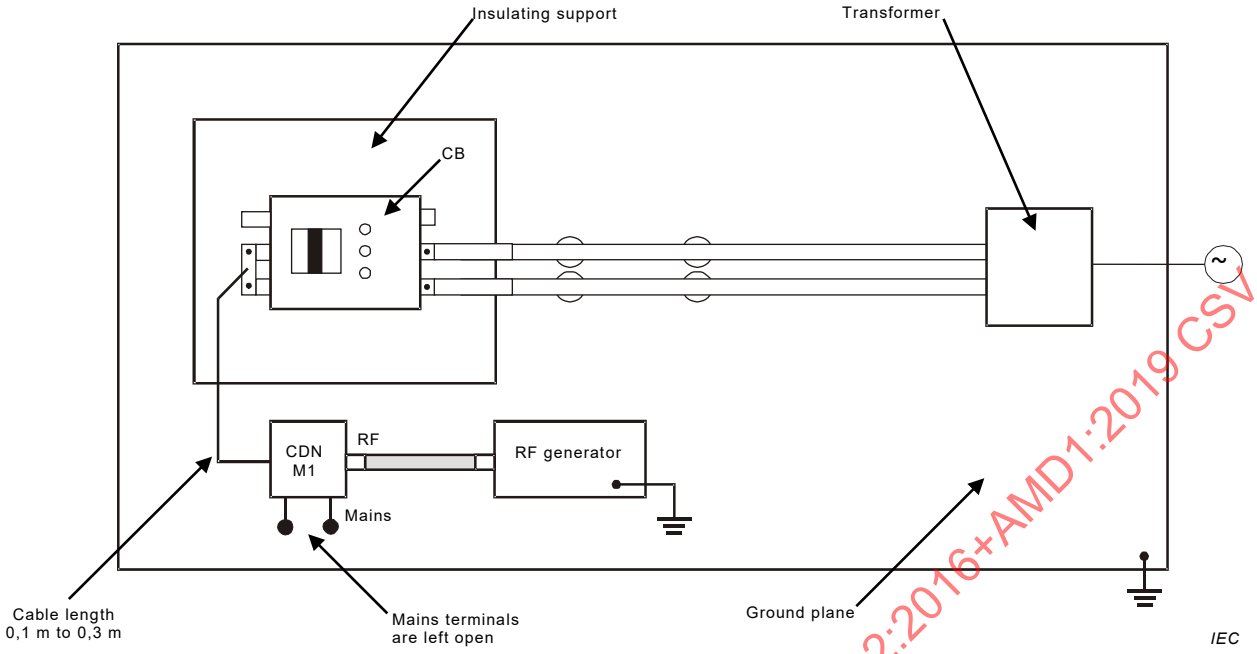
Key

CB circuit-breaker

NOTE The dimension *L* is the length of the conductor coupled at 0,1 m to the ground plane.

Figure F.20 – General test set-up for the verification of immunity to conducted disturbances induced by RF fields (common mode)

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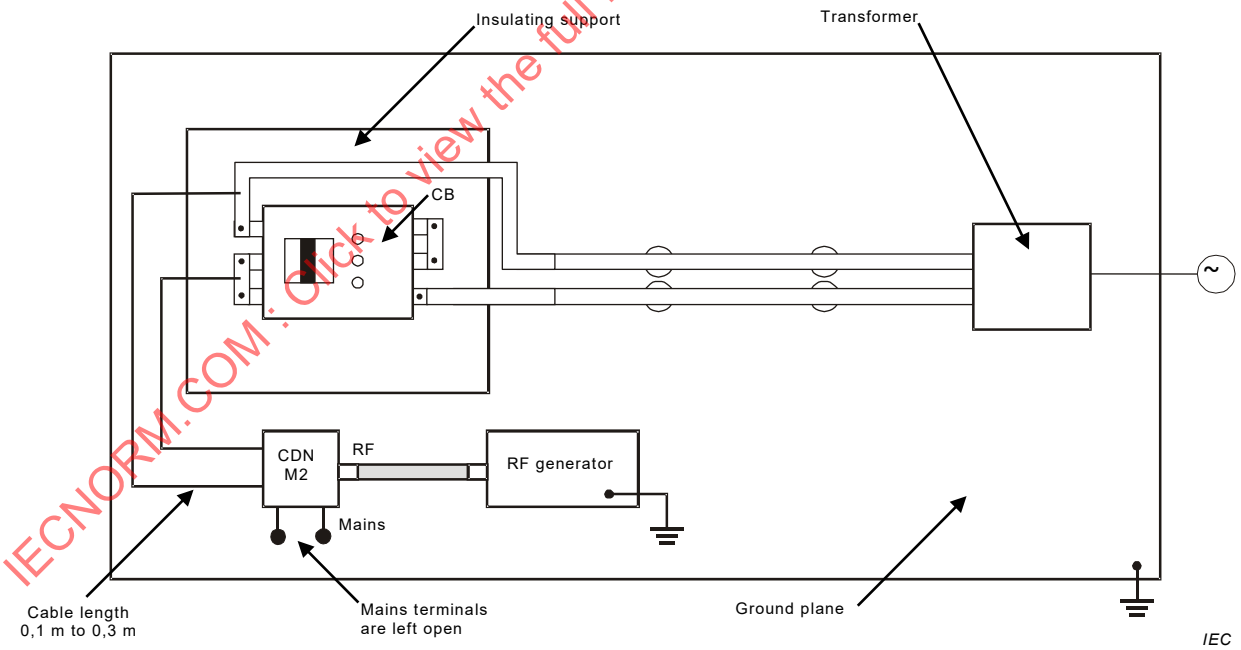
Key

CB circuit-breaker

CDN M1 coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, the coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.21 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Two phase poles in series configuration



Key

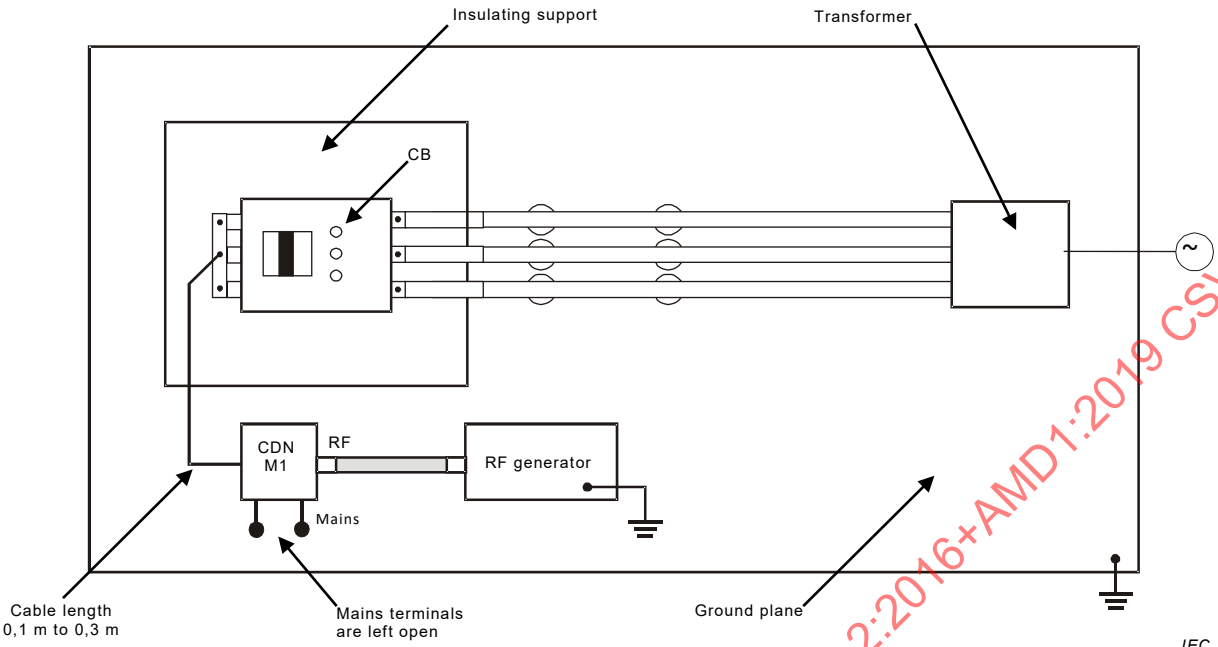
CB circuit-breaker

CDN M2 coupling-decoupling network M2

NOTE As an alternative to the coupling-decoupling network M2, coupling-decoupling network M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.22 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three phase poles in series configuration

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Key

CB	circuit-breaker
CDN M1	coupling-decoupling network M1

NOTE As an alternative to the coupling-decoupling network M1, coupling-decoupling network M2 or M3 can be used, in which case the two or three connecting wires, as applicable, are connected to the same point of the EUT.

Figure F.23 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three-phase configuration

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Annex G
(normative)

Power loss

G.1 General

Power loss is not a fundamental characteristic of a circuit-breaker and need not be marked on the product.

It gives some indication of the heat generated under specified conditions.

Measurement of power loss shall be made in free air, on new samples, and shall be stated in watts.

G.2 Test methods

G.2.1 General case

Power loss is evaluated as follows, connections being in accordance with Figure G.1.

$$\sum_{k=1}^{k=p} \Delta U_k \; I_k \; \cos \varphi_k$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I is the test current which shall be equal to I_n within the tolerances according to 8.3.2.2.2;

$\cos \varphi$ is the power factor.

The use of a wattmeter on each pole is recommended.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

For a.c. circuit-breakers of rated current not exceeding 400 A, it is acceptable to use single-phase a.c. measurement without power factor measurement.

The power loss is evaluated as follows, connections being in accordance with Figure G.2.

$$\sum_{k=1}^{k=p} \Delta U_k \; I_n$$

where

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop;

I_n is the rated current.

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G.2.3 DC circuit-breakers

For d.c. circuit-breakers, the power loss shall be measured with d.c. current.

It is evaluated as in G.2.2.

G.3 Test procedure

The power loss evaluation shall be made under rated current steady-state temperature conditions.

The voltage drop shall be measured between incoming and outgoing terminals on each pole.

The connecting leads to measuring instruments (e.g. voltmeter, wattmeter) shall be twisted together. The measuring loop shall be as small as practicable and shall be positioned similarly for each pole.

For evaluating the power loss of three-pole and four-pole a.c. circuit-breakers according to G.2.1, the test is performed under three-phase current conditions (see Figure G.1), without current in the fourth pole in the case of four-pole circuit-breakers.

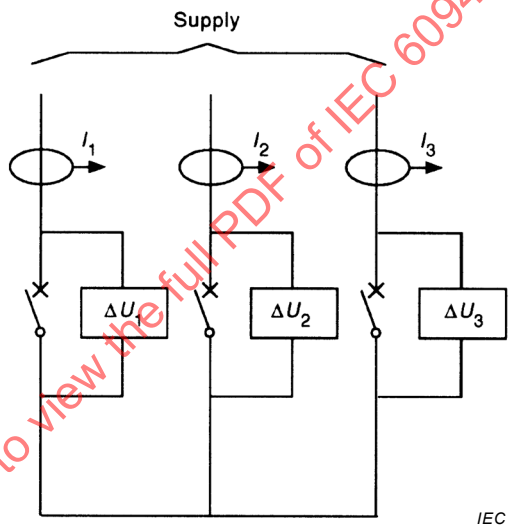


Figure G.1 – Example of power loss measurement according to G.2.1

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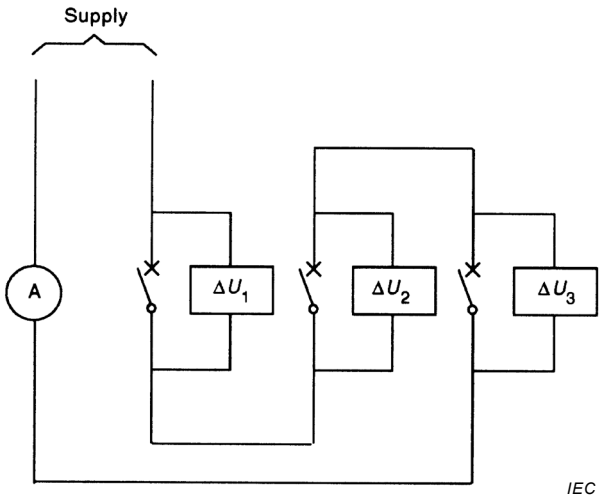


Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3

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Annex H
(normative)

Test sequence for circuit-breakers for IT systems

NOTE This test sequence is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a circuit-breaker when installed in IT systems (see 4.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 4.3.2.1; it comprises the following tests:

Test	Clause
Individual pole short-circuit (I_{IT})	H.2
Verification of dielectric withstand	H.3
Verification of overload releases	H.4

H.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole circuit-breaker under the general conditions of 8.3.2, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay release tripping current or, in the absence of such a release, 1,2 times the maximum setting of the tripping current of the instantaneous release,

or, where relevant

– 1,2 times the maximum setting of the definite time delay release tripping current,

but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous pick-up current, allowing for the impedance of the circuit-breaker and its connections.

NOTE 2 Values higher than I_{IT} can be required, tested instead and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the circuit-breaker at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 10. The power factor shall be according to Table 11, appropriate to the test current. When I_{IT} = 50 kA, the short-time or instantaneous pick-up setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

For 4-pole circuit-breakers with a protected neutral pole, the test voltage for that pole shall be phase-to-phase voltage divided by √3. This test is applicable only where the construction of the protected neutral pole differs from that of the phase poles.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be

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O – *t* – CO

and shall be made on each pole separately, in turn.

If the circuit-breaker is provided with both a short-time delay release and an instantaneous release, the instantaneous release may operate before the short-time delay release, depending on the setting and the tolerances.

H.3 Verification of dielectric withstand

Following the test according to H.2, the dielectric withstand shall be verified according to 8.3.5.4.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 8.3.5.5.

H.5 Marking

Subclause 5.2 applies with the following addition:

Circuit-breakers for which not all values of rated voltage are covered by the testing in accordance with this annex shall be marked in accordance with Table H.1.

Table H.1 – Product information

Item	Information	Marking location
H2.1	rated voltage(s) not suitable for IT system, as follows: immediately following each corresponding rated voltage, e.g. 690 V  (IEC 60417-6363:2016-07) or immediately following the rated voltages grouped, e.g. 415 V 500 V  (IEC 60417-6363:2016-07) 690 V	Marked
Key Marked: marked on the product		

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Annex J
(normative)

Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers

J.1 General

Two sets of environmental conditions are considered and are referred to as follows:

– environment A;
– environment B.

Environment A: relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE 1 Environment A corresponds to equipment class A in CISPR 11 and CISPR 32.

NOTE 2 Environment A equipment can cause electromagnetic interferences when installed in environment B.

Environment B: relates to low-voltage public networks such as domestic, commercial and light industrial locations/installations. Highly disturbing sources such as arc welders are not covered by this environment.

NOTE 3 Environment B corresponds to equipment class B in CISPR 11 and CISPR 32.

NOTE 4 Environment B equipment will not cause electromagnetic interferences when installed in environment A.

For the purposes of this annex the term "EUT" means “equipment under test”.

NOTE 5 The EMC requirements for CBI (Annex L) and ICB (Annex O) are deemed to be covered by the relevant tests on the equivalent circuit-breaker (see L.2.1 and O.2.1).

The tests of J.2 and J.3 are applicable to devices incorporating electronic circuits except where specified otherwise in this standard.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this standard to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this standard, i.e., Annex B for circuit-breakers incorporating residual current protection (CBR), Annex F for circuit-breakers with electronic overcurrent protection, Annex M for modular residual current devices (MRCD) and Annex N for circuit-breaker auxiliaries.

A new device may be used for each test or one device may be used for several tests, at the manufacturer’s discretion. Devices rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

In the case of a range of devices with identical electronic controls (including dimensions, components, printed circuit board assemblies and enclosure, if any) and the same design of current sensors, it is sufficient to test only one device in the range.

The tests shall be performed with a specific mounting; free air or within an enclosure, as specified in J.2 and J.3.

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J.2 Immunity

J.2.1 General

Subclause 7.3.2.2 of IEC 60947-1:2007/AMD1:2010 applies with the following additions.

Immunity tests shall be performed according to Table J.1. The immunity levels specified in this table can be higher than those required by Table 23 of IEC 60947-1:2007/AMD1:2010, in order to provide increased reliability of the circuit-breaker protection functions.

The reference data for the additional test specifications is given in Table J.2.

For the purposes of this clause (J.2), the term "power port" covers the main circuit, auxiliary power supply port(s) and any auxiliary connected to the main circuit.

For the immunity tests, the following performance criteria shall be defined:

Performance criterion A: during the test, the resistance against unwanted operation (step 1) and the functional characteristics (step 2) are verified. Any monitoring function shall correctly indicate the status.

Performance criterion B: during the test, the resistance against unwanted operation is verified. Monitoring functions may indicate a false status. After the test the functional characteristics are verified.

Details of the verification of performance are given in the respective annex (Annex B, Annex F, Annex M or Annex N).

For all immunity tests, the EUT shall be tested as floor-standing equipment (see IEC 61000-4 series).

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Table J.1 – EMC – Immunity tests

Description	Reference standard	Test level	Performance criterion	Mounting
Electrostatic discharges	IEC 61000-4-2	6 kV contact 8 kV air	B	Enclosure Figure J.1
Radiated radio-frequency electromagnetic fields	IEC 61000-4-3	80 MHz to 1 GHz: 10 V/m 1,4 GHz to 6 GHz: 3 V/m	A	Free air [c]
Electrical fast transients/bursts [k]	IEC 61000-4-4	Power port: $U_e \geq 100$ V, a.c. / d.c.: 4 kV 5 kHz or 100 kHz $U_e < 100$ V, a.c. / d.c. [f]: 2 kV 5 kHz or 100 kHz Signal port [g]: 2 kV 5 kHz or 100 kHz	B	Enclosure Figure J.1
Surges	IEC 61000-4-5	Power port, $U_e \geq 100$ V a.c.: 4 kV line-to-earth 2 kV line-to-line (Annex F and Annex N) 4 kV line-to-line (Annex B and Annex M) [e] Power port, $U_e < 100$ V a.c.: 2 kV line-to-earth 1 kV line-to-line Power port, d.c. [f]: 1 kV line-to-earth 0,5 kV line-to-line Signal port [h, j]: 2 kV line-to-earth 1 kV line-to-line	B	Enclosure Figure J.1
Conducted disturbances induced by radio-frequency fields	IEC 61000-4-6	Power port a.c. / d.c.: 10 V (150 kHz – 80 MHz) Signal port [g]: 10 V (150 kHz – 80 MHz)	A	Free air [c]
Power frequency magnetic fields	Not applicable	Not applicable	Not applicable	Not applicable
Voltage dips and interruptions	IEC 61000-4-11 [d]	[d]	[d]	Free air
Harmonics	IEC 61000-4-13 [b]	[b]	[b]	Free air
Current dips	[b]	[b]	[b]	Free air

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a	Vacant.
b	A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.
c	Unless the circuit-breaker is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report. The enclosure shall be connected to the ground plane in accordance with the manufacturer's instructions.
d	A specific test procedure and a performance criterion are defined in Annex B in the case of CBRs functionally dependent on line voltage and in Annex M in the case of MRCDs functionally dependent on a voltage source, in the absence of an appropriate basic standard. These tests are not applicable to circuit-breakers with electronic overcurrent protection as described in Annex F (see F.1), but are replaced by tests for current dips and interruptions (see F.4.7).
e	The immunity level is higher for residual current devices because they perform safety functions.
f	Not applicable to input ports intended for connection to a battery or a rechargeable battery, which shall be removed or disconnected from the apparatus for recharging. Apparatus with a d.c. power input port intended for use with an a.c. – d.c. power adapter shall be tested on the a.c. power input of the a.c. – d.c. power adapter specified by the manufacturer or, where none is so specified, using a typical a.c. – d.c. power adapter. The test is not applicable to d.c. power input ports intended to be permanently connected to cables less than 3 m in length.
g	Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.
h	Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 10 m. When shielded cables are used, this test is applied only to the shield.
j	Signal lines with direct connection to a.c. power ports shall be treated as a.c. power ports.
k	The repetition frequency (5 kHz or 100 kHz) shall be agreed between the manufacturer and the testing station, and shall be stated in the test report.

The appropriate test set-up and circuit diagram for each immunity test are as shown in Table J.2.

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Table J.2 – Reference data for immunity test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Electrostatic discharges	CBR	J.2.2, B.8.13.1.2	Figure J.1, Figure J.3	Figure B.1
	CB	J.2.2, F.4.2	Figure J.3, Figure F.16	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.2, M.8.16.1.2	Figure J.1, Figure J.3	Figure M.3
	Other devices [a]	J.2.2, N.2.2	[b]	[b]
Radiated radio-frequency electromagnetic fields	CBR	J.2.3, B.8.13.1.3	Figure J.4	Figure B.1
	CB	J.2.3, F.4.3	Figure F.16, Figure F.17	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.3, M.8.16.1.3	Figure J.4, Figure M.20	Figure M.3
	Other devices [a]	J.2.3, N.2.3	[b]	[b]
Electrical fast transients/bursts	CBR	J.2.4, B.8.13.1.4	Figure J.5, Figure J.6	Figure B.1
	CB	J.2.4, F.4.4	Figure F.16, Figure F.18, Figure F.19	Figure F.6, Figure F.7 or Figure F.8
	MRCD	J.2.4, M.8.16.1.4	Figure J.5, Figure J.6, Figure M.21	Figure M.3
	Other devices [a]	J.2.4, N.2.4	[b]	[b]
Surges	CBR	J.2.5, B.8.13.1.5	[b]	Figure B.1
	CB	J.2.5, F.4.5	Line-to-earth: Figure F.16 Line-to-line: Figure F.16	Line-to-earth: Figure F.9, Figure F.10 or Figure F.11 Line-to-line: Figure F.12, Figure F.13 or Figure F.14
	MRCD	J.2.5, M.8.16.1.5	[b]	Figure M.3
	Other devices [a]	J.2.5, N.2.5	[b]	[b]
Conducted disturbances induced by radio-frequency fields	CBR	J.2.6, B.8.13.1.6	[b]	Figure B.1
	CB	J.2.6, F.4.6	Figure F.16, Figure F.20, Figure F.21, Figure F.22, Figure F.23	Figure F.2, Figure F.3 or Figure F.4
	MRCD	J.2.6, M.8.16.1.6	Figure M.22	Figure M.3
	Other devices [a]	J.2.6, N.2.6	[b]	[b]

[a] Devices in the scope of Annex N.

[b] No additional figure necessary.

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J.2.2 Electrostatic discharges

The EUT shall be tested in a specific enclosure (see Table J.1). The test set-up and additional test requirements are given in Table J.2. Direct and indirect discharges shall be applied in accordance with IEC 61000-4-2.

The direct discharge tests shall be performed only on parts of the EUT normally accessible to the user, such as setting means, keyboards, displays, pushbuttons etc. The application points shall be stated in the test report.

Direct discharges are made 10 times for each polarity, at intervals of ≥ 1 s.

Indirect discharges shall be applied at selected points on the surface of the enclosure; the test at such points is made 10 times, for each polarity, at intervals of ≥ 1 s.

J.2.3 Radiated RF electromagnetic fields

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The EUT shall be tested on the front face only.

To enable repeatability, the actual test set-up shall be detailed in the test report.

Tests shall be performed with both horizontal and vertical antenna polarization.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the ranges of 80 MHz to 1 000 MHz, 1 400 MHz to 2 000 MHz, and 2 110 MHz to 2 700 MHz, in accordance with Clause 8 of IEC 61000-4-3:2006. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 80 MHz; 100 MHz; 120 MHz; 180 MHz; 240 MHz; 320 MHz; 480 MHz; 640 MHz; 960 MHz; 1 400 MHz; 1 920 MHz, 2 150 MHz and 2 450 MHz, the operation being verified after the field at each frequency has stabilized.

J.2.4 Electrical fast transients/bursts (EFT/B)

The test shall be performed with the EUT in a specific enclosure (see Table J.1).

The test set-up is given in Table J.2.

For power and auxiliary supply ports, the coupling-decoupling network shall be used, except for Annex F where the direct injection method shall be used (see Figure F.18).

For signal ports the coupling-decoupling network or the clamp injection method shall be used, as applicable.

The disturbance shall be applied for 1 min, except where otherwise specified.

J.2.5 Surges

The test shall be carried out with the EUT in a specific enclosure (see Table J.1). The test levels and test set-up are given in Table J.1 and Table J.2, depending upon the EUT.

Pulses with both positive and negative polarity shall be applied, the phase angles being 0° and 90°.

A series of five pulses is applied for each polarity and each phase angle (total number of pulses: 20), the interval between two pulses being approximately 1 min. A shorter interval may be used by agreement with the manufacturer.

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J.2.6 Conducted disturbances induced by RF fields (common mode)

The EUT shall be tested in free air (see Table J.1) with the additional test requirements given in Table J.2.

The disturbances shall be injected, on power lines, by means of a coupling-decoupling network M1, M2 or M3 as applicable.

On signal lines, the disturbances shall be injected by means of a coupling-decoupling network. If not feasible, an E.M. clamp may be used.

The particular test set-up shall be detailed in the test report.

The test is performed in two steps: a first step (step 1) where the EUT is tested for unwanted operation on the whole range of frequencies, and a second step (step 2) where the EUT is tested for correct operation at discrete frequencies.

For step 1, the frequency shall be swept over the range of 150 kHz to 80 MHz in accordance with Clause 8 of IEC 61000-4-6:2013. The dwell time of the amplitude modulated carrier for each frequency shall be between 500 ms and 1 000 ms, and the step size shall be 1 % of the previous frequency. The actual dwell time shall be stated in the test report.

For step 2, to verify the functional characteristics, the test shall be performed at each of the following frequencies: 0,150 MHZ; 0,300 MHZ; 0,450 MHZ; 0,600 MHZ; 0,900 MHZ; 1,20 MHZ; 1,80 MHZ; 2,40 MHZ; 3,60 MHZ; 4,80 MHZ; 7,20 MHZ; 9,60 MHZ; 12,0 MHZ; 19,2 MHZ; 27,0 MHZ; 49,4 MHZ; 72,0 MHZ and 80,0 MHz, the operation being verified after the level of the disturbing voltage at each frequency has stabilized.

J.3 Emission

J.3.1 General

Subclause 7.3.3.2 of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Emission tests are performed according to Table J.3.

The reference data for the application of the figures for emission tests is given in Table J.4.

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Table J.3 – EMC – Emission tests

Description	Reference standard	Limits	Mounting
Harmonics	IEC 61000-3-2	[c]	[c]
Voltage fluctuations	IEC 61000-3-3	[c]	[c]
Conducted RF disturbances 150 kHz to 30 MHz[e]	CISPR 11[f] / CISPR 32	Class A or class B, group 1[b, e]	Free air[d]
Radiated RF disturbances 30 MHz to 1 000 MHz[a]	CISPR 11[f] / CISPR 32	Class A or class B, group 1[b]	Free air[d]

[a] Applicable only for EUT containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.

[b] Equipment class A in CISPR 11 and CISPR 32 corresponds to environment A in IEC 60947-1. Environment A equipment can cause electromagnetic interferences when installed in environment B. The manufacturer of environment A equipment shall declare the risk of electromagnetic interference in the product documentation.

Equipment class B in CISPR 11and CISPR 32 corresponds to environment B in IEC 60947-1. Environment B equipment will not cause electromagnetic interference when installed in environment A.

[c] No test required since the electronic control circuits operate at very low power and hence create negligible disturbances.

[d] Unless the EUT is intended to be used only in a specified individual enclosure, in which case it shall be tested in such an enclosure. Details, including dimensions of the enclosure, shall be stated in the test report.

[e] Circuit-breakers covered by Annex F are independent of line voltage or of any auxiliary supply. The electronic circuits have no direct coupling to the supply and operate at very low power. These circuit-breakers create negligible disturbances and therefore no tests are required.

[f] A description of the test, the test method and the test set-up is given in Clause 7 of CISPR 11:2015, CISPR 11:2015/AMD1:2016.

Table J.4 – Reference data for emission test specifications

Test	EUT	Subclause	Test set-up	Circuit diagram
Conducted RF disturbances	CBR	J.3.2, B.8.12.2.1	[a]	[a]
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.12.2.1	[a]	[a]
	Other devices	J.3.2, N.3.2	[a]	[a]
Radiated RF disturbances	CBR	J.3.3, B.8.12.2.1	Figure J.2	[a]
	CB	J.3.3, F.5.4	Figure J.2	Figure F.2, Figure F.3 Figure F.4
	MRCD	J.3.3, B.8.12.2.1	Figure J.2	[a]
	Other devices	J.3.3, N.3.3	[a]	[a]

[a] No additional figure necessary.

J.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

The test method and test arrangement shall be as in CISPR 11 or CISPR 32, as relevant.

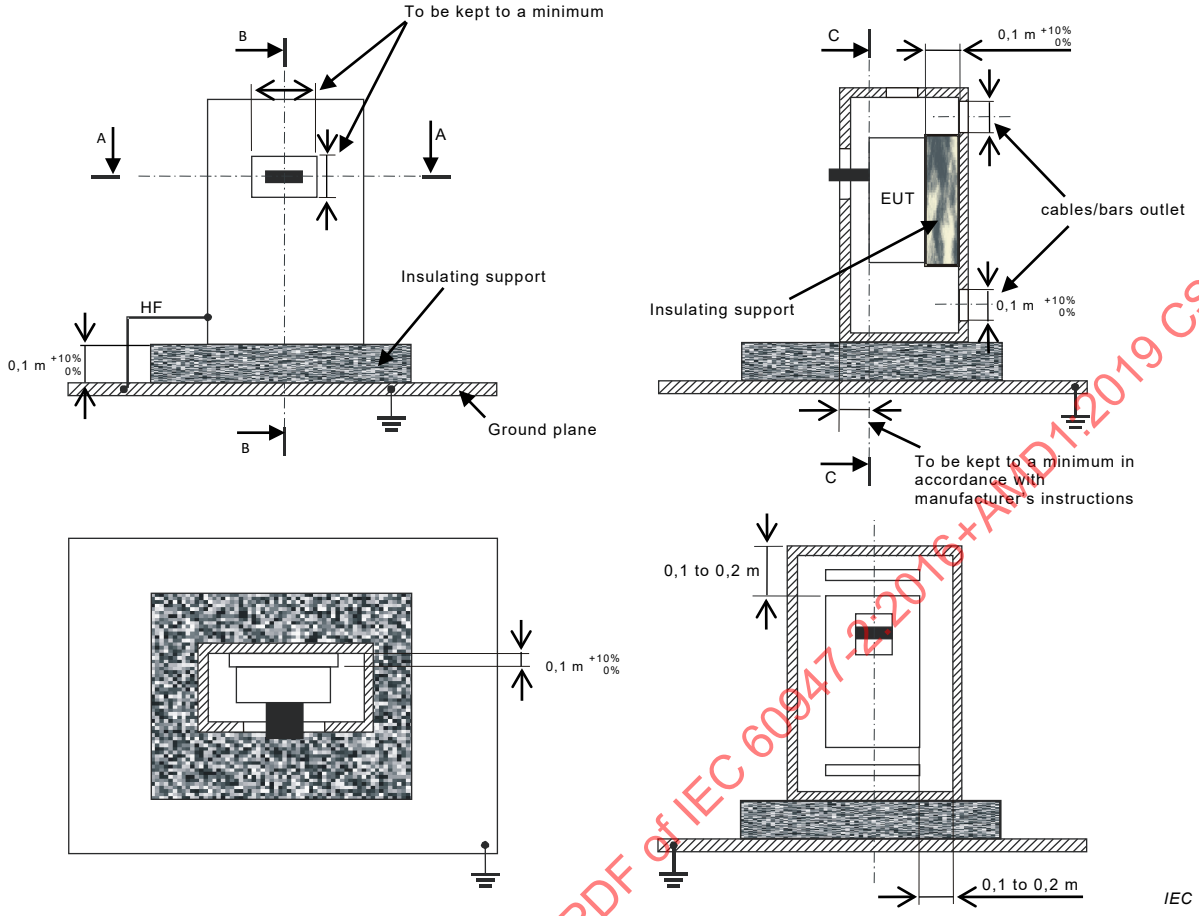
The particular test set-up, including the type of cable, shall be detailed in the test report.

J.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

The test set-up is shown in Figure J.2.

The particular test set-up including supply bars, transformer, etc. shall be detailed in the test report.

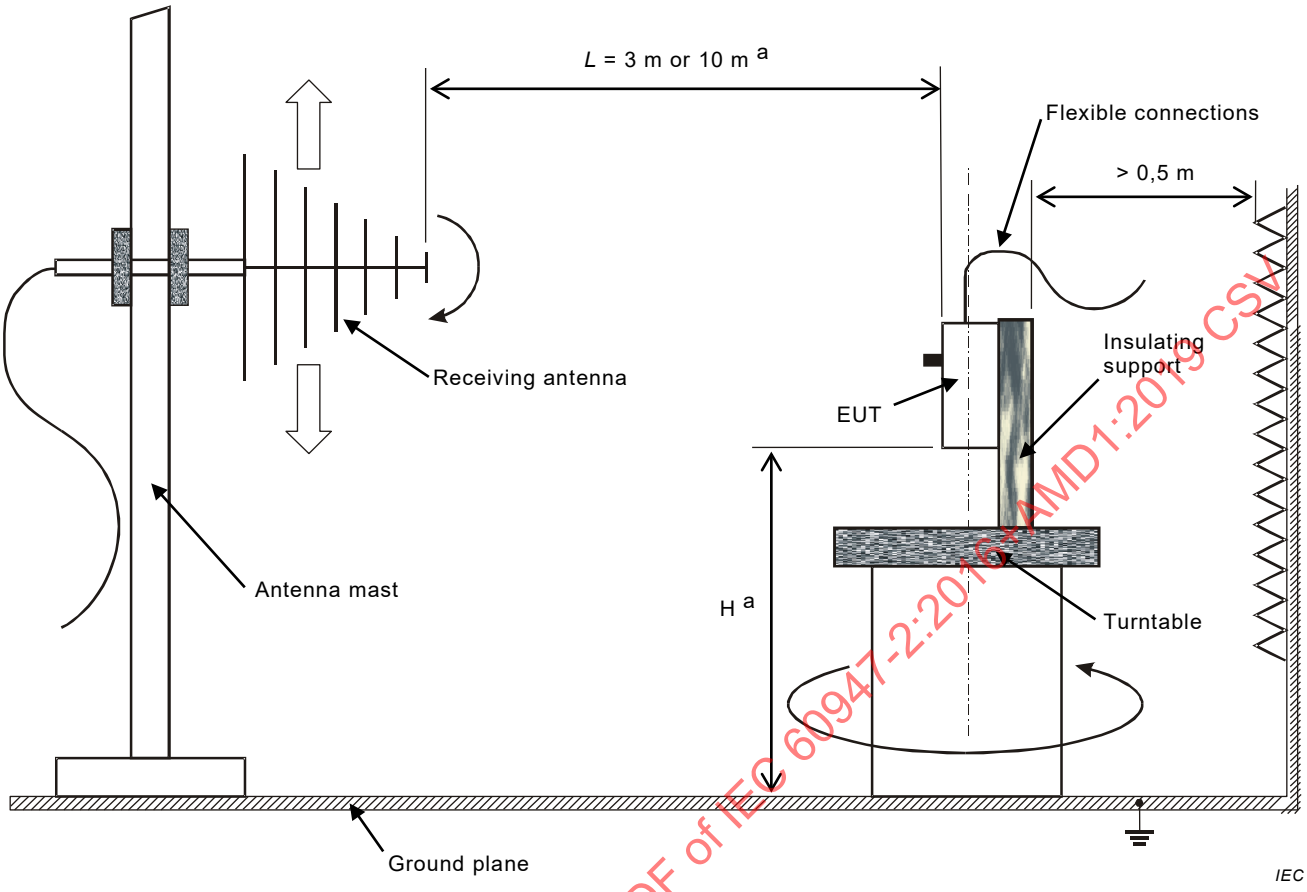
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NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure

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a See CISPR 11/CISPR 32.

Figure J.2 – Test set up for the measurement of radiated RF emissions

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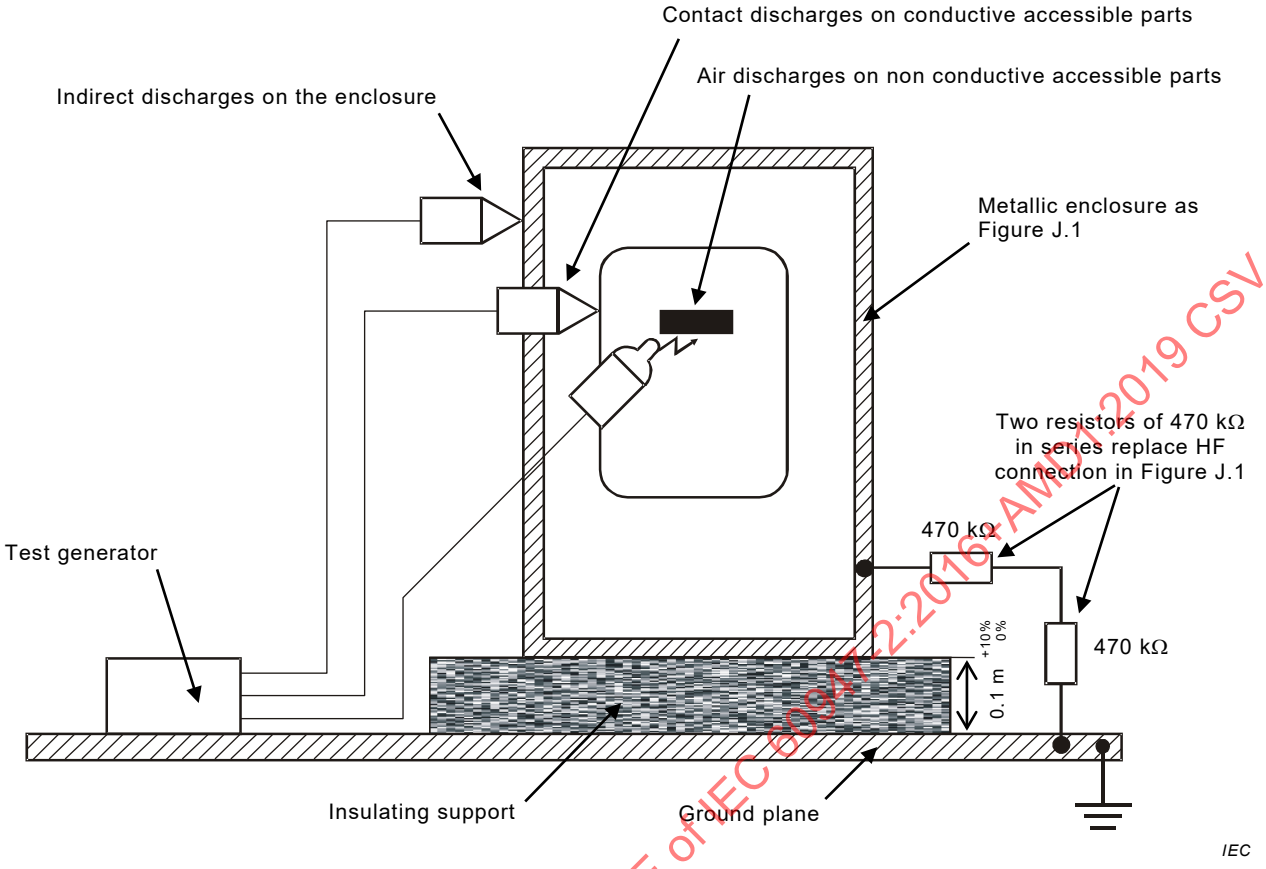
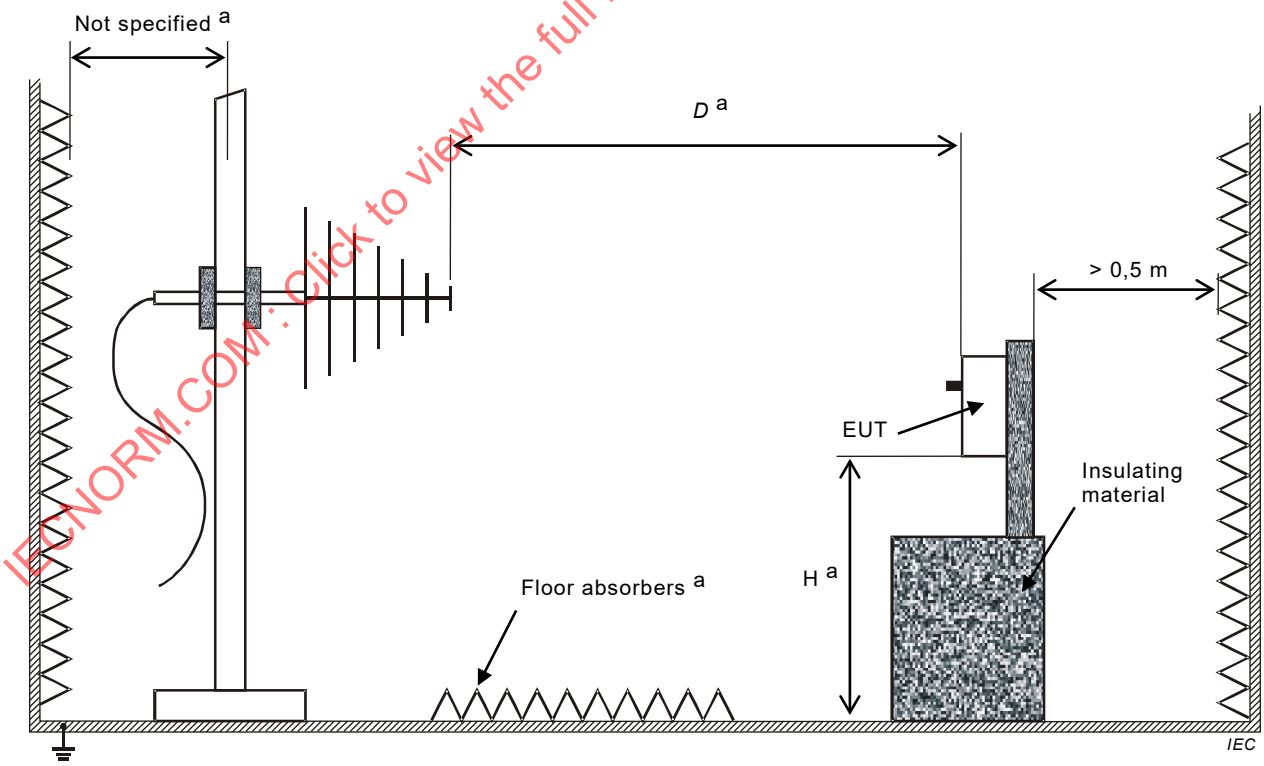


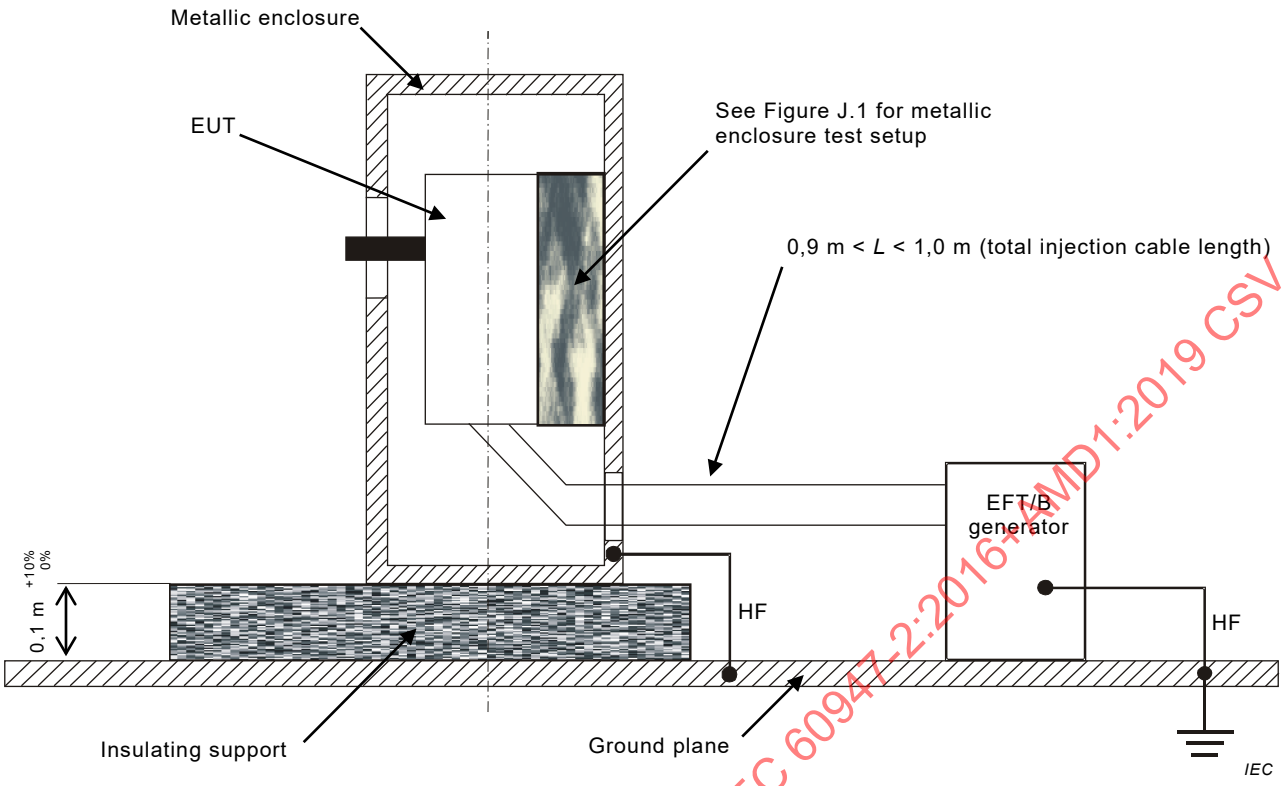
Figure J.3 – Test set up for the verification of immunity to electrostatic discharges



a See IEC 61000-4-3.

Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields

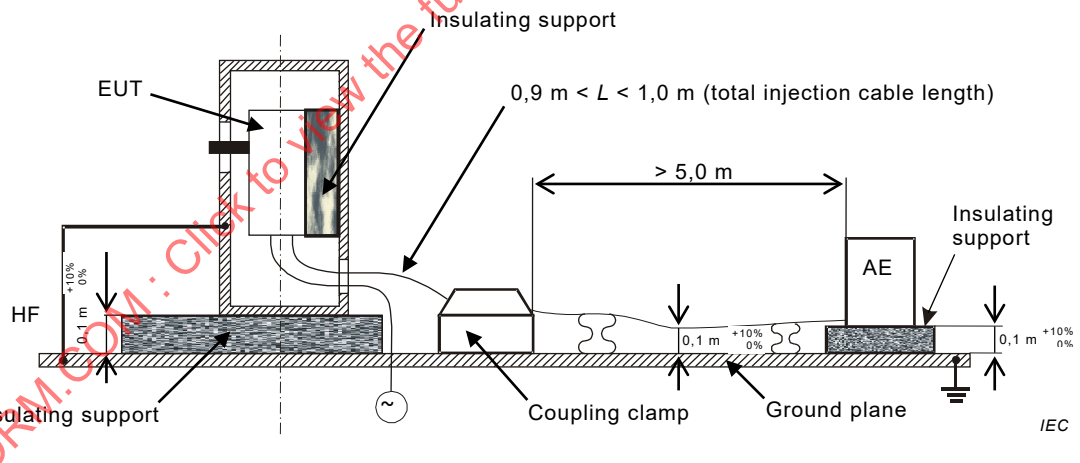
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Key

HF high frequency connection

Figure J.5 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines



Key

AE auxiliary equipment

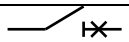
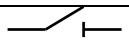
HF high frequency connection

Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

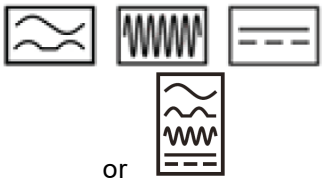
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Annex K
(informative)

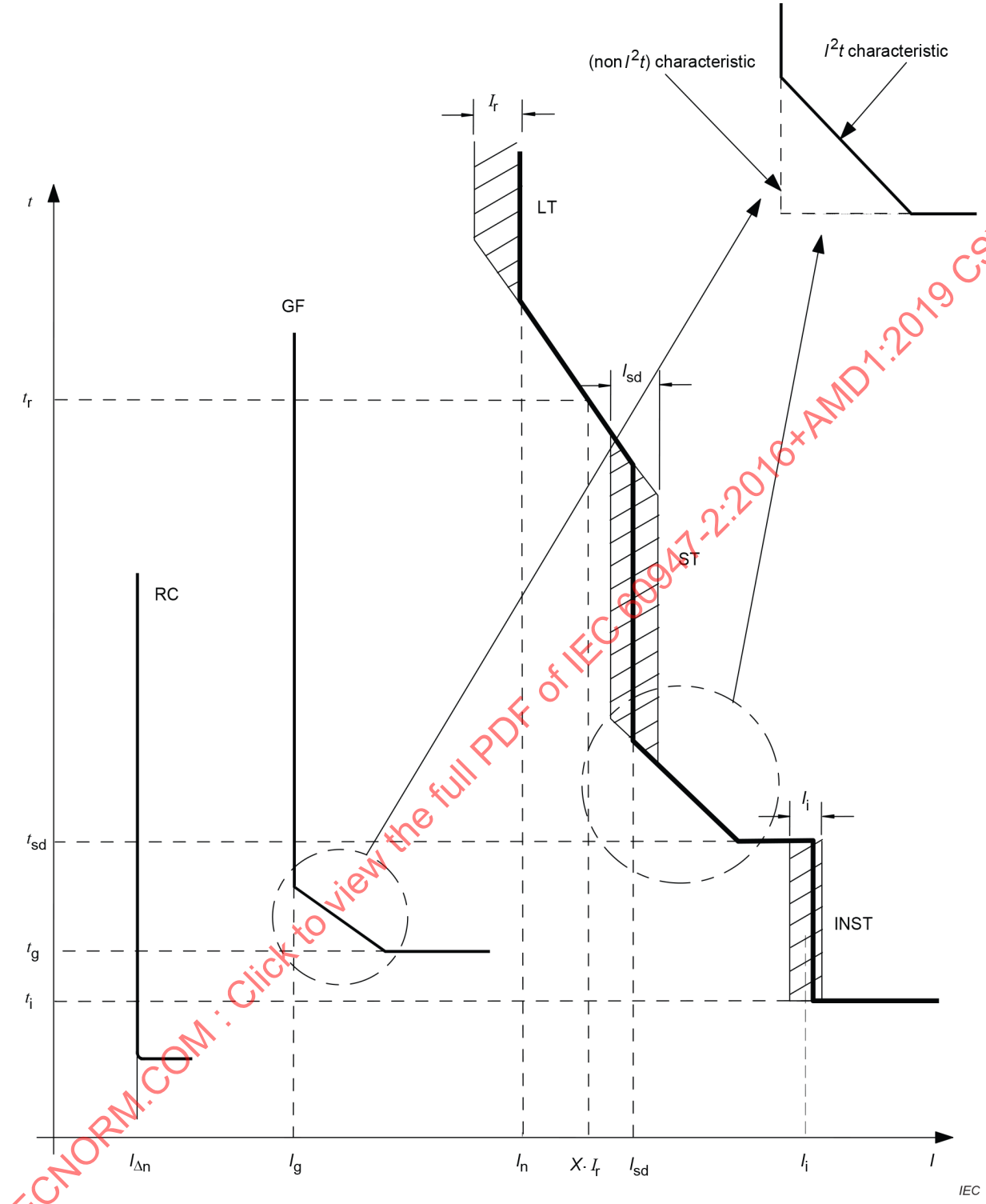
Glossary of symbols and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	5.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	5.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 combined with IEC 60617-S00220 (2007-01)	5.2 O.4
Isolation suitability – CBI		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		5.2
Protective earth terminal		IEC 60417-5019 (2006-08)	5.2
Rated control circuit voltage	U_c		4.7.2
Rated voltage of the voltage source of an MRCD	U_s		M.4.1.2.1
Rated voltage of the monitored circuit for an MRCD	U_n		Annex M
Rated current	I_n		4.3.3.3
Rated impulse withstand voltage	U_{imp}		4.3.2.3
Rated insulation voltage	U_i		4.3.2.2
Rated operational voltage	U_e		4.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		4.3.6.2.3
Rated short-circuit making capacity	I_{cm}		4.3.6.1
Rated short time withstand current	I_{cw}		4.3.6.4
Rated residual short time withstand current of an MRCD	$I_{\Delta w}$		M.4.3.5
Rated conditional short-circuit current	I_{cc}		Annex L Annex M
Rated conditional residual short-circuit current of an MRCD	$I_{\Delta c}$		M.4.3.2
Rated ultimate short-circuit breaking capacity	I_{cu}		4.3.6.2.2
Selectivity limit current	I_s		2.17.4
Take-over current	I_B		2.17.5
Conventional enclosed thermal current	I_{the}		4.3.3.2
Conventional free air thermal current	I_{th}		4.3.3.1
CBRs and MRCDs of type AC		IEC 60417-6148 (2012-01)	B.4.4.1 M.4.2.2.1
CBRs and MRCDs of type A		IEC 60417-6149 (2012-01)	B.4.4.2 M.4.2.2.2

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Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Subclause of this standard
CBRs and MRCDs of type B	 or	IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11 or IEC 60417-6398:2017-12	M.4.2.2.3 B.4.4.3
Test device CBR or MRCD	T		B.7.2.6 M.7.2.6
Current setting of adjustable overload release	I_r		4.7.3
Corresponding tripping time	t_r		Figure K.1
Ground fault current setting	I_g		Figure K.1
Corresponding tripping time	t_g		Figure K.1
Individual pole short-circuit breaking capacity (phase/earthed systems)	I_{su}		Annex C
Individual pole short-circuit test current (IT systems)	I_{IT}		Annex H
Rated instantaneous short-circuit current setting	I_i		2.20 Figure K.1 Annex L Annex O
Maximum corresponding tripping time	t_i		Figure K.1
Not suitable for use in IT systems		IEC 60417-6363:2016-07	Annex H
Rated residual short-circuit making and breaking capacity	$I_{\Delta m}$		Annex B Annex M
Rated residual non-operating current	$I_{\Delta no}$		Annex B Annex M
Rated residual operating current	$I_{\Delta n}$		Annex B Annex M
Short time pick-up current	I_{sd}		Figure K.1
Corresponding tripping time	t_{sd}		Figure K.1
Suitability for phase earthed systems	C		4.3.2.1
Limiting non-actuating time at 2 $I_{\Delta n}$	Δt		Annex B
CBRs for use with 3-phase supply only		IEC 60417-6364:2016-07	B.8.9.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2

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RC residual current
GF ground fault
LT long time
ST short time
INST instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

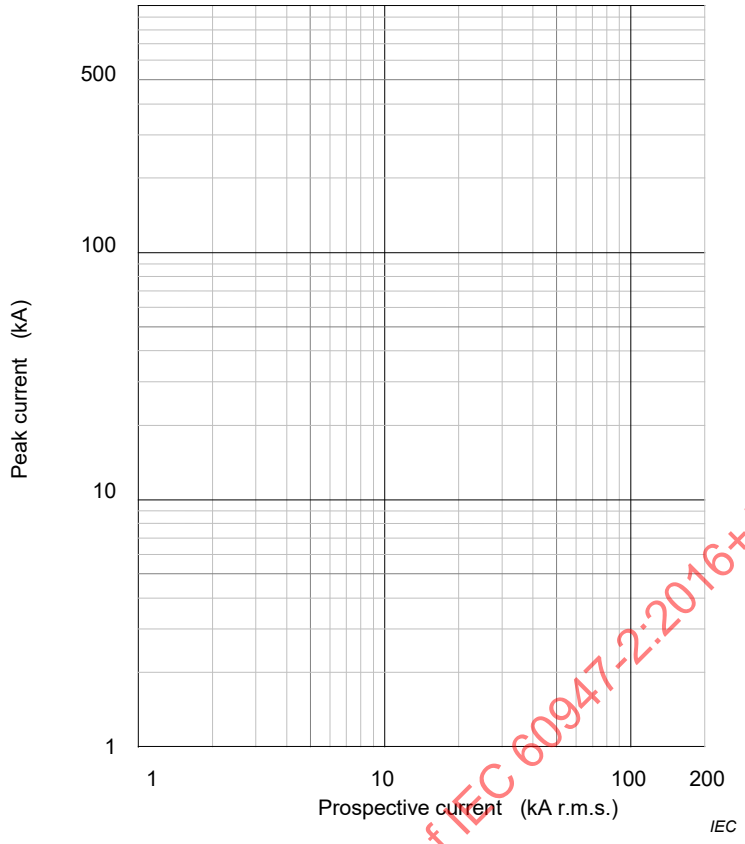


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

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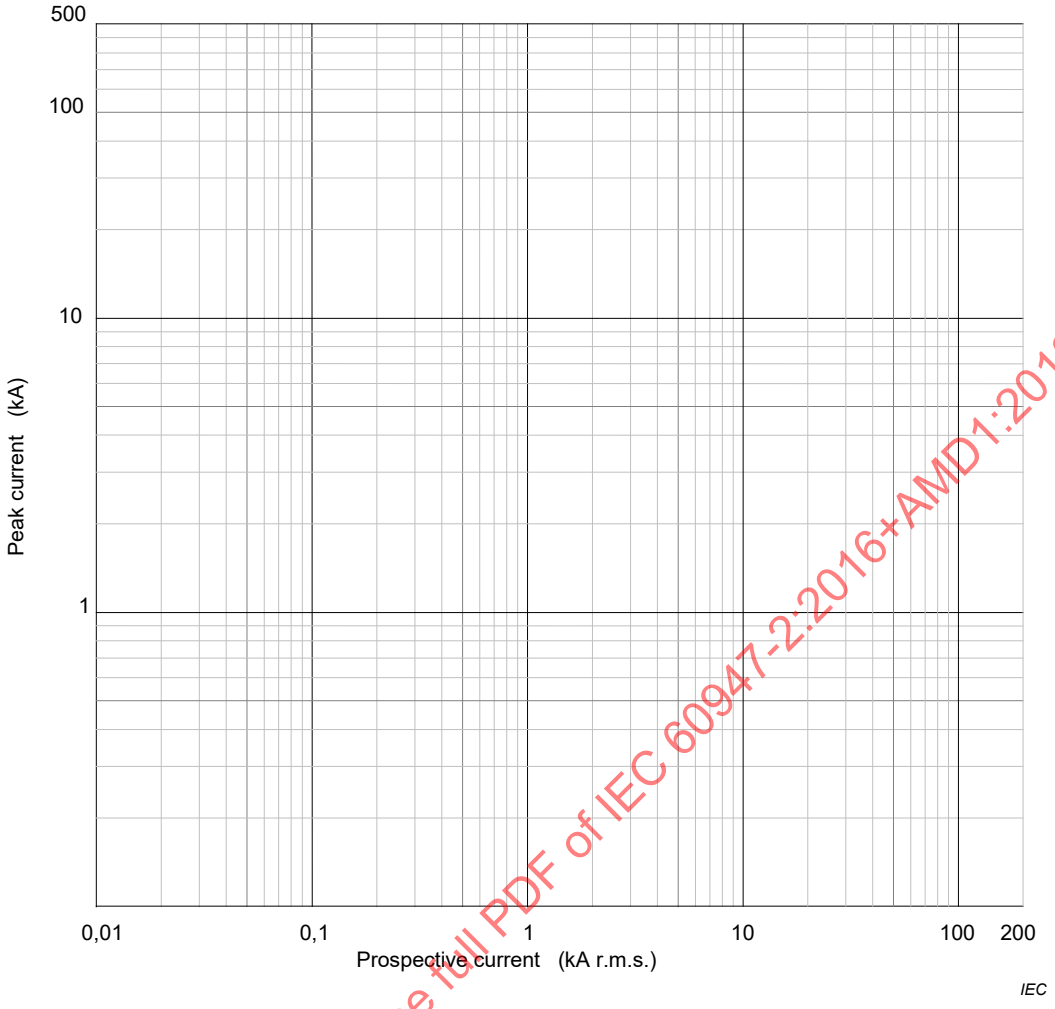


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

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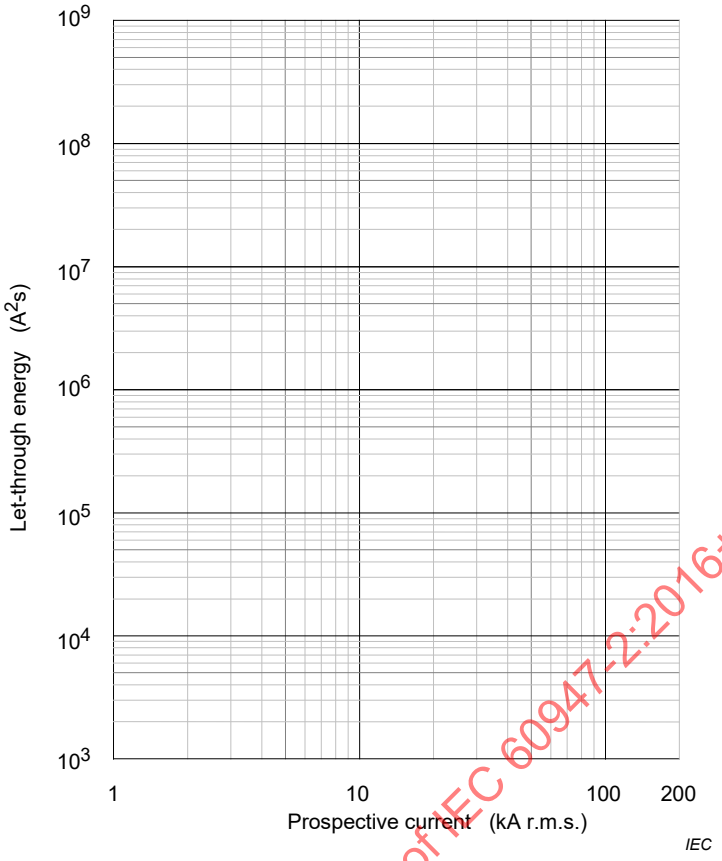


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

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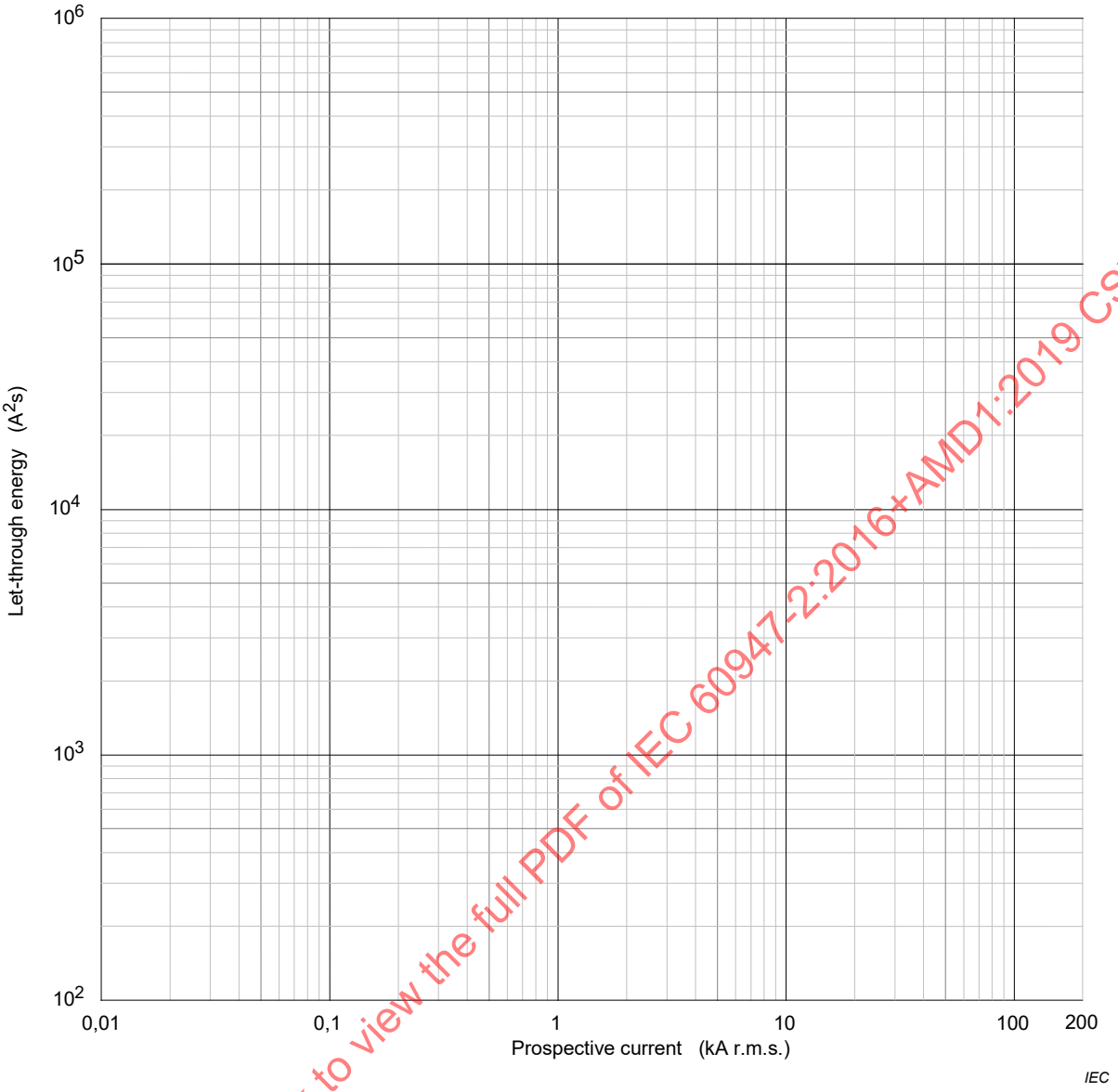
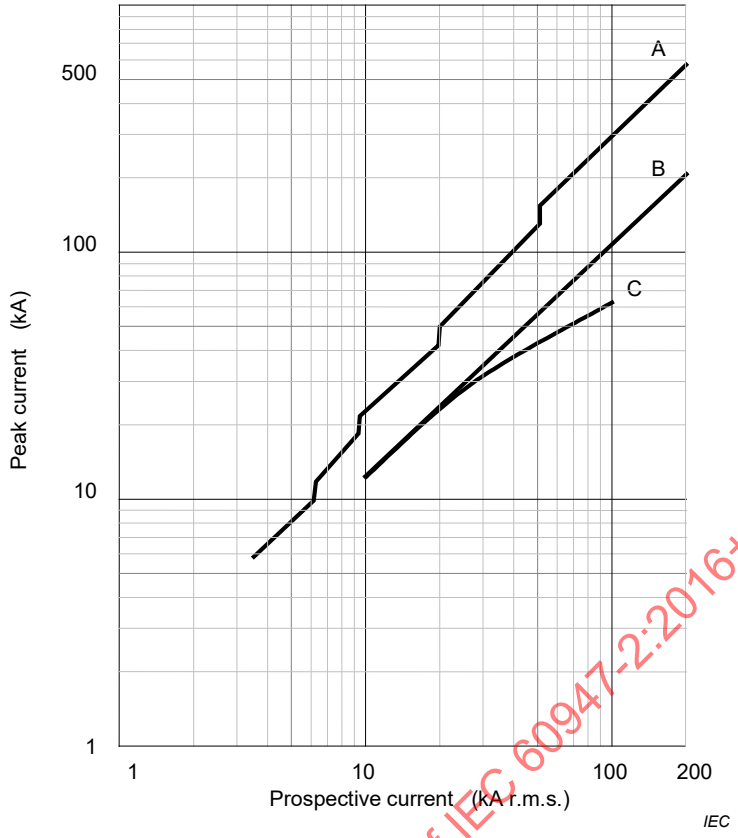


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA

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A Prospective asymmetric peak current under the test conditions of this standard

B Prospective symmetrical peak current

C Typical cut-off current characteristic

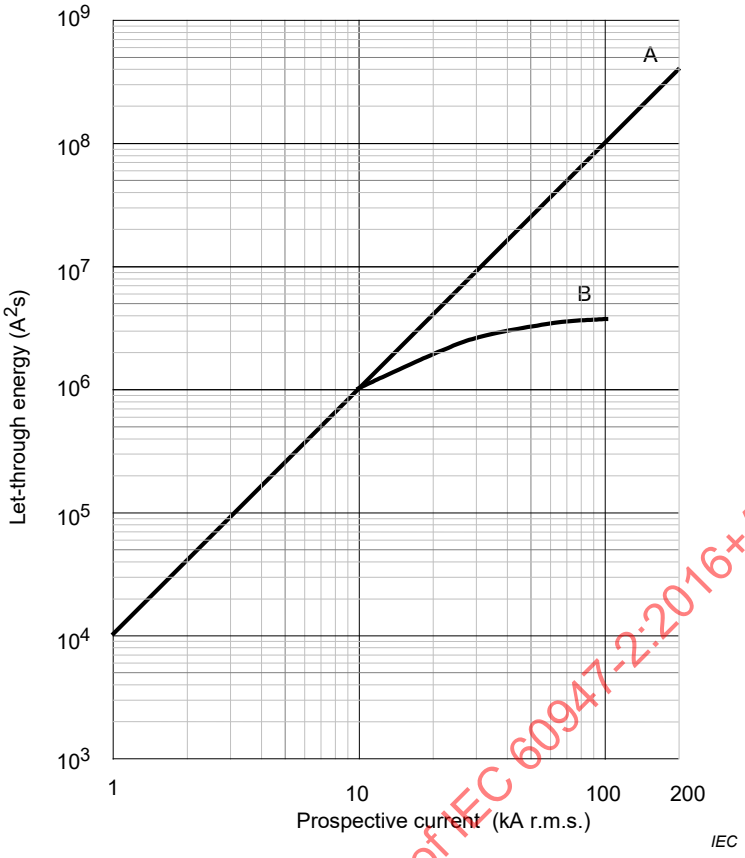
The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of cut-off current the effect of current limiting is shown by comparison with the current that would be let through (prospective current) if the circuit-breaker were not present. The comparison is made with the asymmetric (inrush) peak current or the symmetrical peak current (see 2.3).

The typical curve does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.6 – Example of the use of template to Figure K.2

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A Let-through energy of one half cycle of prospective current at 50 Hz

B Typical let-through energy characteristic of a 250 A MCCB at 400 V 50 Hz

The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

In the case of let-through energy the effect of current limiting is shown by comparison with the energy that would be let through in one half-cycle of the symmetrical prospective current if the circuit-breaker were not present (see 2.3).

The typical curve for the 250 A MCCB does not imply any requirement of the standard for a particular curve shape or value, which will vary according to the design of the product.

Figure K.7 – Example of the use of template to Figure K.4

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Annex L
(normative)

Circuit-breakers not fulfilling the requirements for overcurrent protection

L.1 General

This annex covers circuit-breakers which do not fulfil the requirements for overcurrent protection specified in the main part of this standard, hereinafter referred as CBIs. They are capable of being tripped by an auxiliary device, e.g. shunt or undervoltage release. They do not provide circuit protection but may trip under short-circuit conditions for self-protection. They have a conditional short-circuit rating and may be used for isolation. They may incorporate accessories such as auxiliary and alarm switches for control purposes, and/or remote operators.

A CBI forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases (class Y) or the overload releases only (class X), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

L.2.1
equivalent circuit-breaker
circuit-breaker from which the CBI has been derived, which has been tested according to this standard and which has the same frame size as the CBI

L.2.2
overcurrent protective device
OCPD
device intended to protect a CBI against overcurrents by interrupting them, and incorporating overload protection no less effective than that of the equivalent circuit-breaker and an I_{cu} (for a circuit-breaker) or a breaking capacity (for a fuse) equal to or higher than that of the equivalent circuit-breaker

Note 1 to entry: The OCPD may be the equivalent circuit-breaker.

L.3 Classification

CBIs are classified as follows:

- class X: with integral non-adjustable instantaneous short-circuit releases for self-protection;
- class Y: without integral short-circuit releases.

L.4 Rated values

L.4.1 Rated current (I_n)

The rated current of a CBI shall not exceed the rated current of the equivalent circuit-breaker.

NOTE The rated current of a CBI can be correlated to the rated current corresponding to utilization category AC-22 (see Annex A of IEC 60947-1:2007/AMD2:2014).

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L.4.2 Rated conditional short-circuit current (I_{cc})

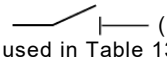
Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

A CBI may have a value of I_{cc} equal to or higher than that of the I_{cu} of the equivalent circuit-breaker.

L.5 Product information

Subclause 5.2 applies, as relevant, with modifications and additions as per Table L.1.

Table L.1 – Product information

Item	Information	Marking location
L1.1	Suitability for isolation, if applicable, with the symbol  (IEC 60617-S00288:2001-07) (this symbol substitutes the symbol used in Table 13, item 1.2)	Visible
L1.2	Classification, with the marking  or  as applicable, where I_i is the rated instantaneous short-circuit current setting (see 2.20)	Visible
L3.1	Rated conditional short-circuit current (I_{cc}) and, if specified, overcurrent protective device (OCPD)	Literature
L3.2	Statement that CBIs do not provide overcurrent protection	Literature
Key Visible:visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Literature:provided in the manufacturer's literature		

L.6 Constructional and performance requirements

A CBI, being derived from the equivalent circuit-breaker (see L.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4.

NOTE A CBI can additionally comply with IEC 60947-3 and be marked accordingly.

L.7 Tests

L.7.1 General

L.7.1.1 CBI of class X

The OCPD is specified.

Case 1:

I_{cc} = I_{cu} of the equivalent circuit-breaker.

No additional tests are required.

NOTE The specified OCPD can be

– the equivalent circuit-breaker (see L.2.1);

– another circuit-breaker (see L.2.2);

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– a fuse of conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and of a breaking capacity ≥ I_{cc} of the CBI.

Case 2:

$I_{cc} > I_{cu}$ of the equivalent circuit-breaker.

Tests shall be made according to L.7.2.1 and L.7.2.2, with the specified OCPD.

This applies when

– the specified OCPD is a circuit-breaker of the same frame size as the equivalent circuit-breaker and of $I_{cu} \geq I_{cc}$ of the CBI,

or

– the specified OCPD is a fuse having a conventional fusing current ≤ the conventional tripping current of the equivalent circuit-breaker and a breaking capacity ≥ I_{cc} of the CBI.

L.7.1.2 CBI of class Y

No tests are required, provided that one of the following two conditions are fulfilled:

– condition 1: $I_{cc} \leq I_{cw}$ of the equivalent circuit-breaker;
– condition 2: I_{cc} ≤ maximum setting of the rated instantaneous short-circuit current setting of the equivalent circuit-breaker.

If neither of the above conditions are fulfilled, tests are required as follows:

Case 1:

The OCPD is specified by the manufacturer.

Tests shall be made according to L.7.2.1 and L.7.2.2.

Case 2:

The OCPD is not specified.

Tests shall be made according to L.7.2.1 and L.7.2.3.

L.7.2 Rated conditional short-circuit tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.1 case 2, or by L.7.1.2 case 1 or case 2, as applicable.

For CBIs having variants with different number of poles, tests shall be carried out on each variant.

L.7.2.1.2 Test conditions

Subclause 8.3.2.6 applies.

The test circuit shall be according to Figure A.4, SCPD being replaced by OCPD. If the OCPD is a circuit-breaker with adjustable overcurrent settings, these shall be set at maximum.

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If the OCPD consists of a set of fuses, each test shall be made with a set of new fuses.

Where applicable, the connecting cables shall be included as specified in 8.3.2.6.4 except that, if the OCPD is a circuit-breaker, the full length of cable (0,75 m) associated with the circuit-breaker may be on the supply side (see Figure A.4).

L.7.2.1.3 Behaviour during tests

Subclause 8.3.2.6.5 applies.

L.7.2.2 OCPD specified

L.7.2.2.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.2.2
Verification of dielectric withstand	L.7.2.2.3

L.7.2.2.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

After each operation, the CBI shall be manually closed and opened three times.

L.7.2.2.3 Verification of dielectric withstand

Following the test of L.7.2.2.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

L.7.2.3 OCPD not specified

L.7.2.3.1 Test sequence

The test sequence comprises the following tests:

Test	Subclause
Verification of I_{cc}	L.7.2.3.2
Verification of dielectric withstand	L.7.2.3.3

L.7.2.3.2 Verification of I_{cc}

The test shall be made with a prospective current equal to I_{cc} of the CBI.

Each test shall consist of a O – t – CO sequence of operations made in accordance with 8.3.5.3, the CO operation being made by closing the CBI.

During the test, the current shall be maintained for three cycles and then disconnected at the power supply.

After each operation, the CBI shall be manually closed and opened three times.

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L.7.2.3.3 Verification of dielectric withstand

Following the test of L.7.2.3.2, the dielectric withstand shall be verified in accordance with 8.3.5.4.

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Annex M
(normative)

Modular residual current devices (without integral current breaking device)

M.1 General

M.1.1 Preamble

To provide protection against the effects of electric shock hazards, devices reacting to residual differential currents are used as protective systems. Residual current devices, where the current-sensing means and the processing device are mounted together with the circuit-breaker, are covered in Annex B.

The provisions of Annex B apply to this annex, adapting, amending or supplementing Annex B as necessary to cover its applicability to equipment where the current-sensing means and/or the processing device are mounted separately from the current-breaking device.

Throughout this annex, "CBR" as used in Annex B (see B.2.3.1) is replaced by "MRCD" (see M.2.2.1).

Wherever relevant, reference is made to the corresponding subclause of Annex B. In other cases, reference is made to the relevant subclause of the main body of this document, or, where applicable, of IEC 60947-1.

Since the equipment covered by this annex does not include a current-breaking device, certain conventional phrases used in Annex B have been adapted accordingly in this annex, e.g. "ON position" is replaced by "ready condition", meaning "ready to operate".

M.1.2 Scope and object

This annex applies to residual current operated devices which do not incorporate a current-breaking device, hereinafter called "Modular Residual Current Device (MRCD)". They are primarily intended to be used in conjunction with circuit-breakers in accordance with this document.

They may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements that shall be complied with by the MRCD in association with the specified current-breaking device(s).

M.2 Terms and definitions

The terms and definitions of Annex B apply.

The following additional terms and definitions apply to this annex.

M.2.1 Terms and definitions relating to the energization of an MRCD

M.2.1.1
voltage source
source intended to supply the energizing quantity that may consist of:

– the line voltage;

– a voltage other than the line voltage

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M.2.2 Terms and definitions relating to the operation and the functions of an MRCD

M.2.2.1
modular residual current device
MRCD
device or an association of devices comprising a current-sensing means and a processing device designed to detect and to evaluate the residual current and to control the opening of the contacts of a current-breaking device

M.2.2.2 Terms and definitions relating to time

M.2.2.2.1
operating time of an MRCD
time that elapses between the instant when the residual operating current is suddenly applied and the instant when the MRCD output changes status

M.2.2.2.2
combination time
time that elapses between the instant when the residual operating current is suddenly applied and the instant of the arc extinction of the associated current-breaking device

M.2.2.2.3
limiting non-operating time
maximum delay during which a residual current higher than the rated residual non-operating current can be applied to the MRCD without actually bringing it to operate

M.2.3
conditional residual short-circuit current
prospective residual current that an MRCD, protected by a specified short-circuit protective device, can satisfactorily withstand for the total operating time of that device under specified conditions

M.2.4
residual short-time withstand current
residual current that an MRCD in the closed position can carry during a specified short time under specified conditions

M.3 Classification

M.3.1 Classification according to the configuration of the primary conductors

M.3.1.1 Terminal type: MRCD with incoming and outgoing terminals and integral primary conductors

M.3.1.2 Through-conductor type

M.3.1.2.1 MRCD with sensing means and processing device combined

M.3.1.2.2 MRCD with sensing means and processing device separated

M.3.2 Classification according to the method of operation

M.3.2.1 MRCD without voltage source (see Figure M.22)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in the case of failure of the voltage source

M.3.2.2.2 Not operating automatically after failure of the voltage source but able to operate as intended in the case of a residual current fault

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M.3.3 Classification according to the possibility of adjusting the residual operating current

Subclause B.3.2 applies.

M.3.4 Classification according to time delay of the residual current function

Subclause B.3.3 applies.

M.3.5 Classification according to behaviour in presence of a d.c. component

M.3.5.1 MRCD of type AC (see M.4.2.2.1)

M.3.5.2 MRCD of type A (see M.4.2.2.2)

M.3.5.3 MRCD of type B (see M.4.2.2.3)

M.4 Characteristics of MRCDs

M.4.1 General characteristics

M.4.1.1 Characteristics of the monitored circuit

M.4.1.1.1 Rated frequency range

Range of frequency values of the monitored circuit for which the MRCD is designed and for which it operates correctly under specified conditions.

M.4.1.1.2 Rated voltage (U_n)

Value of the voltage assigned by the manufacturer to the MRCD.

M.4.1.1.3 Rated current (I_n)

M.4.1.1.3.1 Terminal type

Subclause 4.3.3.3 applies.

M.4.1.1.3.2 Through-conductor type

Value of current, assigned to the MRCD by the manufacturer and marked in accordance with Table M.1, item M1.4, which the MRCD can monitor in uninterrupted duty under specified conditions (see M.8.6).

M.4.1.1.4 Rated insulation voltage (U_i)

Voltage, assigned by the manufacturer, to which the dielectric tests and the MRCD creepage distances are referred with respect to the monitored circuit.

M.4.1.1.5 Rated impulse withstand voltage (U_{imp})

Peak value of the impulse voltage that the MRCD can withstand without failure and to which the values of the clearances are referred with regard to the monitored circuit.

M.4.1.2 Characteristics of the voltage source of MRCDs

M.4.1.2.1 Rated values of the voltage source of MRCDs (U_s)

Values of the voltage source to which the operating functions of the MRCD are referred.

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M.4.1.2.2 Rated values of the frequencies of the voltage source of MRCDs

Values of the frequencies of the voltage source to which the operating functions of the MRCD are referred.

M.4.1.2.3 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

NOTE In the case of a specified power supply, the requirement applies to the incoming connections.

M.4.1.3 Characteristics of auxiliary contacts

Subclause 4.6 of IEC 60947-1:2007 applies.

M.4.2 Characteristics of MRCDs concerning their residual current function

M.4.2.1 General

Subclause B.4.2.4 applies, replacing "non-actuating time" by "non-operating time", and with the following additions.

The maximum values of the MRCD operating time shall be stated by the manufacturer for residual current values equal to $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$ (or 0,25 A for $I_{\Delta n} \leq$ 30 mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n} \leq$ 30 mA).

The maximum combination time shall comply with Table B.1 for a non-time-delay type MRCD and with Table B.2 for a time-delay type MRCD having a limiting non-operating time of 0,06 s.

MRCDs having $I_{\Delta n} \leq$ 30 mA shall be of the non-time-delay type.

M.4.2.2 Operating characteristic in the case of residual current with d.c. component

M.4.2.2.1 Type AC MRCD

Subclause B.4.4.1 applies.

M.4.2.2.2 Type A MRCD

Subclause B.4.4.2 applies.

M.4.2.2.3 Type B MRCD

Subclause B.4.4.3.applies

M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

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M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 4.3.6.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.4.3.4 Peak withstand current

Subclause 2.5.28 of IEC 60947-1:2007 applies to the primary circuit of the MRCD.

M.4.3.5 Rated residual short-time withstand current ($I_{\Delta w}$)

The rated residual short-time withstand current of an equipment is the value of residual short-time withstand current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in this document.

M.4.4 Preferred and limiting values

M.4.4.1 Preferred values of the rated residual operating current ($I_{\Delta n}$)

Subclause B.4.2.1 applies.

M.4.4.2 Minimum value of the rated residual non-operating current ($I_{\Delta no}$)

Subclause B.4.2.3 applies.

M.4.4.3 Limiting value of the non-operating overcurrent in the case of a single-phase load in a multiphase circuit

Subclause B.4.2.4 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

Subclause 4.5.1 applies.

M.5 Product information

The MRCD, processing device or sensing means, as applicable, shall be provided with the information as given in Table M.1. Any marking shall be durable. The marking shall be on the MRCD itself or on one or more nameplates.

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Table M.1 – Product information

Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M1.1	operating characteristic in the case of residual currents in the presence or absence of a d.c. component: – MRCDs of type AC with the symbol (IEC 60417-6148:2012-01) – MRCDs of type A with the symbol (IEC 60417-6149:2012-01) – MRCDs of type B with the symbol (IEC 60417-6398:2017-12) or (IEC 60417-6149:2012-01 + IEC 60417-6160:2012-04 + IEC 60417-6297:2014-11)	Visible	-	Visible
M1.2	rated residual operating current (value(s) or range, as applicable) ($I_{\Delta n}$)	Visible	-	Visible
M1.3	limiting non-operating time (value or range) at 2 $I_{\Delta n}$ for time-delay type, as applicable (Δt)	Visible	-	Visible
M1.4	maximum rated current of the monitored circuit (I_n)	Visible	Marked	Visible [a]
M1.5	test device with the letter "T"	Visible	-	Visible
M2.1	manufacturer's name or trade mark	Marked	Marked	Marked
M2.2	type designation or catalogue reference	Marked	Marked	Marked
M2.3	IEC 60947-2	Marked	-	Marked
M2.4	rated voltage of the voltage source (U_s)	Marked	-	Marked
M2.5	rated voltage of the monitored circuit (U_n)	Marked	Marked	-
M2.6	rated impulse voltage of the monitored circuit (U_{imp})	Marked	Marked	-
M3.1	rated frequency of the voltage source	Literature	-	Literature
M3.2	rated impulse withstand voltage of the voltage source (U_{imp})	Literature	-	Literature
M3.3	output characteristics and/or specified current-breaking device(s)	Literature	-	Literature
M3.4	rated residual non-operating current if it differs from 0,5 $I_{\Delta n}$ ($I_{\Delta no}$)	Literature	-	Literature
M3.5	rated frequency of the monitored circuit	Literature	Literature	-
M3.6	lowest residual current setting at 6 I_n for MRCDs with separate sensing means	-	Literature	Literature
M3.7	rated conditional short-circuit current (I_{cc}) and/or rated short-time withstand current (I_{cw}), and rated conditional residual short-circuit current ($I_{\Delta c}$)	Literature	Literature	Literature
M3.8	IP code, where applicable (see Annex C of IEC 60947-1:2007)	Literature	Literature	Literature
M3.9	position of use and mounting precautions	Literature	Literature	Literature
M3.10	wiring diagram	Literature	Literature	Literature
M3.11	connection of the sensing means to the processing device (cable type, length, etc.)	-	Literature	-

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Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M3.12	for a through conductor type MRCD, dimensions of the conductor aperture (s) and the position relative to the sensing means	Literature	Literature	-
M3.13	for a terminal type MRCD, the maximum cross-sectional area of the conductors to be connected	Literature	-	-
M3.14	distances to be respected with regard to nearby conductors	Literature	Literature	Literature
M3.15	conditions to be observed for the connections between the processing device and the current-breaking device	Literature	-	Literature
M3.16	the SCPDs to be associated with the MRCD	Literature	-	Literature
M3.17	for a non-time-delay type, the current-breaking device(s) to be associated with MRCD to meet the maximum combination times of Table B.1	Literature	-	Literature
M3.18	for a time-delay type having a limiting non-operating time of 0,06 s, the current-breaking device(s) to be associated with the MRCD to meet the combination times of Table B.2	Literature	-	Literature
Key Visible: visible from the front when the MRCD is installed as in service and the test device is accessible Marked: marked on the product Literature: provided in the manufacturer's literature				
[a] Only applicable if the residual current is marked as a percentage of I_n.				

M.6 Normal service, mounting and transport conditions

Clause 6 applies.

M.7 Design and operating requirements

M.7.1 Design requirements

It shall not be possible to modify the operating characteristic of an MRCD except by means which are specifically provided for setting the rated residual operating current or the definite time delay. Changing from one setting to another shall only be possible through a deliberate action, such as the use of a tool, a password or equivalent means.

NOTE MRCDs can be provided with means indicating the status of the outputs.

M.7.2 Operating requirements

M.7.2.1 Operation in the case of a residual current

Subclause B.7.2.1 applies.

Compliance shall be checked by the tests of M.8.3.

M.7.2.2 Operation under short-circuit conditions

MRCDs shall have a rated conditional short-circuit current (I_{cc}) or a rated short-time withstand current (I_{cw}), but may have both. They shall also have a rated conditional residual short-circuit current ($I_{\Delta c}$) or a rated residual short-time withstand current ($I_{\Delta w}$), but may have both.

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MRCDs shall meet the requirements of the relevant tests of M.8.14.

M.7.2.3 Mechanical and electrical endurance

MRCDs shall meet the requirements of the tests of M.8.11.

M.7.2.4 Effects of environmental conditions

MRCDs shall meet the requirements of the test of M.8.15.

M.7.2.5 Dielectric properties

MRCDs shall be capable of withstanding the impulse withstand voltage declared by the manufacturer in accordance with 7.2.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

MRCDs shall meet the requirements of the tests of M.8.4.

Clearances from the live parts of the monitored circuit to:

– the live parts of the MRCD,
– the parts intended to be grounded,
– the clearances between the current paths, for terminal-type MRCDs,

shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 according to the rated impulse withstand voltage.

M.7.2.6 Test device

MRCDs shall be provided with a test device to simulate the passing through the detecting device of a residual current, in order to allow periodic testing of the ability of MRCDs to operate.

The test device shall satisfy the tests of M.8.5.

The protective conductor, if any, shall not become live when the test device is operated.

The operating means of the test device shall be designated by the letter T, and its colour shall not be red or green; the use of a light colour is recommended.

NOTE The test device is only intended to check the tripping function, not the value at which the function is effective with respect to the rated residual operating current and to the break time.

M.7.2.7 Value of the non-operating overcurrent in the case of a single phase load

MRCDs shall meet the requirements of the test of M.8.6.

M.7.2.8 Resistance of MRCDs to unwanted tripping due to surge currents resulting from impulse voltages

MRCDs shall withstand the test of M.8.7.

M.7.2.9 Behaviour of MRCDs of types A and B in the case of an earth fault current comprising a d.c. component

MRCDs of type A and type B shall meet the requirements of the tests of M.8.8, as applicable.

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M.7.2.10 Requirements for MRCDs with voltage source

MRCDs functionally dependent on a voltage source shall operate correctly at any value of the voltage between 0,85 and 1,1 times the rated value U_s (see Figure M.22 and M.4.1.2.1).

According to their classification, MRCDs functionally dependent on a voltage source shall comply with the requirements given in Table M.2.

Table M.2 – Requirements for MRCDs with voltage source

Classification of the device according to M.3.2.2	Behaviour in the case of failure of the voltage source
MRCD operating automatically without delay in the case of voltage source failure (M.3.2.2.1)	Operating without delay according to M.8.12
MRCD operating automatically with delay in the case of voltage source failure (M.3.2.2.1)	Operating with delay according to M.8.12
MRCD not operating automatically after failure of the voltage source but able to operate as intended in the case of a residual-current fault arising (M.3.2.2.2)	Operating according to M.8.13

M.7.2.11 Temperature-rise of terminal-type MRCDs

M.7.2.11.1 General

The temperature rise of the parts of terminal-type MRCDs shall not exceed the values specified in 7.2.2 of IEC 60947-1:2007/AMD2:2014.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014 are only applicable if the ambient air temperature remains between the limits given in M.6.

M.7.2.11.3 Main circuit of terminal type MRCDs

The main circuit of the MRCD, to which the monitored circuit is connected, shall be able to carry the rated current as defined in M.4.1.2.3, without the temperature-rises exceeding the limits given in Table 2 of IEC 60947-1:2007 and in Table 3 of IEC 60947-1:2007/AMD2:2014.

M.7.2.12 Electromagnetic compatibility

Requirements of Annex J apply to the sensing means and the processing device of the MRCD, connected in accordance with the manufacturer's instructions.

Tests shall be carried out in accordance with M.8.16.

Immunity to voltage variations is covered by the requirements of M.7.2.10.

M.7.2.13 Behaviour of MRCDs in the case of failure of the sensing means connection

For MRCDs with separate sensing means, if the sensing means are disconnected, then:

– the MRCD shall operate, or
– the MRCD shall provide a signal to indicate such disconnection, or
– it shall be possible to verify the disconnection by operating the test device.

Compliance is verified by the tests of M.8.9.

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M.7.2.14 Behaviour of MRCDs according to the rated frequency

The MRCD shall operate correctly within its rated frequency range.

Compliance is verified by the tests of M.8.3.3 and M.8.5.

M.8 Tests

M.8.1 General

M.8.1.1 Type tests

Type tests are grouped together in a number of sequences, as shown in Table M.3.

In the case of MRCDs with adjustable residual operating current, the tests shall be made at the lowest setting, unless otherwise stated.

In the case of MRCDs with adjustable time delays (see B.3.3.2.2), the tests shall be carried out at the highest setting, unless otherwise stated.

The release of the associated current breaking device, when applicable, shall be supplied at its lowest rated voltage.

Table M.3 – Test sequences

Sequences	Tests	Subclause
M I	Verification of the operating characteristics	M.8.3
	Verification of dielectric properties	M.8.4
	Verification of the operation of the test device at the limits of rated voltage	M.8.5
	Verification of the limiting value of the non-operating current under overcurrent conditions, in the case of a single phase load	M.8.6
	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	M.8.7
	Verification of the behaviour in the case of an earth fault current comprising a d.c. component	M.8.8
	Verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensing means connection	M.8.9
	Verification of temperature rise of terminal type MRCDs	M.8.10
	Verification of mechanical and electrical endurance	M.8.11
	Verification of the behaviour of MRCDs classified under M.3.2.2.1 in the case of failure of the voltage source	M.8.12
	Verification of the behaviour of MRCDs classified under M.3.2.2.2 in the case of failure of the voltage source	M.8.13
M II	Verification of the behaviour of MRCDs under short-circuit conditions	M.8.14
M III	Verification of the effects of environmental conditions	M.8.15
M IV	Verification of electromagnetic compatibility	M.8.16

For terminal-type MRCDs having variants with different numbers of poles, tests shall be carried out on the variant with the greatest number of poles. For a variant where there is no construction break from the tested variant, no additional tests are required. If the variants' construction is not identical to the variant tested, then those variants shall also be tested.

One sample shall be tested for each of the test sequences M I, M II and M III.

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For test sequence M IV, a new sample may be used for each test, or one sample may be used for several tests, at the manufacturer's discretion.

Unless otherwise specified, each type test (or sequence of type tests) shall be carried out on the MRCD in new and clean condition, the influencing quantities having their normal reference values.

The MRCD shall be installed individually, according to the manufacturer's instructions, in free air, unless otherwise specified. Ambient air temperature shall be between 15 °C and 30 °C, unless otherwise specified. Connections and mounting shall comply with the manufacturer's instructions.

M.8.1.2 Routine tests

Subclause 8.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies except in so far as 7.1 applies.

M.8.3 Verification of the operating characteristics

M.8.3.1 General

The MRCD shall be installed, mounted and wired according to the manufacturer's instructions. Unless otherwise specified, it shall be connected to test equipment, as specified by the manufacturer, representing normal service conditions for the output circuit in order to verify the change in the status of the output. For the measurement of the combination time (see M.2.2.2.2), the MRCD shall be connected to a current-breaking device, specified by the manufacturer, and installed in the monitored circuit. The characteristics of this device shall be given in the test report.

M.8.3.2 Test conditions for MRCDs without voltage source

Subclause B.8.2.2 applies.

M.8.3.3 Test conditions for MRCDs with voltage source

The tests shall be carried out at the following values:

– 0,85 times the minimum rated value of the source voltage for tests specified in M.8.3.4 and M.8.3.5.2;
– 1,1 times the maximum rated value of the source voltage for tests specified in M.8.3.5.3.

MRCDs with a range of rated frequencies shall be tested at the highest and lowest frequencies. However, for MRCDs rated at 50 Hz and 60 Hz, tests at 50 Hz or 60 Hz are considered to cover both frequencies.

M.8.3.4 Off-load tests at 20 °C ± 5 °C

M.8.3.4.1 General

With the connections as shown in Figure M.1, Figure M.2 or Figure M.3, the MRCD shall comply with the tests of M.8.3.4.2, M.8.3.4.3 and M.8.3.4.4 as well as with the test of M.8.3.4.5 where applicable; all these tests are carried out on a single current path.

Unless otherwise specified:

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– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time delay shall be set to its minimum value.

M.8.3.4.2 Verification of operation in the case of a steady increase of the residual current (Figure M.1)

The switches S_1 and S_2, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current shall be steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, up to $I_{\Delta n}$ in approximately 30 s. The value of current causing the change in status of the output is recorded. The test shall be carried out three times.

The three values measured shall be situated between the rated residual non-operating current $I_{\Delta no}$ and $I_{\Delta n}$.

M.8.3.4.3 Verification of operation in the case of closing on residual current (Figure M.2)

The test circuit being calibrated at the rated value of the residual operating current $I_{\Delta n}$ (or at each specific setting of the residual operating current if applicable), the switch S_2 and the current breaking device being closed, switches S_1 and S_a (if applicable) are closed simultaneously. The combination time shall be measured three times.

No measurements shall exceed the limiting value specified for $I_{\Delta n}$ in M.4.2.

M.8.3.4.4 Verification of operation in the case of a sudden appearance of residual current (Figure M.2 and Figure M.3)

The MRCD shall be connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at each of the values of the residual operating current I_Δ specified in M.4.2, the switches S_1, and S_a if applicable, and the test equipment being in the closed position, and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_Δ:

– none of the values of operating time shall exceed the values stated by the manufacturer,

– none of the values of combination time shall exceed the limits specified in M.4.2.

M.8.3.4.5 Verification of the limiting non-operating time of time-delayed type MRCDs (Figure M.3)

The MRCD shall be connected to the test equipment as specified in M.8.3.1.

The test circuit being calibrated at the value 2 $I_{\Delta n}$, the switches S_1, and S_a if applicable, being in the closed position, and the MRCD being ready to operate, the residual current is established by closing the switch S_2 for a time equal to the limiting non-operating time declared by the manufacturer in accordance with M.4.2.

The test shall be carried out 3 times. The MRCD shall not operate.

If the MRCD has an adjustable current setting and/or an adjustable time delay, the test shall be carried out, as applicable, at the lowest setting of the residual operating current and at the maximum and minimum settings of the time delay.

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M.8.3.5 Tests at the temperature limits

M.8.3.5.1 General

Subclause B.8.2.5 applies.

M.8.3.5.2 Off-load test at −5 °C

Subclause B.8.2.5.2 applies, but in accordance with M.8.3.4.4 and M.8.3.4.5 if applicable.

M.8.3.5.3 On-load test at +40 °C

Subclause B.8.2.5.3 applies.

After reaching thermal steady-state conditions, the MRCD shall be submitted to the tests described in M.8.3.4.4 and in M.8.3.4.5 if applicable.

M.8.4 Verification of dielectric properties

M.8.4.1 Verification of rated impulse withstand voltage

M.8.4.1.1 General

The MRCD shall comply with the requirements stated in M.7.2.5. The tests shall be carried out in all the auxiliary contact positions.

The tests are carried out in accordance with 8.3.3.4 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 with the additions listed in M.8.4.1.2 and M.8.4.1.3.

M.8.4.1.2 Verification of rated impulse withstand voltage with respect to the monitored circuit

M.8.4.1.2.1 Tests for terminal type MRCD

The test voltage, defined in M.7.2.5, shall be applied as indicated in 8.3.3.4.1 item 2), of IEC 60947-1:2007/AMD1:2010.

M.8.4.1.2.2 Tests for MRCDs of through-conductor type

The test shall be carried out on a sensing means through which runs an uninsulated busbar, installed according to the manufacturer's instructions.

The test voltage, defined in M.7.2.5, shall be applied as follows:

a) between all the conductors of the monitored circuit connected together and the mounting plate if the sensing means are separate;

b) between all the conductors of the monitored circuit connected together and the processing device enclosure or its mounting plate if the sensing means are combined;

c) between each auxiliary circuit and
   - the monitored circuit;
   - the enclosure or mounting plate of the MRCD.

M.8.4.1.3 Verification of rated impulse withstand voltage of the voltage source circuit (if applicable)

If the voltage source circuit is supplied directly from the monitored circuit, the tests are carried out in accordance with M.8.4.1.2.1.

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If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2007 shall be applied as follows:

a) between all the supply terminals of the voltage source circuit connected together and the enclosure or mounting plate of the MRCD;

b) between each supply terminal of the voltage source circuit and the other supply terminals connected together and connected to the enclosure or mounting plate of the MRCD.

M.8.4.2 Capability of any circuits connected to the monitored circuit in respect of withstanding d.c. voltages due to insulation measurements

The need for this verification of MRCDs that cannot be disconnected in service is under consideration.

M.8.5 Verification of the operation of the test device at the limits of the rated voltage

Subclause B.8.4 applies, but by replacing "rated voltage" with "rated voltage of the voltage source". The MRCD shall be tested in association with the test equipment specified in M.8.3.1.

M.8.6 Verification of the limiting value of non-operating current under overcurrent conditions, in the case of a single phase load

The MRCD shall be connected in accordance with Figure M.4 a), b) or c), as applicable, paying particular attention to the positioning of the conductors in the case of a through-conductor type in accordance with the manufacturer's instructions, the switch S_1 being open. The switch S_a, where applicable, is then closed and the voltage U_s is applied.

The test shall be made in accordance with B.8.5 at a current of 6 I_n. For MRCDs with separate sensing means, the test shall be carried out at the lowest residual current setting value declared by the manufacturer.

No change of state of the MRCD shall occur.

M.8.7 Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages

M.8.7.1 General

For MRCDs with adjustable time delays, the time delay shall be set at its minimum.

M.8.7.2 Verification of the resistance to unwanted tripping in the case of loading of the network capacitance

Subclause B.8.6.2 applies with Figure M.5 replacing Figure B.5.

No change of state of the MRCD shall occur.

M.8.7.3 Verification of the resistance to unwanted tripping in the case of flashover without follow-on current

Subclause B.8.6.3 applies with Figure M.6 replacing Figure B.7.

No change of state of the MRCD shall occur during the test at 250 A. During the test at 3 000 A, the MRCD may operate.

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M.8.7.4 Verification after the tests

After the tests of M.8.7.2 and M.8.7.3, the operation of the MRCD shall be verified in accordance with M.8.3.4.4, with one measurement of operating time, at $I_{\Delta n}$ only.

M.8.8 Verification of the behaviour in the case of an earth fault current comprising a d.c. component

M.8.8.1 General

The test conditions of M.8.3.1, M.8.3.2 and M.8.3.3 apply.

For MRCDs, the operation of which depend on a voltage source, the tests shall be carried out at 1,1 and 0,85 times the rated voltage of the voltage source (U_s).

Unless otherwise specified:

– for MRCDs with setting of the residual operating current by continuous variation or by discrete values, the tests shall be carried out at the highest and at the lowest settings, as well as at an intermediate setting;

– for MRCDs of the adjustable time-delay type, the time delay shall be set to its minimum value.

M.8.8.2 Type A MRCD

M.8.8.2.1 Verification of the correct operation in the case of a continuous rise of a residual pulsating direct current

Subclause B.8.7.2.1 applies with Figure M.7 replacing Figure B.8.

The switches S_1 and S_2, and S_a if applicable, are closed, the MRCD being ready to operate.

M.8.8.2.2 Verification of the correct operation in the case of a suddenly appearing residual pulsating direct current

B.8.7.2.2 applies with the following modifications.

The test circuit shall be in accordance with Figure M.8 or Figure M.9, as applicable.

Verification is carried out in two steps:

– for the first step, the MRCD is connected to a measurement instrument indicating the change in status of the output;

– for the second step, the MRCD is connected to a current-breaking device, specified by the manufacturer, and installed in the monitored circuit. The characteristics of this current-breaking device shall be stated in the test report.

The switches S_1, and S_a if applicable, are in the closed position and the MRCD being ready to operate, the residual current is suddenly established by closing the switch S_2.

The test shall be carried out at each value of the residual current specified:

– for the first step, none of the operating times measured shall exceed the values stated by the manufacturer;

– for the second step, no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

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M.8.8.2.3 Verification of the correct operation with load at the reference temperature

The tests of M.8.8.2.2 are repeated, the current path under test and another current path of the MRCD being loaded with the rated current, the current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure M.7 c).

M.8.8.2.4 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a smooth direct current of 6 mA

B.8.7.2.4 applies with the following modifications.

The test circuit shall be in accordance with Figure M.10 a), b) or c), as applicable.

M.8.8.3 Type B MRCD

M.8.8.3.1 Verification of the correct operation in the case of a steady increase of composite residual current

Subclause B.8.8.1 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

M.8.8.3.2 Verification of the correct operation in the case of sudden appearance of composite residual current

Subclause B.8.8.2 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

Three measurements of operating time and of combination time (if applicable) are made at each value of I_{Δ}.

None of the operating times measured shall exceed the values stated by the manufacturer for the response time at 5 $I_{\Delta n}$ of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.3 Verification of the correct operation in the case of residual sinusoidal alternating currents up to 1 000 Hz

Subclause B.8.8.3 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.16.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time at $I_{\Delta n}$ of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1 for $I_{\Delta n}$.

M.8.8.3.4 Verification of the correct operation in the case of a residual alternating current superimposed by a residual smooth direct current

Subclause B.8.8.4 applies, but "MRCD" replaces "CBR", and with the following modification:

The tests shall be performed in accordance with Figure M.17.

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M.8.8.3.5 Verification of the correct operation in the case of a residual pulsating direct current superimposed by a residual smooth direct current

Subclause B.8.8.5 applies, but "MRCD" replaces "CBR", and with the following modification:

The tests shall be performed in accordance with Figure M.10.

M.8.8.3.6 Verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from two phases

Subclause B.8.8.6 applies, but "MRCD" replaces "CBR", and with the following modifications:

The tests shall be performed in accordance with Figure M.15.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.7 Verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from three phases

Subclause B.8.8.7 applies, but "MRCD" replaces "CBR", with the following modifications:

The tests shall be performed in accordance with Figure M.14.

The verification of the break time is replaced by a verification of the operating time, and the combination time if applicable; none of the operating times measured shall exceed the values stated by the manufacturer for the response time of the MRCD only; no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

M.8.8.3.8 Verification of the correct operation in the case of residual smooth direct current

M.8.8.3.8.1 Verification of the correct operation in the case of residual smooth direct current without load

Verification is carried out in two steps:

a) The test circuit shall be in accordance with Figure M.11, switches S_1 and S_2, and S_a if applicable, being closed.

   One current path, chosen at random, shall be tested twice in position I and twice in position II of switch S_3.

   The residual current, starting from zero, shall be steadily increased to 2 $I_{\Delta n}$ within 30 s. The MRCD shall operate between 0,5 $I_{\Delta n}$ and 2 $I_{\Delta n}$.

b) The test circuits shall be in accordance with Figure M.12 and Figure M.13.

   The circuit being successively calibrated at the values specified hereafter, the switch S_1 or S_a, as applicable, being closed and the MRCD being ready to operate, the residual current is suddenly established by closing switch S_2.

   The test shall be carried out at each value of residual current specified in Table B.1, multiplied by two.

   Two operating time measurements are performed for each value, the switch S_3 being in position I for the first measurement and in position II for the second measurement.

   None of the operating times shall exceed the values stated by the manufacturer, and no value of combination time, when applicable, shall exceed the limiting values specified in M.4.2.1.

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M.8.8.3.8.2 Verification of the correct operation in the case of residual smooth direct current with load

The test of M.8.8.3.8.1 a) shall be repeated, the current path under test and another current path of the MRCD being loaded with the rated current.

M.8.8.3.9 Tests at the temperature limits

The MRCD shall perform the tests specified in M.8.8.3.6 and M.8.8.3.7 (but, in each case, only the verification of the operating time) and M.8.8.3.8.1 b), under the following conditions successively:

a) ambient air temperature: −5 °C, without load;

b) ambient air temperature: +40 °C, and, for terminal-type MRCDs, the MRCD having been previously loaded with its rated current until it has attained thermal steady-state conditions. In practice, these conditions are reached when the variation of temperature-rise, measured at one of the main terminals, does not exceed 1 K per hour. The loading of the main circuit may be carried out at reduced voltage but auxiliary circuits shall be supplied with their rated operating voltage, particularly for components depending on the line voltage.

In the case of MRCDs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

M.8.9 Verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensing means connection

M.8.9.1 General

For MRCDs with a range of rated values of the voltage source, tests shall be carried out for each rated value, in accordance with M.8.9.2 or M.8.9.3, as applicable, and in accordance with the manufacturer's instructions.

M.8.9.2 Test method 1

The MRCD shall be connected to the external sensing means and shall be supplied successively with each rated voltage, as shown in Figure M.18. There shall be no fault current flowing in the sensing means and the test circuit shall not be activated.

The sensing means are disconnected and the MRCD shall operate or provide a signal to indicate such disconnection.

The time interval between the disconnection and the output status change is measured.

Three measurements are carried out; no value shall exceed 5 s.

M.8.9.3 Test method 2

Tests shall be carried out as follows:

a) the test device is actuated. The MRCD shall operate;

b) the sensing means are disconnected and the test device is actuated. The MRCD shall not operate.

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M.8.10 Verification of temperature-rise of terminal type MRCDs

M.8.10.1 General

Unless otherwise specified, the MRCD shall be connected with the appropriate conductors whose cross-sections are specified in Tables 9, 10 and 11 of IEC 60947-1:2007, and fixed on a mat black painted plywood board of about 20 mm in thickness.

The test shall be carried out in an atmosphere protected against abnormal external heating or cooling.

M.8.10.2 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007/AMD2:2014 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 8.3.3.3.4 of IEC 60947-1:2007, at the rated current I_n.

During this test, temperature-rise shall not exceed the values listed in Table 2 of IEC 60947-1:2007 and Table 3 of IEC 60947-1:2007/AMD2:2014.

M.8.11 Verification of mechanical and electrical endurance

The MRCD output shall be subjected to mechanical and electrical endurance tests including:

– 500 off-load operations controlled by the test device;
– 500 off-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path;
– 500 on-load operations controlled by the test device;
– 500 on-load operations by passing the rated residual operating current $I_{\Delta n}$ through one current path.

The on-load tests are carried out on a circuit corresponding to the output rating given by the manufacturer.

After the tests, the MRCD shall show no damage impairing its further use. The output shall be able to withstand in the open position a voltage equal to twice its maximum rated value given by the manufacturer.

NOTE 1 This verification is not applicable if the output is designed for a specific load and does not have a rated output voltage.

For MRCDs having more than one output rating, two tests shall be carried out:

– a test at the highest rated current at the corresponding voltage;
– a test at the highest rated voltage at the corresponding current.

The MRCD shall be capable of performing satisfactorily the tests specified in B.8.11.4 b).

NOTE 2 If the MRCD output has an appropriate AC-15 rating, in accordance with IEC 60947-5-1, the tests of this subclause are not necessary.

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M.8.12 Verification of the behaviour of MRCDs classified under M.3.2.2.1 in the case of failure of the voltage source

M.8.12.1 General

For MRCDs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For MRCDs having an adjustable time-delay, the test shall be carried out at any one of the time-delay settings.

The voltage applied shall be the rated voltage of the voltage source (U_s).

For MRCDs having a range of rated voltages of the voltage source, the tests shall be carried out at the maximum and minimum values of the voltage range.

M.8.12.2 Determination of the limiting value of the voltage source

Tests shall be carried out in accordance with B.8.9.2, with "voltage source" replacing "line voltage" and "voltage source terminals" replacing "line terminals".

M.8.12.3 Verification of automatic opening in the case of voltage source failure

Tests are carried out in accordance with B.8.9.3, with "voltage source" replacing "line voltage" and "voltage source terminals" replacing "line terminals". The time interval between the switching off and the change in status of the output shall be measured.

Three measurements are carried out:

– for instantaneous MRCDs, no value shall exceed 1 s;

– for time-delayed MRCDs, no value shall exceed 1 s plus the set time delay.

M.8.13 Verification of the behaviour of MRCDs classified under M.3.2.2.2 in the case of failure of the voltage source

The provisions of B.8.10 apply in the case where the voltage source is the line voltage of the monitored circuit. In the case where the voltage source is other than the line voltage, a test shall be carried out as follows.

For MRCDs having an adjustable residual operating current, the test shall be carried out at the lowest setting.

For MRCDs having an adjustable time delay, the test shall be made at any one of the time-delay settings.

The MRCD shall be connected according to Figure M.3 and supplied with its rated voltage, or in the case of a range of rated voltages, with the lowest rated voltage.

The supply is then switched off by opening S_a or S_1, as applicable; the MRCD shall not operate.

The switch S_a or S_1, as applicable, is then reclosed and the voltage is reduced to 70 % of the lowest rated voltage. The rated residual current $I_{\Delta n}$ is then applied by closing S_2; the MRCD shall operate.

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M.8.14 Verification of the behaviour of MRCDs under short-circuit conditions

M.8.14.1 General

Since an MRCD is not a switching device, where it has been tested with a given SCPD in accordance with M.8.14.3 and M.8.14.5, tests with other SCPDs of a lower peak current and lower I^2t are considered to be also covered.

M.8.14.2 General conditions for the test

M.8.14.2.1 Test circuit

Subclause 8.3.4.1.2 of IEC 60947-1:2007/AMD1:2010 applies, except Figures 9, 10, 11 and 12. The test shall be carried out in accordance with Figure M.19, Figure M.20 or Figure M.21, as applicable.

For short-time withstand tests, the SCPD shall be omitted.

M.8.14.2.2 Tolerances on the test quantities

Table 8 of IEC 60947-1:2007 applies.

M.8.14.2.3 Power factor of test circuit

Table 11 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 8.3.2.2.3, item a), of IEC 60947-1:2007/AMD2:2014 applies.

M.8.14.2.5 Calibration of the test circuit

The SCPD and the MRCD, if of the terminal type, are replaced by temporary connections of impedance negligible compared with that of the test circuit. For other MRCDs, the conductors through the sensing means are part of the calibrating circuit.

For the test at rated conditional short-circuit current I_{cc}, the resistors R and the reactors L are adjusted so as to obtain, at the test voltage, a current equal to I_{cc}, at the prescribed power factor. The test circuit shall be energized simultaneously in all poles.

For the tests at rated residual conditional short-circuit current $I_{\Delta c}$, the additional impedance Z is used so as to obtain the required current values.

M.8.14.2.6 Condition of the MRCD for tests

The wiring and the fixing of the MRCD shall be in accordance with the manufacturer's instructions.

This is particularly the case for MRCDs of the through-conductor type for installing conductors that pass through the sensing means.

The MRCD shall be mounted on a metal plate.

M.8.14.2.7 Condition of the MRCD after tests

After each test of M.8.14.3, M.8.14.4 and M.8.14.5, the MRCD shall show no damage impairing its further use and, in the case of a terminal type MRCD, shall be capable of withstanding a voltage equal to twice its rated voltage under the conditions of 8.3.3.6.

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The MRCD shall perform satisfactorily the tests specified in B.8.11.4b) and M.8.12.3, if applicable, and limited to one measurement.

M.8.14.3 Verification of the rated conditional short-circuit current (I_{cc})

M.8.14.3.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated short-time withstand current I_{cw}.

M.8.14.3.2 Test conditions

The negligible impedance connections are replaced by the SCPD and, if applicable, by the terminal-type MRCD.

M.8.14.3.3 Test procedure

The rated voltage of the voltage source, if applicable, shall be applied.

The following sequence of operations is performed:

O – *t* – O

M.8.14.3.4 Behaviour of the MRCD during the tests

During the tests, the MRCD may operate.

M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 8.3.4.3 of IEC 60947-1:2007 applies to the primary circuit.

The test may be carried out at any convenient voltage. The SCPD of Figure M.17, Figure M.18 and Figure M.19 shall be omitted for the test.

M.8.14.5 Verification of the rated conditional residual short-circuit current ($I_{\Delta c}$)

M.8.14.5.1 General

This test is not necessary if the let-through peak current and the let-through energy of the associated SCPD are lower than the peak current and let-through energy corresponding to the rated residual short-time withstand current $I_{\Delta w}$.

M.8.14.5.2 Test conditions

The MRCD shall be tested under the conditions prescribed in M.8.14.2.1 but shall be connected so that the short-circuit current is a residual current. For residual short-circuit tests, the connection B, indicated by the dashed line in Figure M.19, Figure M.20 and Figure M.21, replaces the connection through the sensing means, between X and Y.

The test shall be carried out on one current path.

The negligible impedance connections are replaced by the SCPD and, where applicable, by the MRCD.

M.8.14.5.3 Test procedure

The following sequence shall be performed without synchronisation with respect to the voltage wave:

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O – *t* – O

M.8.14.5.4 Behaviour of the MRCD during the tests

During the tests, the MRCD may operate.

M.8.14.6 Verification of rated residual short-time withstand current ($I_{\Delta w}$)

Subclause M.8.14.4 applies, except that the MRCD shall be connected so that the short-circuit current is a residual current.

M.8.15 Verification of the effects of environmental conditions

The tests conditions of B.8.12 apply.

At the end of the tests, the MRCD shall be capable of performing satisfactorily the tests specified in B.8.11.4 b).

M.8.16 Verification of electromagnetic compatibility

M.8.16.1 Immunity tests

M.8.16.1.1 General

Subclause B.8.13.1 applies, but with "CBR" replaced by "MRCD" where necessary, except that the verifications after the tests shall be a measurement of the operating time (see M.2.2.2.1) at $I_{\Delta n}$, which shall not exceed the value declared by the manufacturer (see M.4.2). The test circuit for the verification shall be in accordance with Figure M.3.

M.8.16.1.2 Electrostatic discharges

Subclause B.8.13.1.2 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.3 Radiated RF electromagnetic fields

Subclause B.8.13.1.3 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.4, and Figure M.22 for MRCDs with separate sensing means.

M.8.16.1.4 Electrical fast transients/bursts (EFT/B)

Subclause B.8.13.1.4 applies with the additional specifications given in M.8.16.1.1.

The test set-up shall be in accordance with Figure J.5 and Figure J.6, and Figure M.23 for MRCDs with separate sensing means.

M.8.16.1.5 Surges

Subclause B.8.13.1.5 applies with the additional specifications given in M.8.16.1.1.

M.8.16.1.6 Conducted disturbances induced by RF fields (common mode)

Subclause B.8.13.1.6 applies with the additional specifications given in M.8.16.1.1.

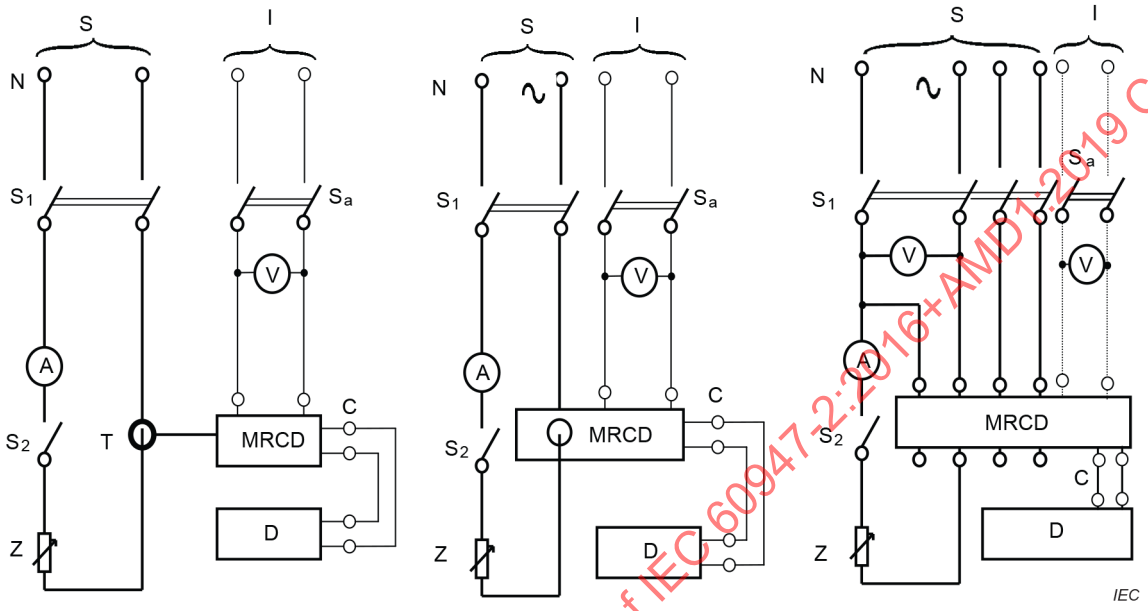
The test set-up shall be in accordance with Figure M.24 for MRCDs with separate sensing means.

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An EM clamp may be used when normal functioning cannot be achieved because of the impact of the CDN on the MRCD.

M.8.16.2 Emission tests

Subclause B.8.13.2 applies.



a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

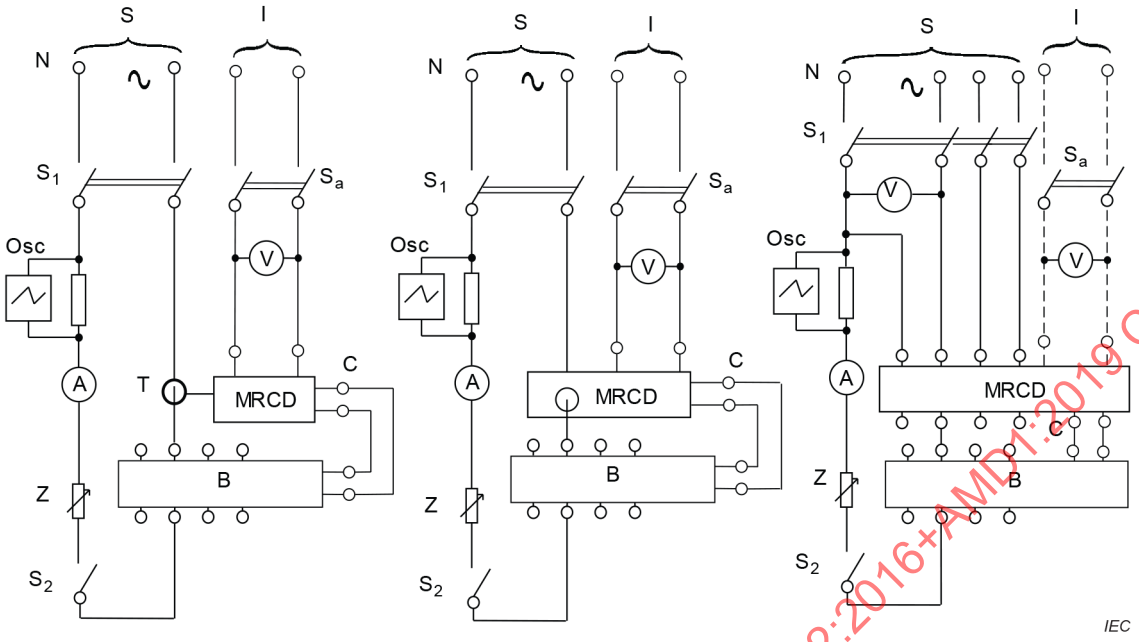
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	single-pole switch		

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

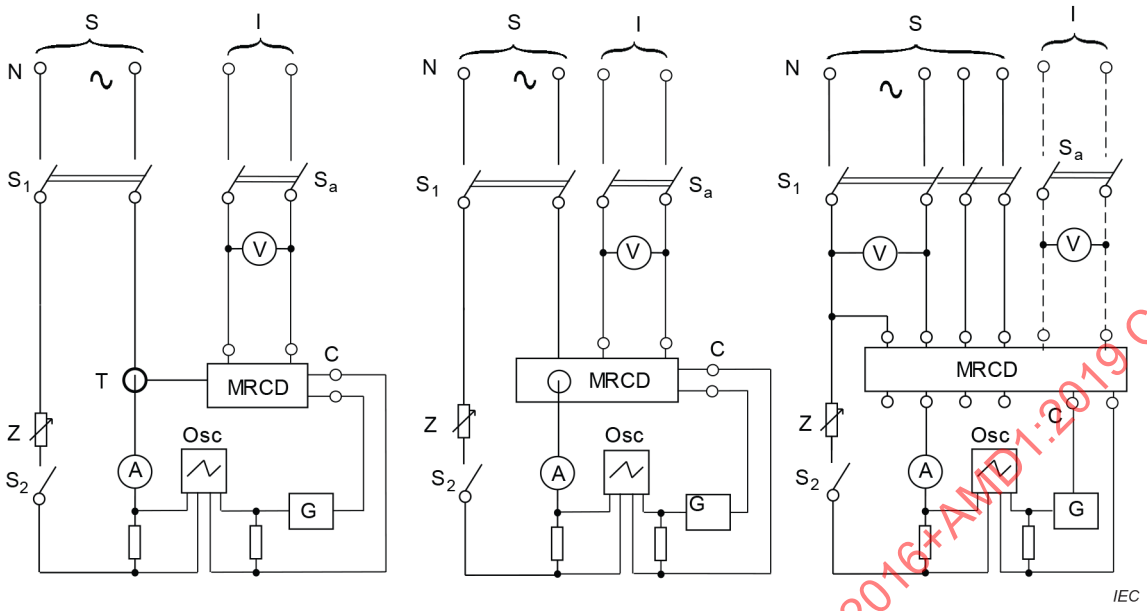
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope

Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with current breaking device)

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

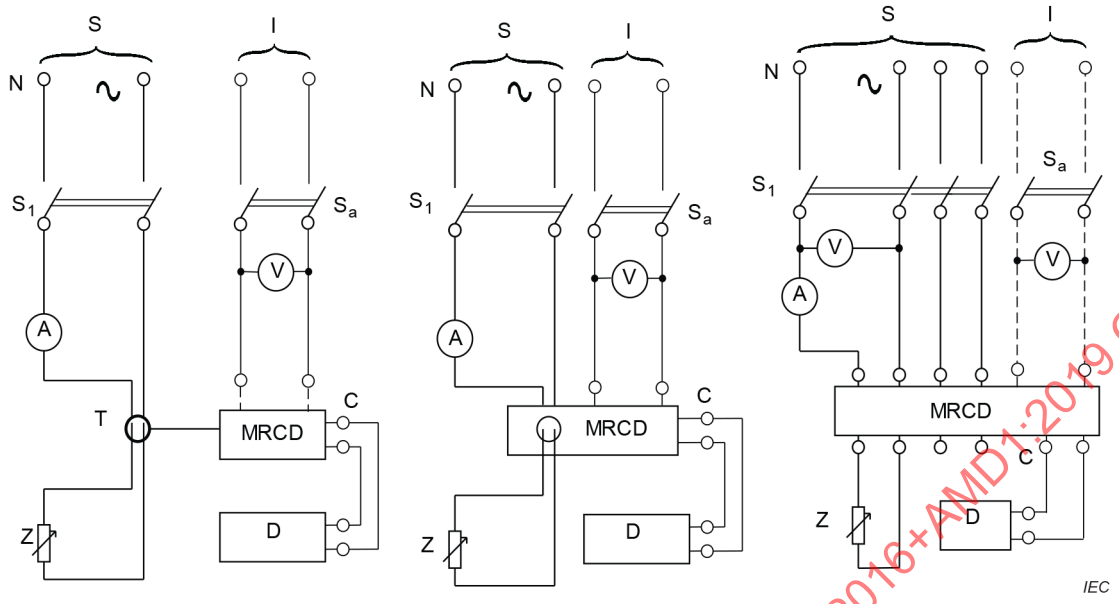
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope

Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without current breaking device)

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

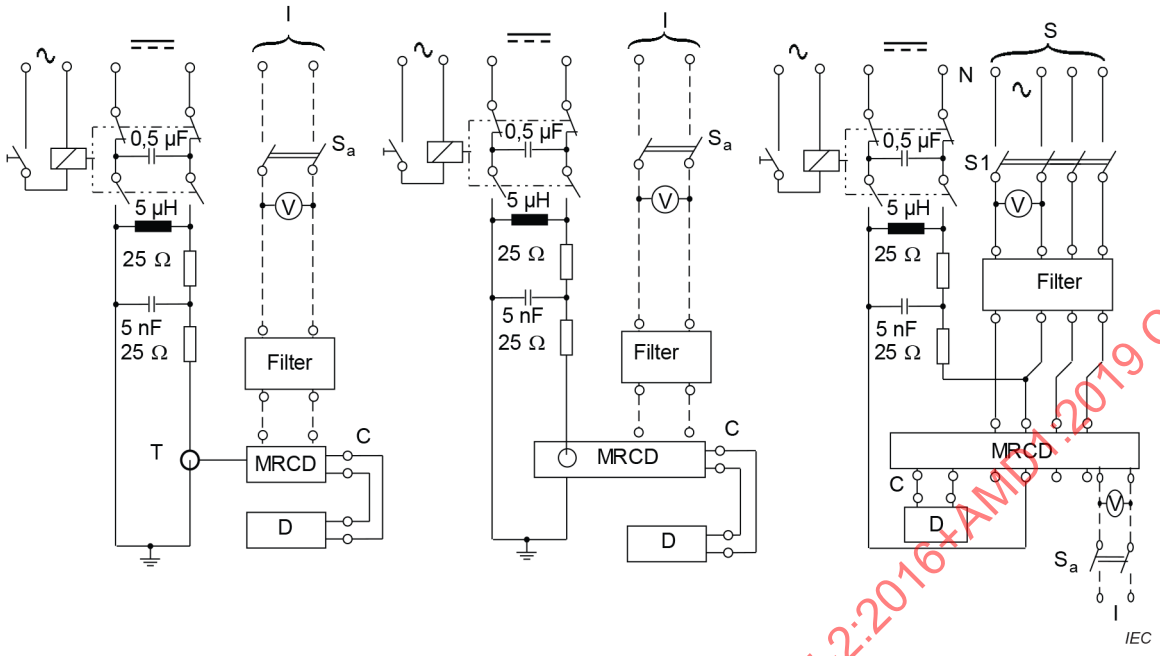
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status

Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

S	power supply	T	sensing means
V	voltmeter	C	output circuit
I	separate voltage source, if applicable	D	instrument indicating the change of status
S_1	multi-pole switch	S_a	auxiliary switch

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

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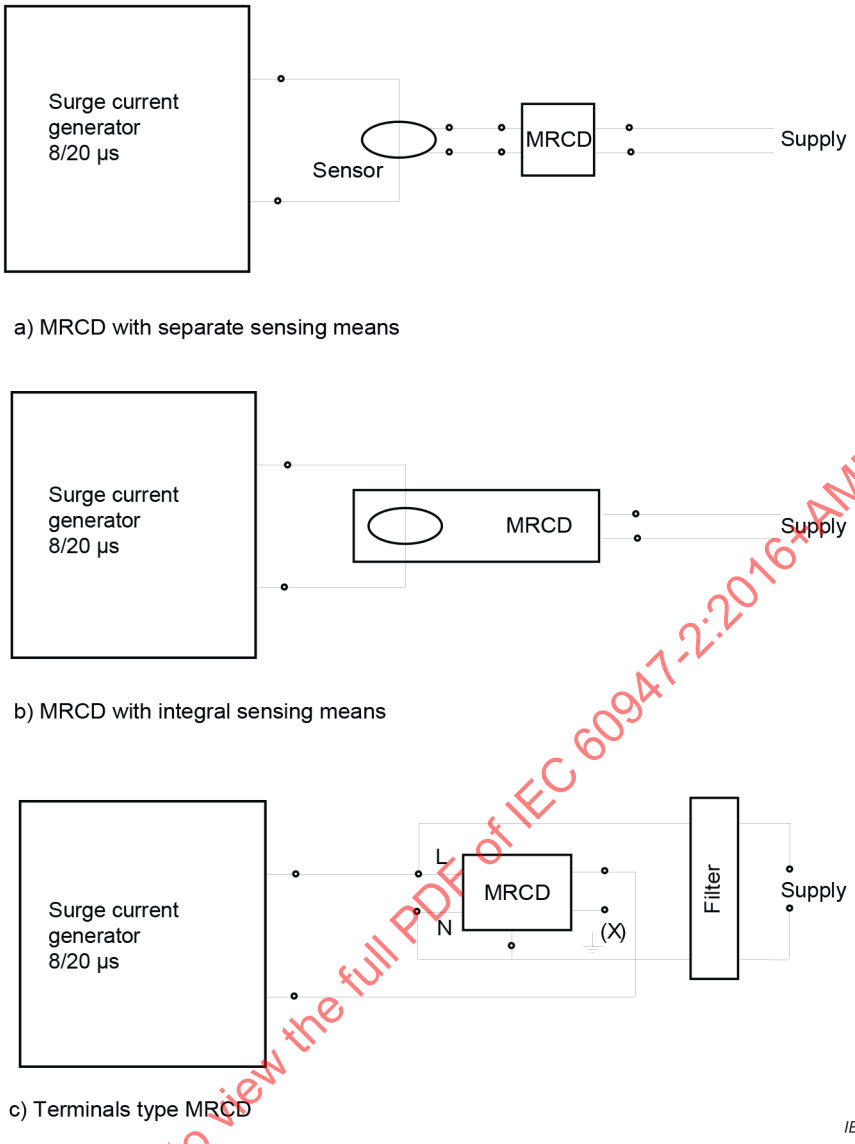
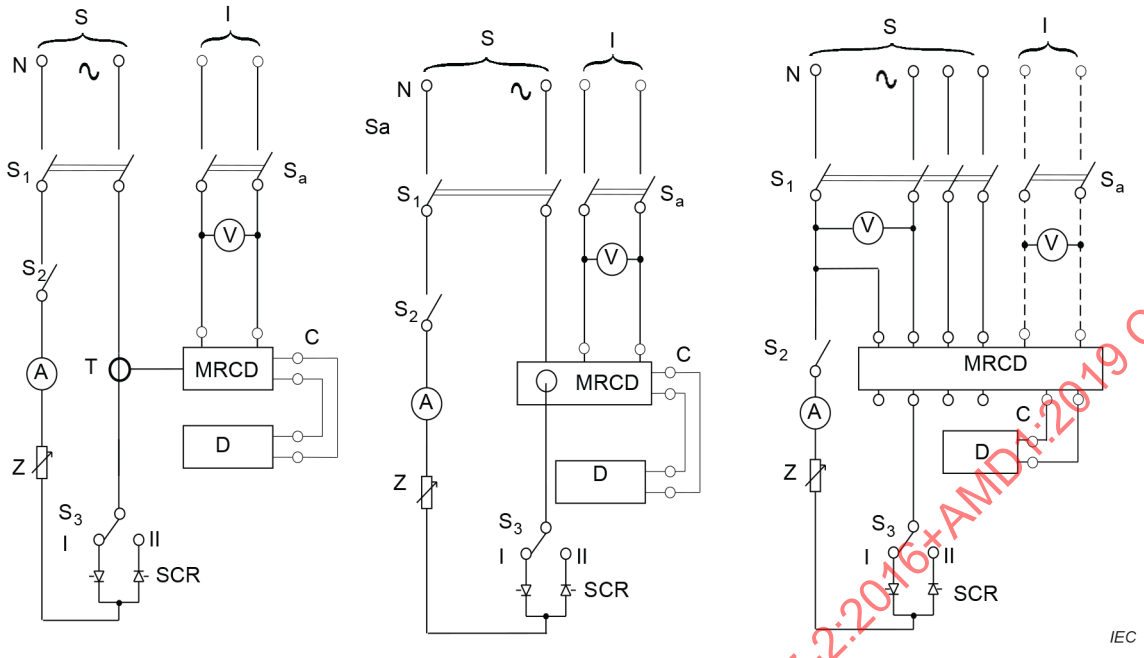


Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

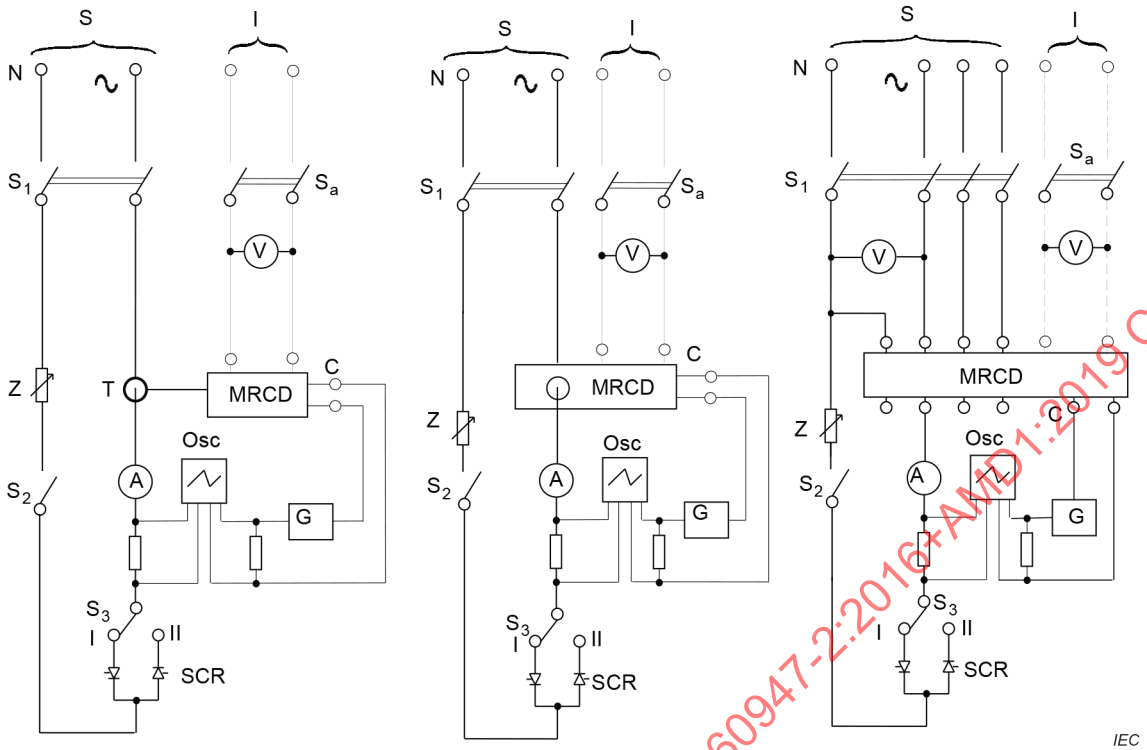
c) Terminal-type MRCD

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	single-pole switch	SCR	thyristors
S_3	inverter switch		

Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

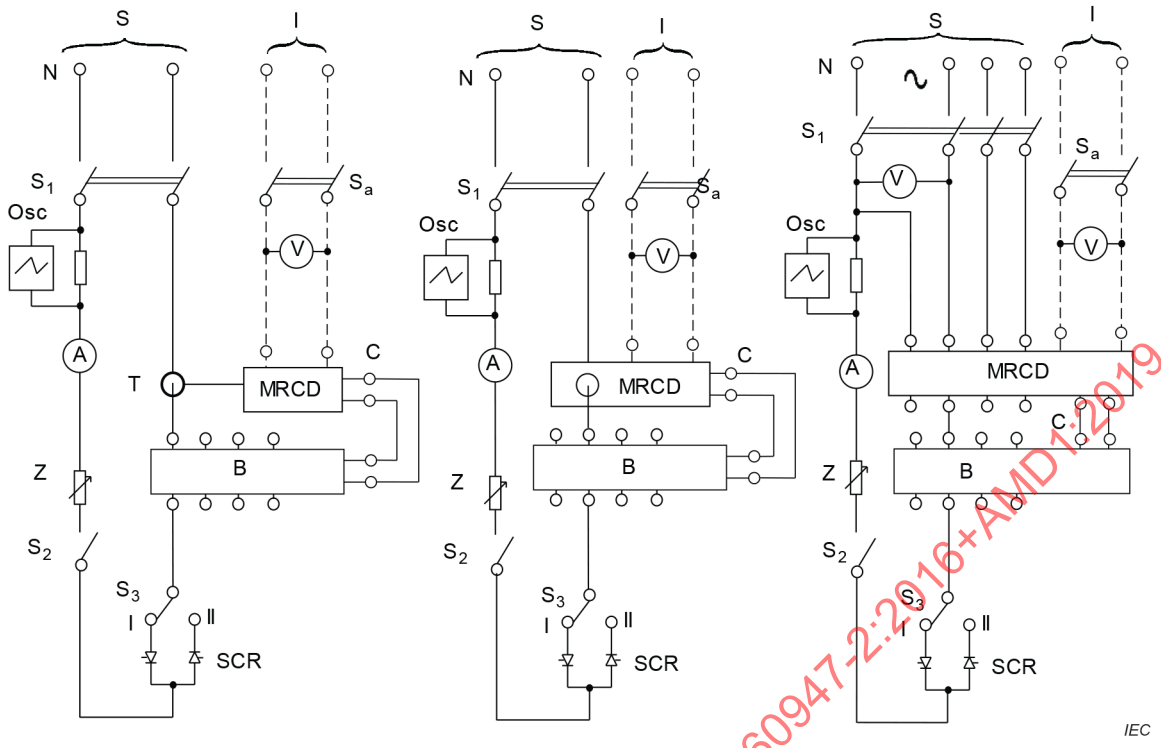
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristors

Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without current-breaking device)

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

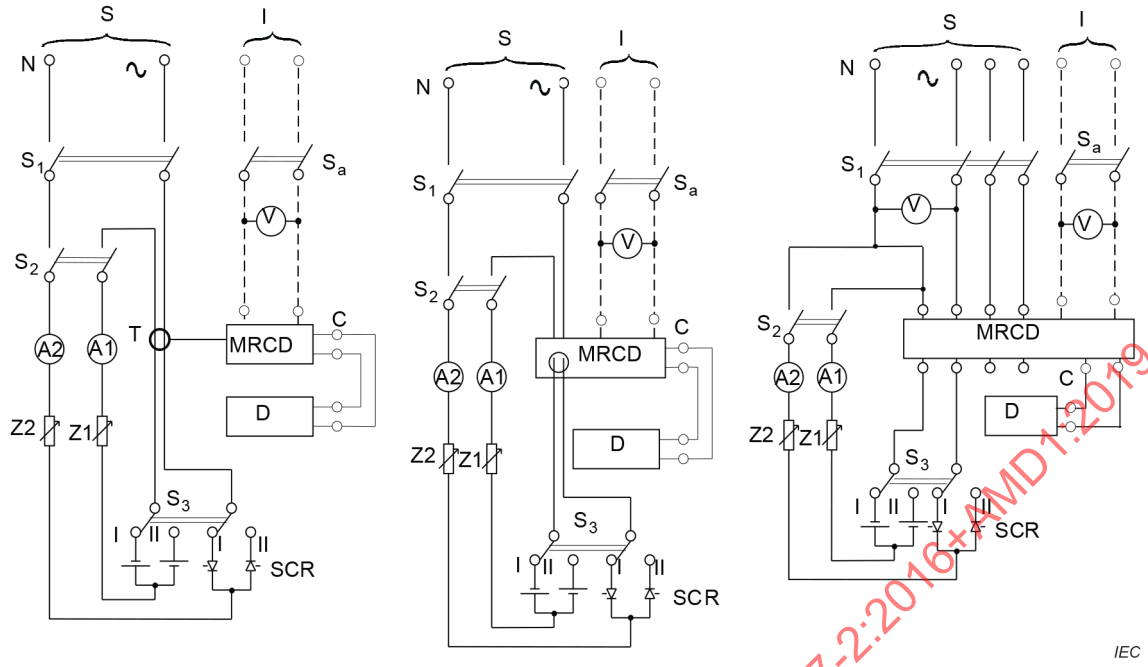
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch	SCR	thyristors

Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with current-breaking device)

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

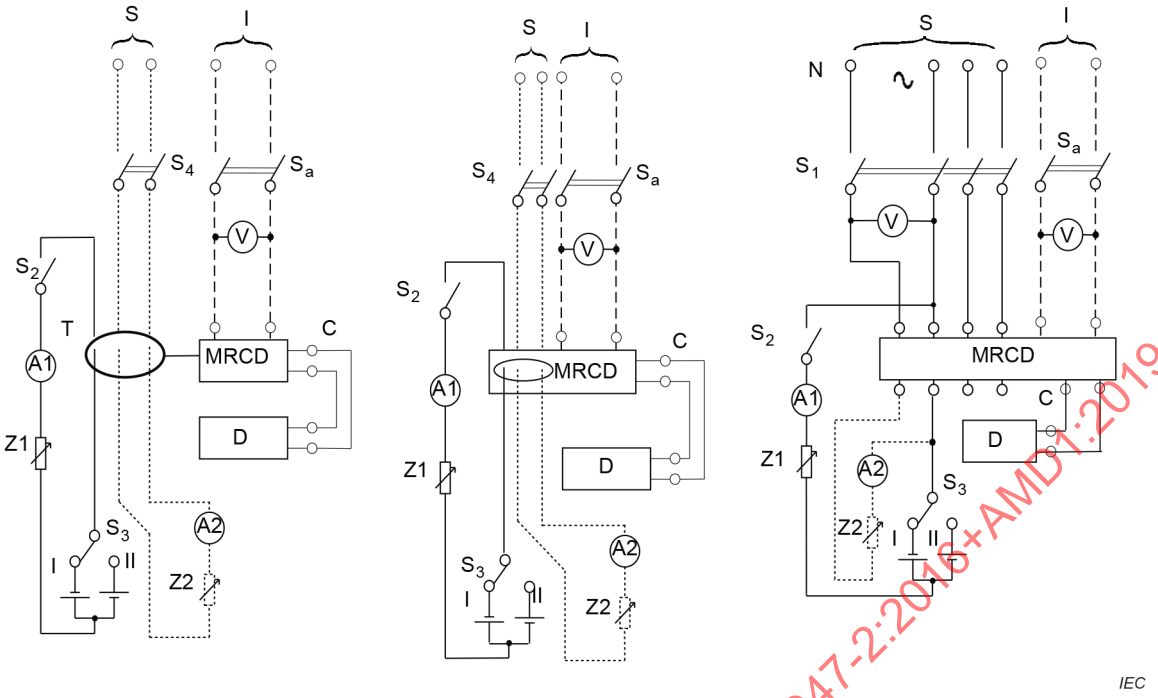
c) **Terminal-type MRCD**

Key

S	power supply	S_3	double inverter switch
I	separate voltage source if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A1	ammeter measuring d.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
S_2	two-pole switch	SCR	thyristors

Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by a smooth direct current

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

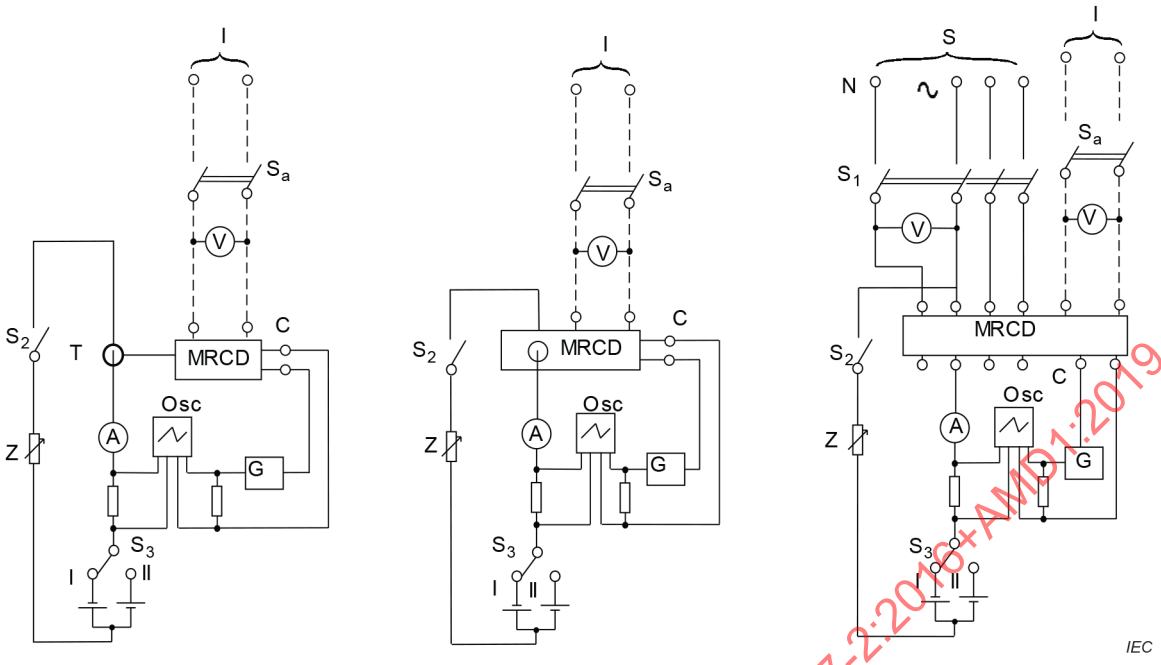
c) **Terminal-type MRCD**

Key

S	power supply	S_3	double inverter switch
I	separate voltage source, if applicable	S_4	two-pole switch
V	voltmeter	S_a	auxiliary switch
A1	ammeter measuring d.c. current	Z1, Z2	adjustable impedances
A2	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

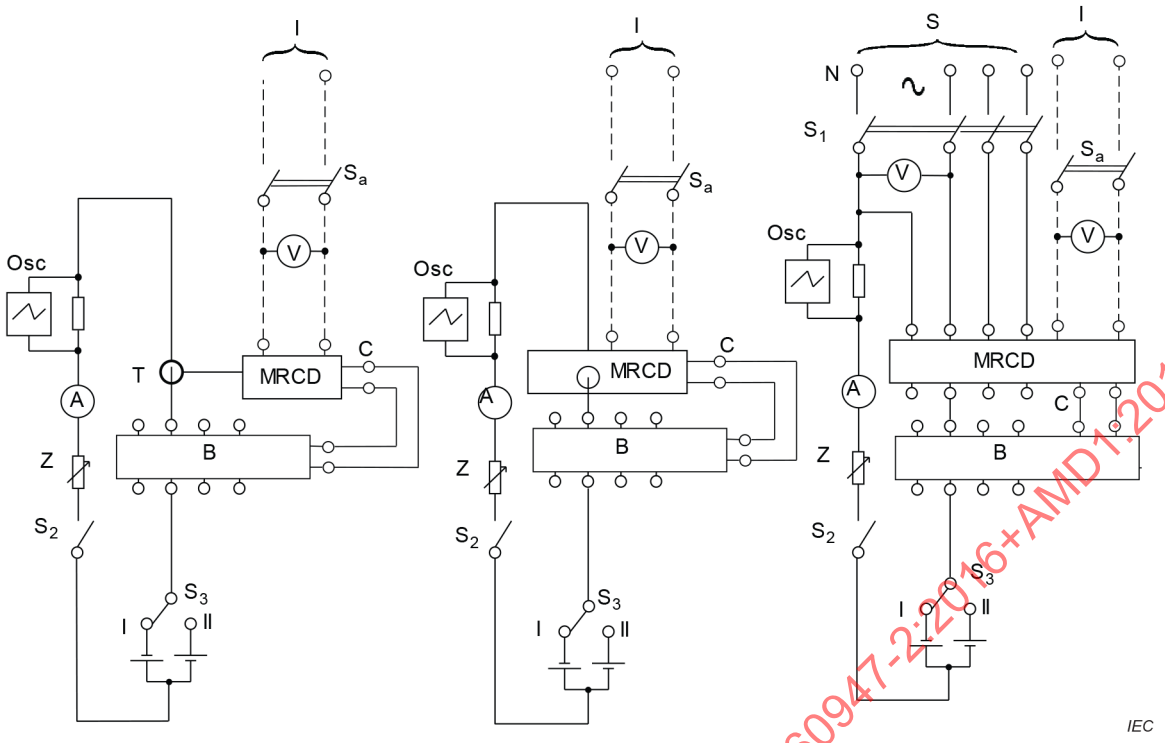
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source, if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multi-pole switch	G	generator
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without current-breaking device)

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

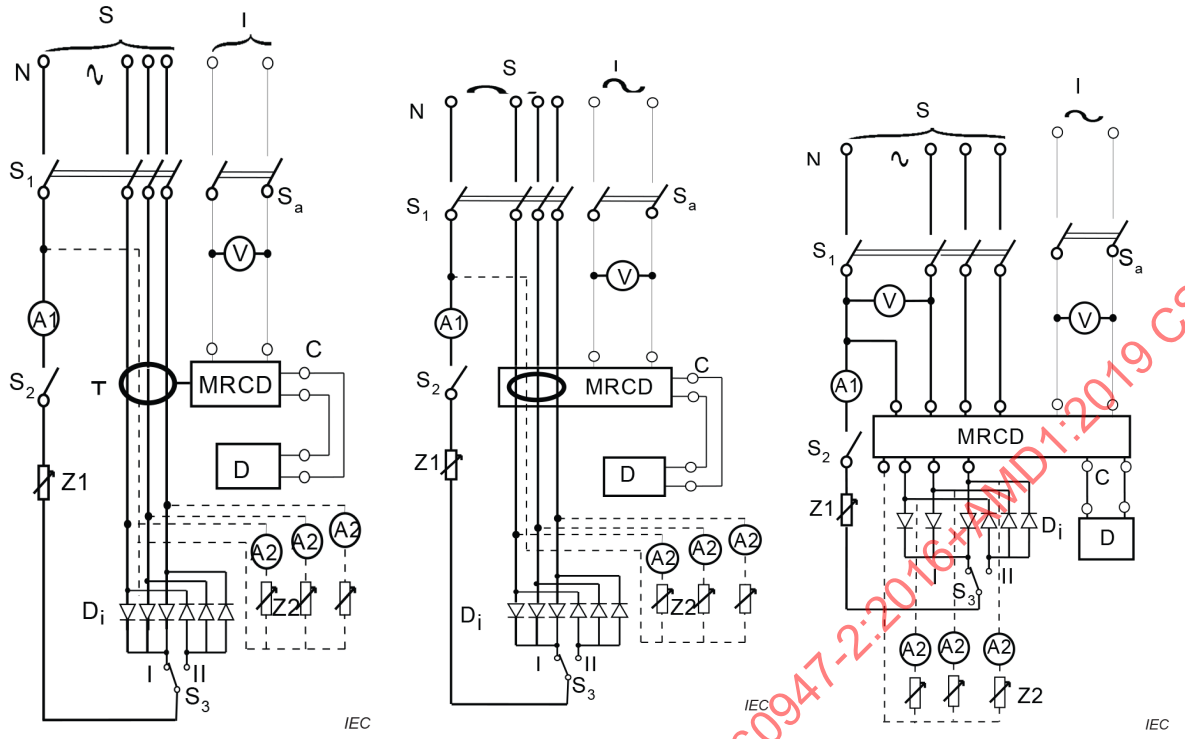
c) **Terminal-type MRCD**

Key

S	power supply	S_a	auxiliary switch
I	separate voltage source if applicable	Z	adjustable impedance
V	voltmeter	T	sensing means
A	ammeter measuring d.c. current	C	output circuit
S_1	multi-pole switch	B	current breaking device
S_2	single-pole switch	Osc	oscilloscope
S_3	inverter switch		

Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with current-breaking device)

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a) **MRCD with separate sensing mean**

b) **MRCD with integral sensing means**

c) **Terminal-type MRCD**

Key

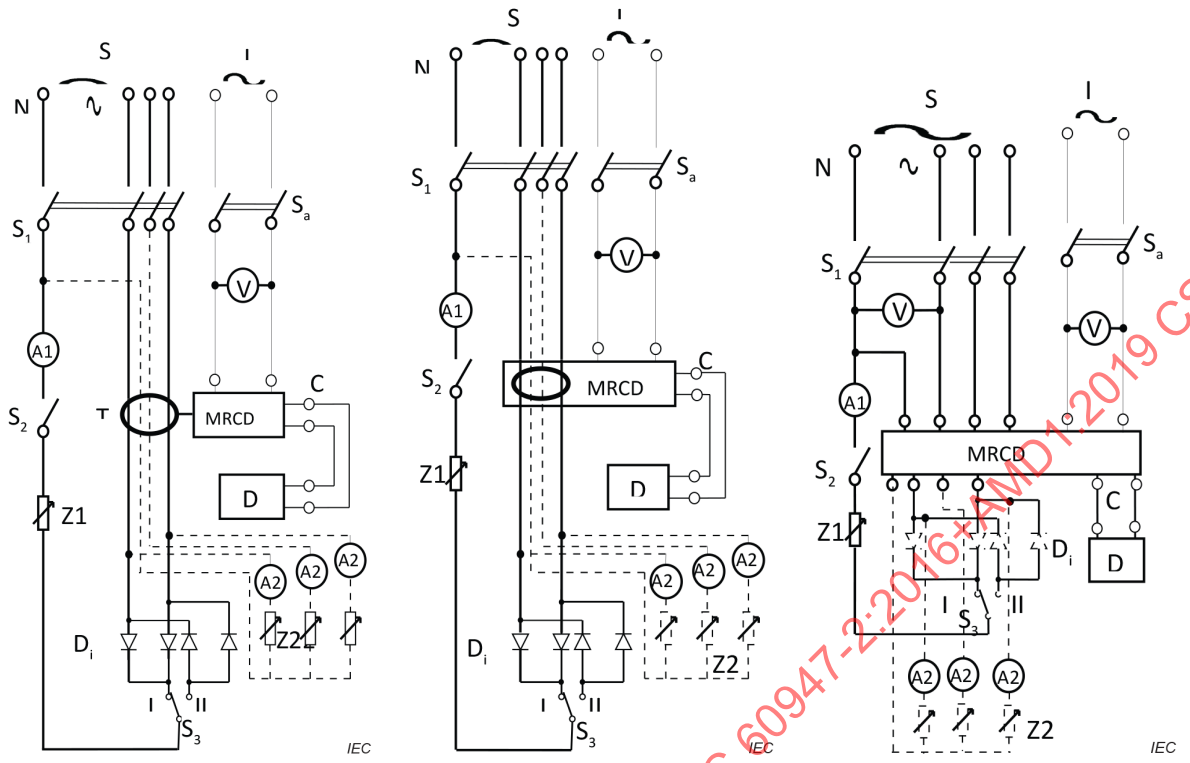
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z1, Z2	adjustable impedances
A1	ammeter measuring a.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
		D_i	diodes

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.14 – Test circuits for the verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from three phases

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

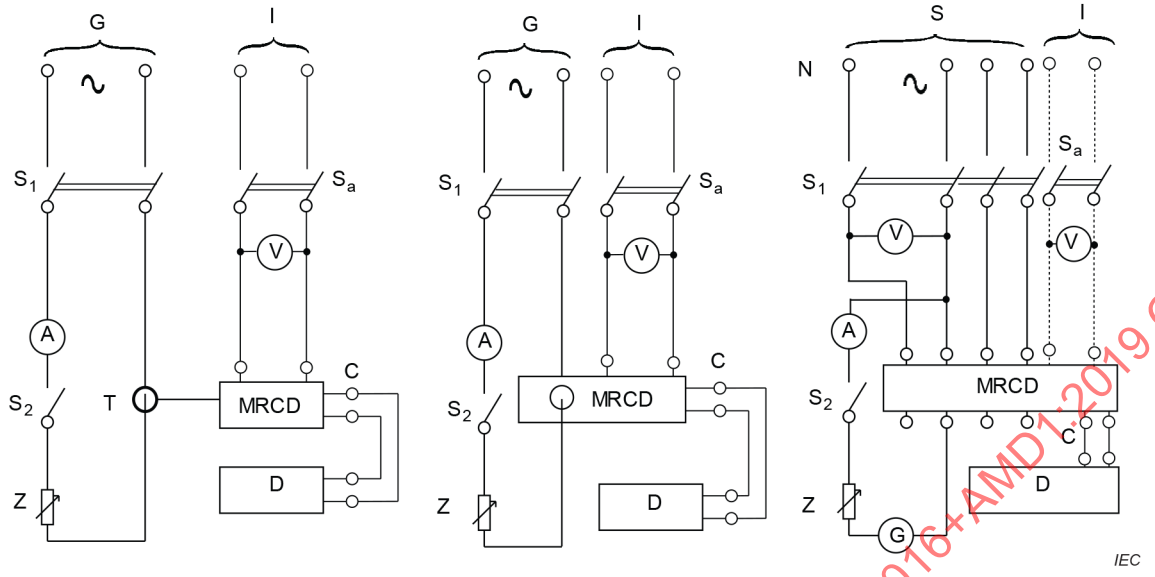
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z1, Z2	adjustable impedances
A1	ammeter measuring a.c. current	T	sensing means
A2	ammeter measuring a.c. current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
D_i	diodes		

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.15 – Test circuits for the verification of the correct operation in the case of residual direct currents which can result from rectifying circuits supplied from two phases

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a) MRCD with separate sensing means

b) MRCD with integral sensing means

c) Terminal-type MRCD

Key

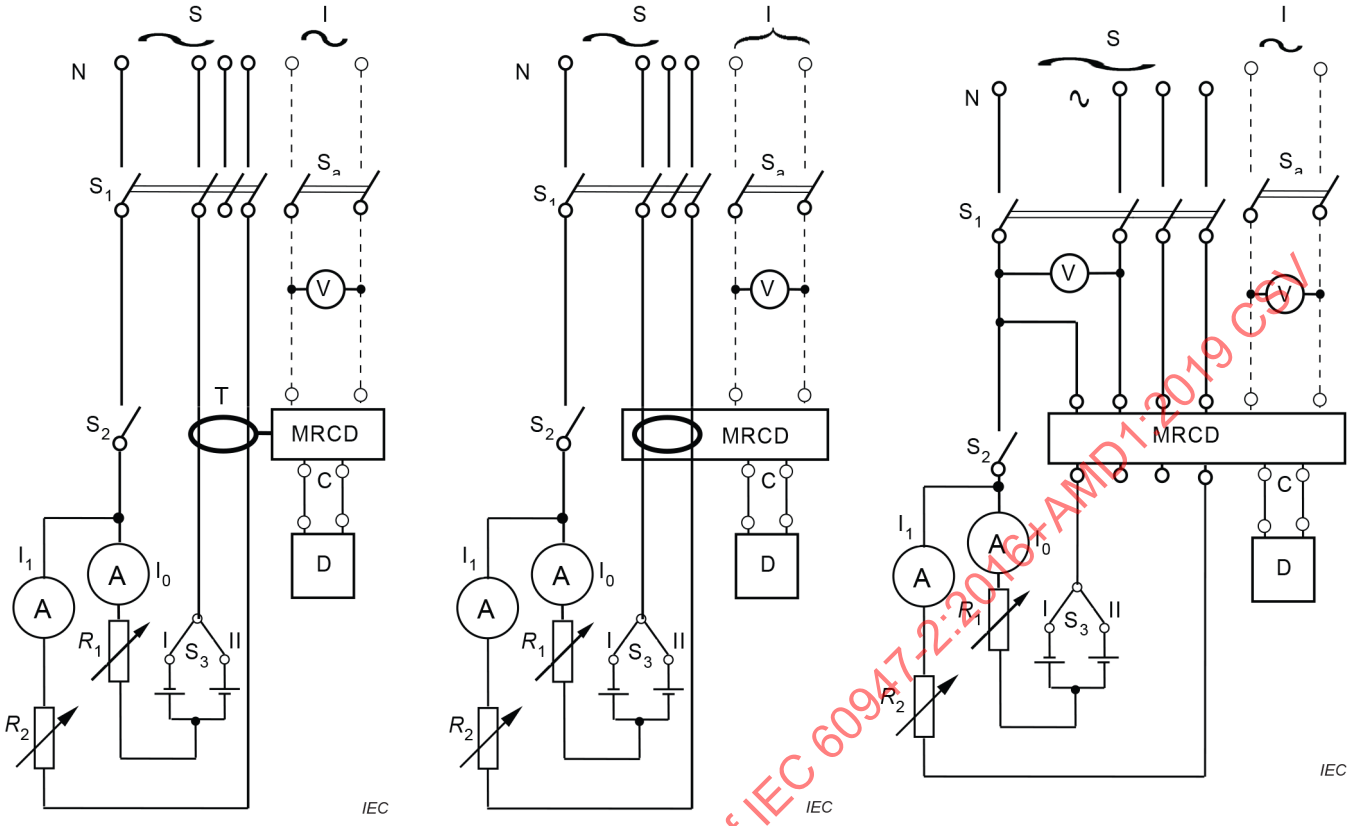
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
G	generator	D	instrument indicating the change of status

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.16 – Test circuits for the verification of correct operation in the case of composite residual currents and residual sinusoidal alternating current up to 1 000 Hz

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

c) **Terminal-type MRCD**

Key

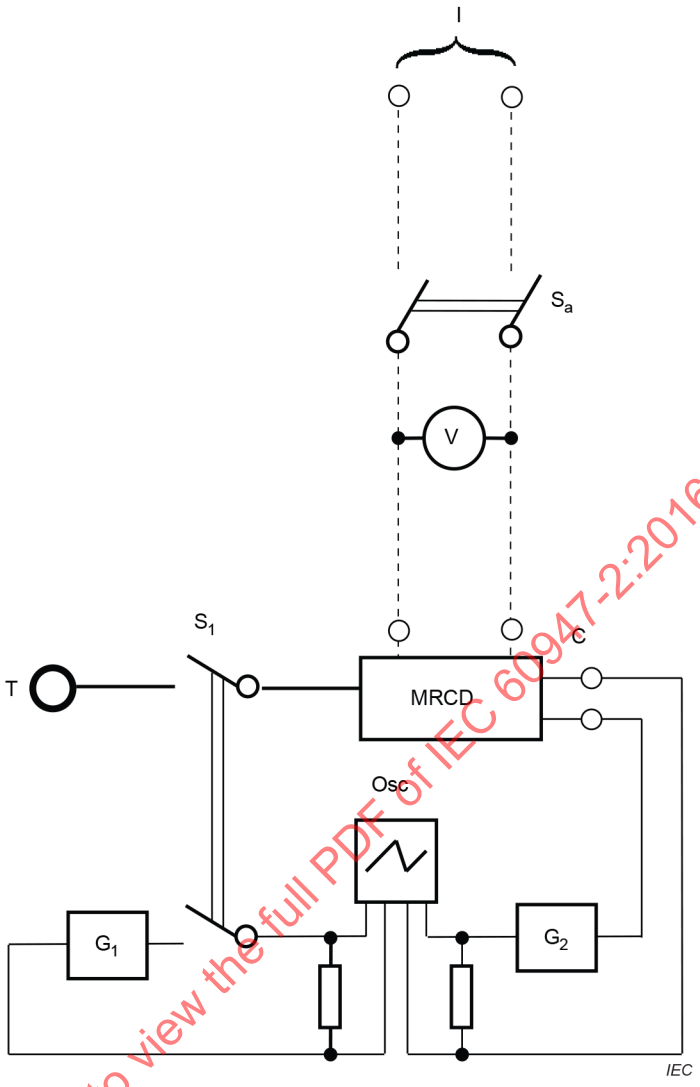
S	power supply	S_3	two-way switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	R_1, R_2	adjustable resistors
A	ammeter measuring a.c. current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

For verification of the operating time, the instrument D is replaced by an oscilloscope monitoring both the residual current and the MRCD output (see principle in Figure M.8 and Figure M.12).

For verification of the combination time, the instrument D is replaced by a current-breaking device whose main circuit is inserted in series with the residual current path. The combination time is measured with an oscilloscope monitoring the residual current (see principle in Figure M.9 and Figure M.13).

Figure M.17 – Test circuits for the verification of the correct operation in the case of a residual alternating current superimposed on a smooth direct current

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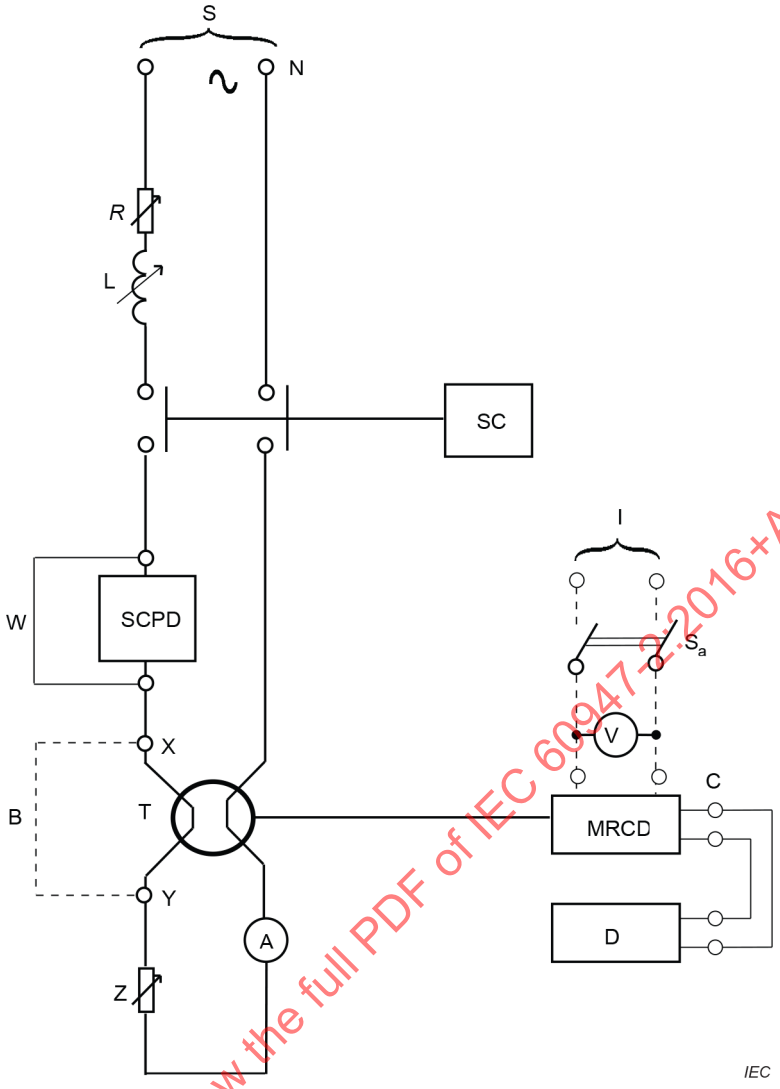


Key

I separate voltage source, if applicable	T sensing means
V voltmeter	C output circuit
S_1 multi-pole switch	G_1, G_2 generators
S_a auxiliary switch	Osc oscilloscope

Figure M.18 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the connection of the sensing means

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Key

S power supply

I separate voltage source, if applicable V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L adjustable reactor

R adjustable resistor

Z adjustable impedance

T sensing means

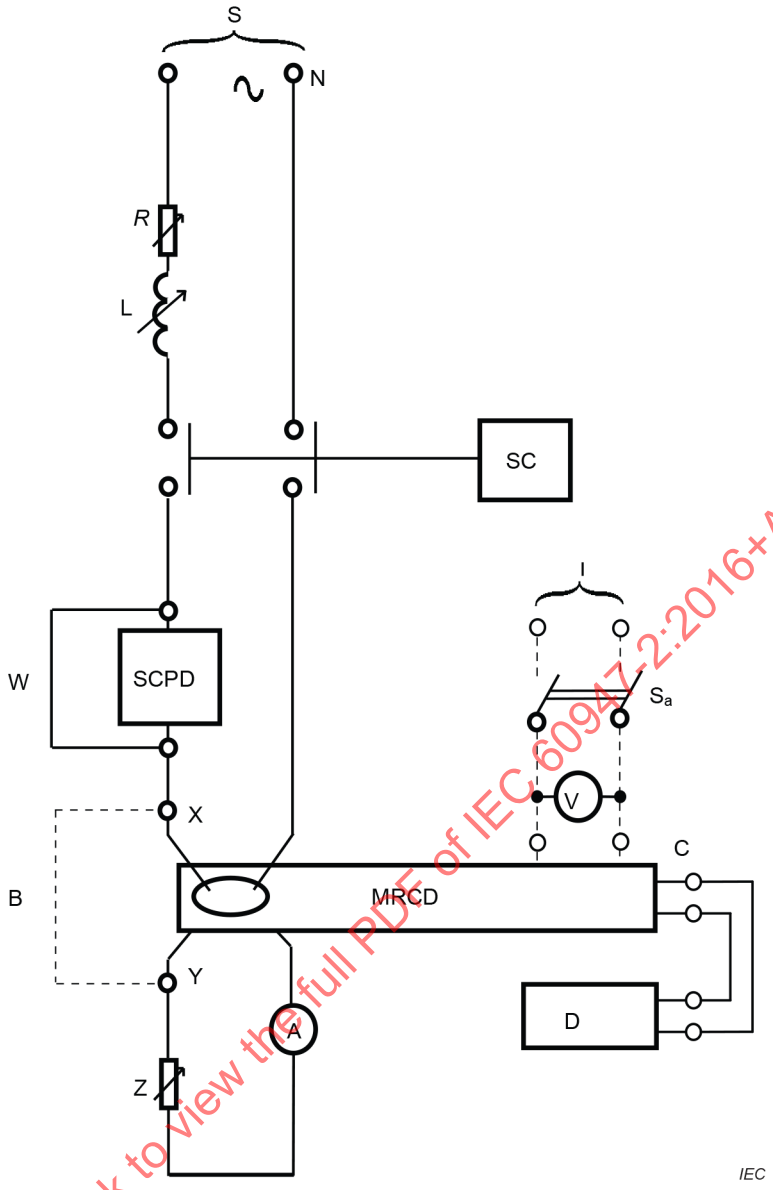
C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.19 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions

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Key

S power supply

I separate voltage source, if applicable

V voltmeter

A ammeter

S_a auxiliary switch

SC short-circuit switch

W temporary connection

B connection for residual short-circuit test, replacing the connection through the sensing means

L adjustable reactor

R adjustable resistor

Z adjustable impedance

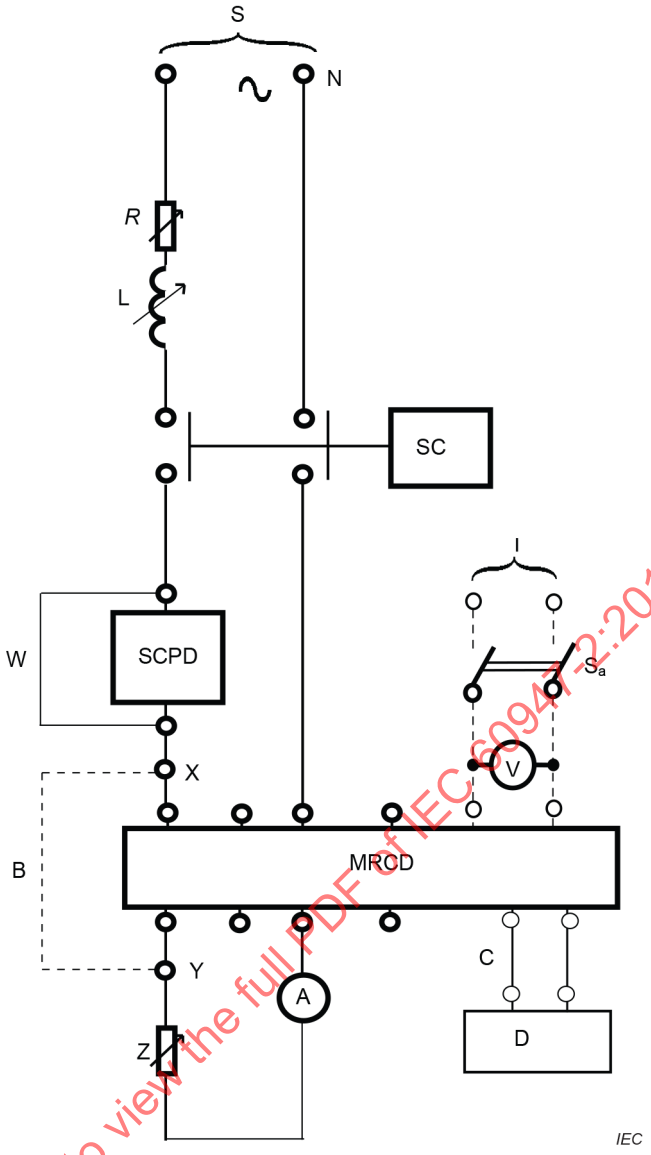
C output circuit

D instrument indicating the change of status

SCPD short-circuit protective device

Figure M.20 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions

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Key

S	power supply	L	adjustable reactor
A	ammeter	*R*	adjustable resistor
S_a	auxiliary switch	Z	adjustable impedance
SC	short-circuit switch	C	output circuit
W	temporary connection	D	instrument indicating the change of status
B	connection for residual short-circuit test, replacing the connection through the sensing means	SCPD	short-circuit protective device

Figure M.21 – Test circuit for the verification of the behaviour of terminal-type MRCDs under short-circuit conditions

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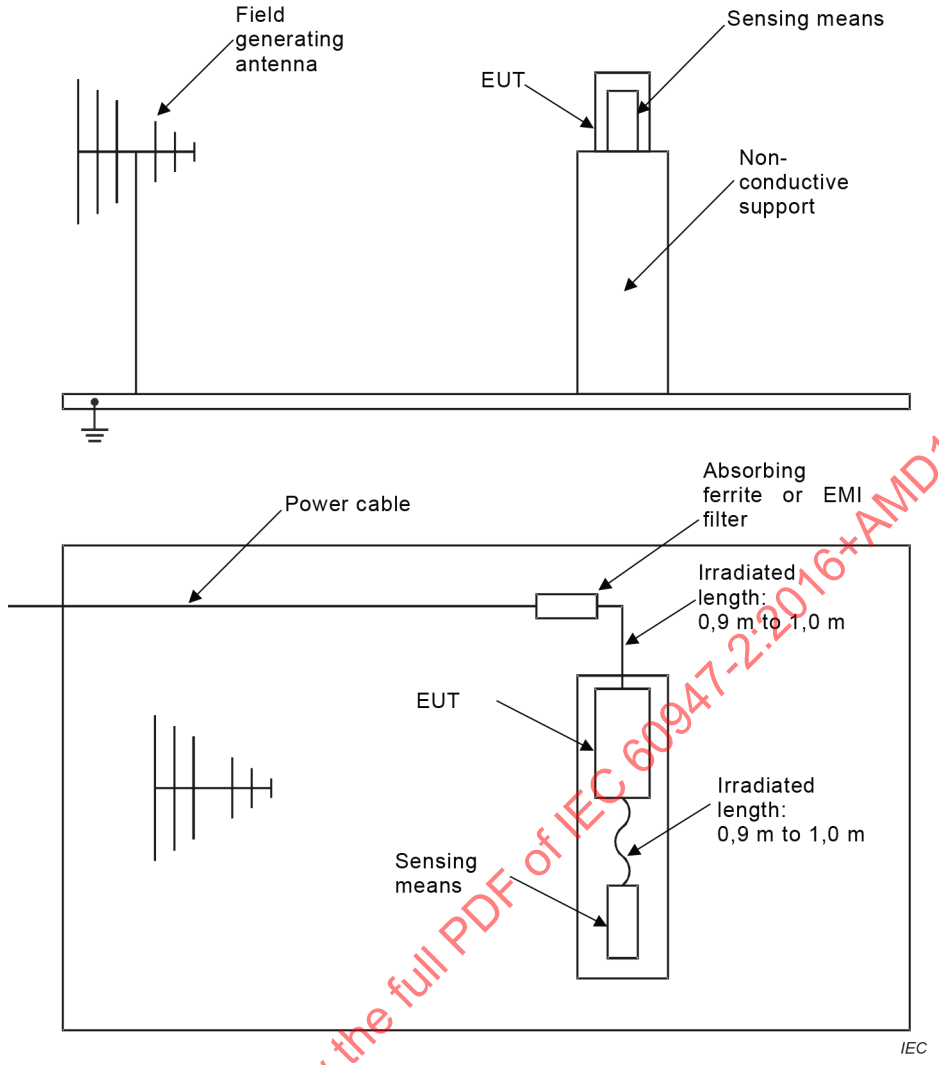


Figure M.22 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCDs with separate sensing means (in addition to the test of Annex B)

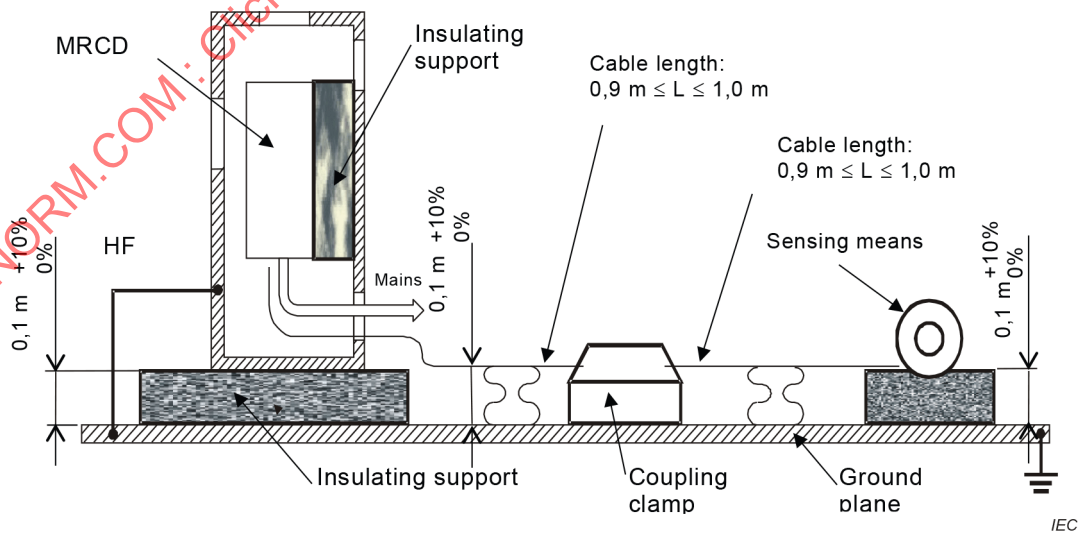
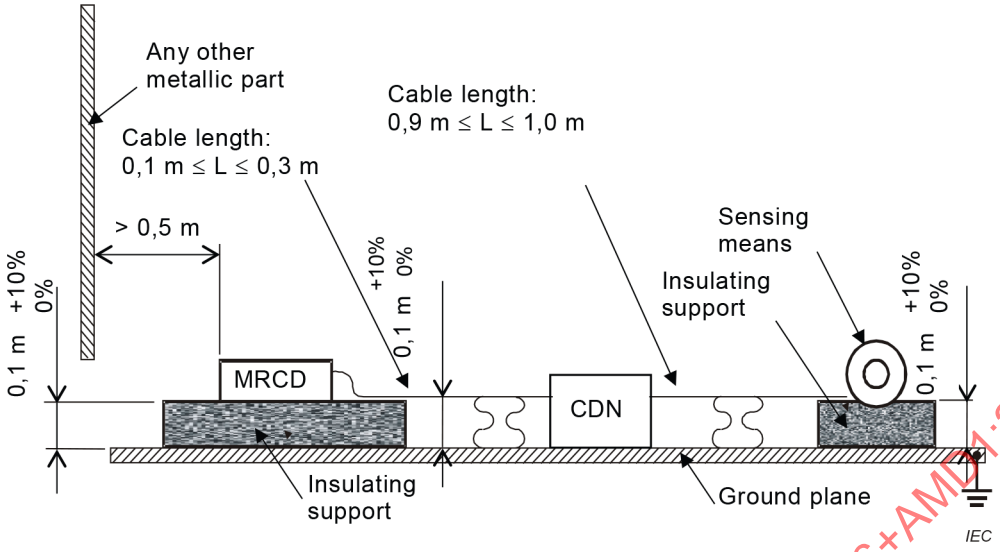


Figure M.23 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (in addition to the test of Annex B)

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Key

CDN coupling-decoupling network

Figure M.24 – Verification of immunity to conducted disturbances induced by RF fields – Test setup for MRCD with separate sensing means (in addition to the test of Annex B)

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Annex N
(normative)

Electromagnetic compatibility (EMC) – Additional requirements and test methods for devices not covered by Annex B, Annex F and Annex M

N.1 General

N.1.1 General

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 7.3 of IEC 60947-1:2007/AMD1:2010/AMD2:2014), and not covered by Annex B (circuit-breakers incorporating residual current protection), Annex F (circuit-breakers with electronic overcurrent protection) and Annex M (modular residual current devices).

It covers circuit-breaker auxiliaries such as undervoltage releases, shunt releases, closing releases, motor-operators, remote status indicators, etc. Communication modules are not covered by these requirements.

It supplements Annex J, for test conditions and acceptance criteria specific to these devices.

N.1.2 General test conditions

Tests according to this annex may be performed separately from the test sequences of Clause 8.

A new device may be used for each test, or one device may be used for several tests, at the manufacturer's discretion.

For devices with different voltage supply ratings, one device of each rating shall be tested.

Tests on closing releases are not necessary if their construction (coil and electronic control) is identical to the equivalent shunt trips.

The devices shall be mounted in or on the circuit-breaker, in accordance with the manufacturer's instructions.

Undervoltage releases and power ports intended to be permanently connected to a power supply shall be supplied with the rated voltage. In case of a range of rated voltages, they shall be supplied at any convenient voltage within this range.

Devices rated from 50 Hz to 60 Hz may be tested at either one of the rated frequencies.

N.2 Immunity

N.2.1 General

N.2.1.1 Test conditions

Immunity tests may be performed on a circuit-breaker fitted with different devices, and may be combined with the corresponding tests of Annex B and Annex F, where applicable (e.g. electrostatic discharges, radiated RF electromagnetic fields, etc.).

Devices, except closing releases, shall be tested with the circuit-breaker closed.

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Closing releases, if applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

N.2.1.2 Performance criteria

Criterion A**:** during the test, the status of the circuit-breaker shall not change and the status of the outputs of remote indication modules shall not change.

Criterion B**:** during the test, the status of the circuit-breaker shall not change while the status of the outputs of remote indication modules may change temporarily, but shall indicate the correct status of the circuit-breaker after the test.

After the tests, the simplified functional verification of N.2.1.3 shall be made.

N.2.1.3 Simplified functional verification

For both criteria, after the test, the operation of the device shall be checked at the rated voltage, or, in the case of a range of rated voltages, at any convenient voltage within this range:

a) An undervoltage release, when energized, shall not prevent the circuit-breaker from being closed; when the voltage is removed, the circuit-breaker shall trip.

b) A shunt trip, when energized, shall trip the circuit-breaker.

c) A closing release, when energized, shall close the circuit-breaker.

d) A motor-operator, when energized in accordance with the manufacturer's instructions, shall be capable of closing and opening the circuit-breaker.

NOTE This test is intended only to check that the device has not been damaged during the immunity tests. It is not intended to check the full compliance with the requirements of the main body of this standard.

N.2.2 Electrostatic discharges

Annex J applies, in particular J.2.2.

Performance criterion B of N.2.1.2 applies.

N.2.3 Radiated RF electromagnetic fields

Annex J applies, in particular J.2.3.

The test connections shall be in accordance with Figures 5 or 6 of IEC 61000-4-3:2006, as applicable, taking into consideration the manufacturer’s instructions for installation. The type of cable used shall be stated in the test report.

For step 1 (see J.2.3), the performance criterion A applies.

For step 2 (see J.2.3), at each of the frequencies listed in J.2.3, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.4 Electrical fast transients/bursts (EFT/B)

Annex J applies, in particular J.2.4.

The test connections shall be in accordance with Figures 11, 12, 13 and 14 of IEC 61000-4-4:2012, taking into consideration the manufacturer’s instructions for installation.

Performance criterion A applies.

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N.2.5 Surges

Annex J applies, in particular J.2.5.

The test connections shall be in accordance with Figures 5, 6, 7, 8, 9, 10 or 11 of IEC 61000-4-5:2014, taking into consideration the manufacturer's instructions for installation.

Performance criterion B applies.

N.2.6 Conducted disturbances induced by RF fields (common mode)

Annex J applies, in particular J.2.6.

For step 1 (see J.2.6), the performance criterion A applies.

For step 2 (see J.2.6), at each of the frequencies listed in J.2.6, the operation of the device shall be checked according to N.2.1.3. This test is not applicable to remote status indicators.

N.2.7 Voltage dips and interruptions

These tests are applicable to devices with permanent a.c. power supply only.

Tests shall be performed in accordance with IEC 61000-4-11, at test levels of Table 23 of IEC 60947-1:2007/AMD1:2010.

During the test, the status of the circuit-breaker may change. The status of the outputs of remote indication modules may change, but shall indicate the correct status of the breaker after the test. After the test, the correct operation of the device shall be checked in accordance with N.2.1.3.

N.3 Emission

N.3.1 General

These tests are applicable to devices incorporating electronic circuits with fundamental switching frequencies greater than 9 kHz (see 7.3.3.2.1 of IEC 60947-1:2007/AMD2:2014), and intended for continuous operation (e.g. undervoltage releases).

They are not applicable to shunt trips intended only for use with a clearing switch, either built-in or separate.

They are not applicable to motor-operators not incorporating permanently energized electronic circuits, because these devices are operated at very infrequent intervals and the duration of the operations (closing, opening or resetting) is very short (a few hundreds of milliseconds to a few seconds).

Each device shall be submitted to separate emission tests, these tests shall not be combined with the corresponding tests of Annex B and Annex F.

Closing releases, when applicable (see N.1.1), shall be tested with the circuit-breaker ready to close (main springs charged).

Undervoltage releases and closing releases shall be tested with the circuit-breaker closed.

Shunt trips and motor-operators shall be tested with the circuit-breaker open.

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Remote status indicators shall be tested with the circuit-breaker closed.

N.3.2 Conducted RF disturbances (150 kHz to 30 MHz)

Annex J applies, in particular J.3.2.

N.3.3 Radiated RF disturbances (30 MHz to 1 000 MHz)

Annex J applies, in particular J.3.3.

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Annex O
(normative)

Instantaneous trip circuit-breakers (ICB)

O.1 General

This annex covers circuit-breakers which fulfil only the short-circuit portion of overcurrent protection specified in the main part of this standard, hereinafter referred to as ICBs. They comprise instantaneous short-circuit releases which may be adjustable but not overload releases. These devices are generally used in conjunction with other equipment such as motor- starters, overload relays, etc. In combination with specified overload relays, they offer complete overcurrent protection (overload and short-circuit) to both the circuit and specified equipment.

An ICB forms part of a circuit-breaker range, being derived from an equivalent circuit-breaker (see O.2.1) by omitting the overload releases and incorporating a short-circuit release, which may be adjustable, designed to provide co-ordinated overcurrent protection when associated with specified motor-starters or overload relays.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 2, the following terms and definitions apply.

O.2.1
equivalent circuit-breaker
circuit-breaker from which the ICB has been derived, which has been tested according to this standard and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 4 apply with the exception of the reference to overload releases and with the following additions.

O.3.2 Rated current (I_n)

The rated current of an ICB shall not exceed the rated current of the equivalent circuit-breaker.

O.3.3 Rated short-circuit making capacity

ICBs may be assigned a rated short-circuit making capacity different to the equivalent circuit-breaker.

NOTE ICBs can be assigned a rated short-circuit making capacity equal to or greater than that of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

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NOTE ICBs can be assigned a rated short-circuit breaking capacity equal to or greater than I_{cu} of the equivalent circuit-breaker when associated with specified motor-starters or overload relays, and tested according to the relevant clauses of IEC 60947-4-1 (see O.6.2).

O.4 Product information

An ICB shall be marked according to 5.2 as relevant.

Rated short-circuit making and breaking capacities shall be marked, where applicable (see O.6.1.1). When the ICB is only rated for short-circuit performance in association with a motor-starter or overload relay (see O.6.2), the short-circuit ratings of the association shall not be marked on the ICB.

In addition, the ICB shall be marked in accordance with Table O.1.

Table O.1 – Product information

Item	Information	Marking location
O1.1	Initialism "ICB"	Visible
O2.1	Rated instantaneous short-circuit current setting I_i (see 2.20) (actual values or multiples of rated current)	Marked
Key Visible: visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked: marked on the product		

Manufacturers' instructions shall draw attention to the fact that, below the rated instantaneous short-circuit current settings, an ICB provides no overcurrent protection to itself or to the circuit. Such protection shall be provided separately.

When an ICB is not associated with a specified protected device (see O.6.2), the manufacturer shall provide data to permit the selection of suitable overload protection, e.g. withstand characteristics of the ICB up to its maximum instantaneous setting.

O.5 Constructional and performance requirements

An ICB, being derived from the equivalent circuit-breaker (see O.2.1), complies with all the applicable construction and performance requirements of Clause 7, except 7.2.1.2.4, item b).

O.6 Tests

O.6.1 Test sequence of the ICB alone

O.6.1.1 General

The tests of this subclause are not required if

– the short-circuit characteristics of the short-circuit releases and the main current paths of the ICB are the same as those of the equivalent circuit-breaker, or

– the ICB is only rated and tested as an association (see O.6.2).

A sample of each of the maximum and minimum values of the rated current I_n of each frame size shall be tested.

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In the case of one or more construction breaks (see 2.1.2 and 7.1.6) within the frame size, a further sample shall be tested at the maximum rated current corresponding to each construction.

O.6.1.2 Test sequences

Tests shall be made according to sequences II and III of this standard without the verification of overload releases.

For ICBs having variants with different number of poles, tests shall be made on the variant with the greatest number of poles. The other variant(s) shall be submitted to the tests of sequence III only (without the verification of overload releases).

O.6.1.3 Verification of short-circuit releases

Following the test of O.6.1.2, a tripping test is made in accordance with 8.3.3.2.2 on each phase pole in turn, at the maximum setting of the rated instantaneous short-circuit current. The test is made at the value of the tripping current declared by the manufacturer for individual poles. The ICB shall trip.

O.6.2 ICB associated with a specified protected device (i.e. motor-starter or overload relay)

The applicable test requirements for these associations are covered in the relevant sections of IEC 60947-4-1, specifically the following clauses:

– co-ordination with short-circuit protective devices;
– additional requirements for combination starters and protected starters suitable for isolation;
– performance under short-circuit conditions;
– co-ordination at the crossover current between the starter and associated SCPD.

NOTE The symbol SCPD in IEC 60947-4-1 applies to various short-circuit protective devices, including the ICB.

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Annex P
(normative)

DC circuit-breakers for use in photovoltaic (PV) applications

P.1 Field of application

This annex applies to d.c. circuit-breakers, rated up to 1 500 V d.c., intended for use with photovoltaic (PV) systems, and hereafter referred to as "PV circuit-breakers".

Circuit-breakers used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of this standard.

The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

– the requirements for circuit-breakers to be used on the d.c. side of PV applications;
– the tests intended to verify the product performances and their maintaining after exposure to the PV service environmental conditions.

P.2 Terms and definitions

Clause 2 applies.

P.3 Classification

Clause 3 applies.

P.4 Characteristics of PV circuit-breakers

Clause 4 applies with the following modification:

A PV circuit-breaker rated for use not only in PV applications shall have only one rated current.

Rated impulse withstand voltage (U_{imp}) of PV circuit-breakers shall comply with Table P.1.

Table P.1 – Rated impulse withstand levels for PV circuit-breakers

Maximum value of rated operational voltage (V)	**Value of rated impulse withstand voltage** (V)
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II, as defined in IEC 60664-1 and IEC/TR 60664-2-1:2011, Annex D.	

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P.5 Product information

Clause 5 applies with the modifications and additions listed in Table P.3.

Circuit-breakers rated for use not only in PV applications shall have the ratings U_e and corresponding I_{cu}/I_{cs} in accordance with this annex clearly separated from the ratings in accordance with the body of this document.

Table P.3 – Product information

Item	Information	Marking location
P2.1	IEC 60947-2:2016 – Annex P,	Marked
P3.1	Method and diagram of series connection of poles, as necessary for each rating	Literature
Key Marked: marked on the product Literature: provided in the manufacturer's literature		

P.6 Normal service, mounting and transport conditions

Clause 6 applies with the following addition:

Guidance on de-rating for ambient air temperature up to 70 °C may be provided. In addition guidance on operation at temperature lower than -5 °C may also be given.

P.7 Constructional and performance requirements

P.7.1 Constructional requirements

Subclause 7.1 applies.

P.7.2 Performance requirements

Subclause 7.2 applies with the following modifications:

PV circuit-breakers shall be capable of interrupting any current up to their rated short-circuit breaking capacity, including critical load current, if exists, in both forward and reverse directions.

Compliance with these requirements is checked by the tests of P.8.3.

With reference to 7.2.4.1, such overload conditions do not arise in the case of PV applications. Overcurrent conditions can only result from a short-circuit. Therefore, no tests to this clause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 7.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.2.

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Table P.2 – Number of operating cycles

Rated current [a] (A)	Number of operating cycles per hour [b]	Number of operating cycles		
		Without current	With current [c]	Total
$I_n \leq 100$	120	9 700	300	10 000
$100 < I_n \leq 315$	120	7 800	200	8 000
$315 < I_n \leq 630$	60	4 800	200	5 000
$630 < I_n \leq 2\,500$	20	2 900	100	3 000
$2\,500 < I_n$	10	1 900	100	2 000

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

[c] During each operating cycle, the circuit-breaker shall remain closed for a sufficient time to ensure that the full current is established, but not exceeding 2 s.

Due to the installation rules defined in IEC 60364-7-712, the risk of a double fault to earth does not need to be taken in consideration. Therefore, Annex H of this standard is not applicable to PV circuit-breakers.

NOTE The case of a PV circuit-breaker having to interrupt a small fault current on one pole only is under consideration.

P.7.3 Electromagnetic compatibility (EMC)

Subclause 7.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 8.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 8.2 applies.

P.8.3 Type tests

Subclause 8.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 8.3.1.2, tests omitted from test sequence I need not be made if the PV circuit-breaker is derived from a circuit-breaker on which identical or more severe tests have already been conducted, except that tripping characteristics conducted in a.c. do not cover d.c. characteristics.

With reference to 8.3.1.4, alternative test programmes do not apply to PV circuit-breakers.

P.8.3.2 General test conditions

For all tests, the series connection of poles of the circuit-breaker shall be in accordance with the manufacturer instructions.

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Samples shall be selected and tested according to column "Terminals marked line/load-No" of Table 10.

With reference to 8.3.2.2.5, the time constant for operational performance capability, short-circuit tests and critical d.c. load current test shall be equal to 1 ms. At the discretion of the manufacturer, a higher value may be used. In this case, it shall be stated in the test report.

P.8.3.3 Test sequence I

Subclause 8.3.3 applies with the following modifications:

With reference to 8.3.3.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.2.

With reference to 8.3.3.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.2, and the time constant shall comply with P.8.3.2. Half of the operations shall be made with the currents flowing in one direction, the other half with the other direction.

With reference to 8.3.3.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 8.3.4 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 8.3.5 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 8.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 8.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 8.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.9 Critical d.c. load current test

Subclause 8.3.9 applies with the following modifications:

The circuit-breaker shall be closed and opened 10 times on to each of the test currents, 5 times with the current flowing in the forward direction, and 5 times with the current flowing in the reverse direction.

The time constant shall comply with P.8.3.2.

During the operational performance verification, if applicable, the breaker shall be subjected to 100 operations instead of 50.

P.8.3.10 Thermal cycling test

PV circuit-breakers shall be subjected to temperature cycling according to IEC 60068-2-14, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at

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+ 85 °C. Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

– a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
– the verification of overload releases according to 8.3.3.2.3;
– a verification of temperature rise at the main terminals in accordance with 8.3.2.5. The temperature rise shall not exceed the values given in Table 7;
– a verification of dielectric withstand according to 8.3.3.6.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I.

P.8.3.11 Climatic test

PV circuit-breakers shall be subjected to the climatic tests of IEC 60947-1:2007/AMD1:2010/AMD2:2014 Annex Q, category B: environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of P.8.3.10.

Where Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 8.4 of this standard, except for the dielectric tests of 8.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, during damp heat test, the functional test shall consist of the mechanical operations of 8.4.2 of this standard. When only manual operating means are available, this test can be done during the beginning of the following cold period.

The number of samples shall be in accordance with the requirements of Table 10 for Test sequence I. At the discretion of the manufacturer, this test may be combined with the thermal cycling test and made on the same samples.

P.8.4 Routine tests

Subclause 8.4 applies.

P.8.5 Special tests

Subclause 8.5 applies.

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Annex Q

Vacant

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Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic re-closing functions

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this standard are used as protective devices to provide protection against the effects of electric shock hazards.

CBRs according to Annex B need to be manually reset after tripping.

CBRs may be installed at remote, unmanned locations such as telecommunication stations or traffic signaling sites. Where such a CBR is tripped due to a lightning surge or temporary earth leakage there will be a delay and cost in travel to site to effect rectification and restoration of the supply.

The results of this tripping by temporary faults such as the blackout of a mobile telecommunication station or malfunction of a traffic light system could cause inconvenience or danger to life.

CBRs with automatic reclosing functions are intended to improve the efficiency of operating unmanned facilities.

This annex is essentially based on the relevant requirements of Annex B of this standard.

R.1.2 Field of application

This annex applies to CBRs, hereinafter referred to as CBARs, which restore the power supply through automatic reclosing without manual operation, in the case of tripping due to the residual current function.

This annex also applies to automatic reclosing devices supplied separately which, when combined with a CBR, fulfils the requirements of a CBAR. For the purpose of this annex, the term CBAR also covers an automatic reclosing device combined with a CBR.

This annex also covers the requirements for CBARs concerning electromagnetic compatibility (EMC).

This annex applies only to CBARs intended for use in a.c. circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs depending on an alternative supply source for the residual current function are not covered by this annex.

The object of this annex is to state:

a) specific features of the automatic reclosing function;
b) specific requirements which shall be complied with by the CBAR:
   – under normal circuit conditions;
   – under abnormal circuit conditions;
   – under temporary fault conditions.

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c) tests which shall be performed to verify compliance with the requirements in b) above, together with the appropriate test procedures;

d) relevant product information.

R.2 Terms and definitions

As a complement to Clause 2 and Clause B.2 of this standard, the following additional terms and definitions apply:

R.2.1
automatic reclosing
operating sequence of a mechanical switching device whereby, following its opening, it closes automatically depending on specific conditions

[SOURCE: IEC 60050-441:1984, 441-16-10, modified – term and supplemented by "depending on specific conditions"]

R.2.2
rated automatic reclosing operating residual current
$I_{\Delta ar}$
maximum value of the residual current at which a type M CBAR recloses automatically under the specified conditions (see R.3.2.1)

R.2.3
selector switch
switch for selecting automatic reclosing or manual reclosing mode

R.2.4
reset time
maximum period of time, declared by the manufacturer, during which consecutive reclosing operations may be made

R.2.5
blocked state
state of the CBAR in which the automatic reclosing function is inhibited and a manual reset is necessary

R.2.6
reclosing time-delay
for type TD CBAR, maximum time between the tripping of the device and the reclosing of the contacts

Note 1 to entry: For definition of type TD CBAR, see R.3.2.2.

R.2.7
reclosing time
for type M CBAR, maximum time between the instant when the reclosing condition is fulfilled and the reclosing of the contacts

Note 1 to entry: For definition of type M CBAR, see R.3.2.1.

R.2.8
monitoring time
for type M CBARs, time during which the monitoring is effective after operation of the residual current tripping function

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R.3 Classification

As a complement to Clause 3 and Clause B.3 of this standard, the following additional classifications apply.

R.3.1 According to the method of construction

R.3.1.1 Integral CBAR

CBAR as a single unit comprising an automatic reclosing function integrated by the manufacturer with the circuit-breaker.

R.3.1.2 External automatic reclosing device

An automatic reclosing device externally connected to a CBR without modification of its internal circuits or components.

R.3.2 According to the method of automatic reclosing

R.3.2.1 Earth leakage monitoring type (M)

CBAR, hereafter called "type M", which monitors the downstream circuit to assess the presence of an earth fault, and does not allow reclosing when the assessed earth leakage current exceeds $I_{\Delta ar}$.

The monitoring shall be achieved through the use of the line voltage. It may be either continuous or intermittent.

Type M CBARs with limitation of test voltage monitors the downstream circuit by means of a non-hazardous voltage, hereinafter called "monitoring voltage".

Type M CBARs with limitation of test current monitors the downstream circuit by means of a non-hazardous current, hereinafter called "monitoring current".

R.3.2.2 Time-delay type (TD)

CBAR, hereafter called "type TD", for which the automatic re-closing takes place after a time-delay without consideration of the circuit conditions.

R.4 Characteristics

Clause 4 and Clause B.4 of this standard apply with the following addition.

R.4.1 Rated automatic reclosing operating residual current ($I_{\Delta ar}$)

The value of the rated automatic reclosing operating residual current shall be declared by the manufacturer, without exceeding $I_{\Delta n}$. The manufacturer may declare different values of $I_{\Delta ar}$ for different rated voltages.

R.4.2 Maximum number of consecutive reclosing operations

The reset time and the maximum number of consecutive reclosing operations within the reset time shall be declared by the manufacturer.

R.5 Marking and instructions

Clause 5 and Clause B.5 apply with the additions listed in Table R.2.

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Table R.2 – Product information

Item	Information	Marking location
R1.1	Indication of the two positions of the selector switch: "automatic reclosing" and "manual reclosing"	Visible
R2.1	Rated control circuit supply voltage (U_s) of the CBAR, if applicable	Marked
R2.2	Rated automatic reclosing operating residual current ($I_{\Delta ar}$)	Marked
R2.3	Meaning of the indicators (e.g. lamps), if applicable	Marked
R3.1	Procedure for replacement of any built-in fuse	Literature
R3.2	Procedure for the connection of the earth terminal when necessary for the automatic reclosing function	Literature
R3.3	Reset time and corresponding maximum number of reclosing operations	Literature
R3.4	Monitoring time and reclosing time for type M CBARs	Literature
R3.5	Reclosing time delay for type TD CBARs	Literature
Key Visible: visible from the front when the circuit-breaker is installed as in service and the actuator is accessible Marked: marked on the product Literature: provided in the manufacturer's literature		

R.6 Normal service, mounting and transport conditions

Clause 6 applies.

R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 7.1 and B.7.1 of this standard, the following additional requirements apply:

R.7.1.1 Mode selection

The device shall be equipped with a selector switch (see R.2.3).

Compliance is checked by the tests of R.8.4.4.

R.7.1.2 Indicators

The device shall be provided with an indicator showing the blocked state.

All indicators shall be visible in the installed position.

R.7.1.3 Type M CBARs

It shall be ensured that no hazardous voltage or current is applied to the load terminals. One of the following methods shall be employed:

– The monitoring voltage (see R.3.2.1) shall be supplied by a transformer providing Class II isolation between primary and secondary circuits. The monitoring voltage shall not exceed 25 V a.c. or 60 V d.c.; or

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– The monitoring current (see R.3.2.1) shall be supplied from a current-limiting source or a protective impedance device complying with IEC 61140. The steady-state current shall not exceed 1 mA a.c. or 2 mA d.c.

R.7.2 Operating requirements

As a complement to 7.2 and B.7.2 of this standard, the following additional requirements apply:

R.7.2.1 General

CBARs shall only reclose automatically after tripping due to the residual current function. Compliance is checked by the tests of R.8.2.

CBARs shall not reclose automatically after intentional opening of the circuit-breaker. Compliance is checked by the tests of R.8.3.

When the maximum number of automatic reclosing operations within the reset time is reached, the automatic reclosing function shall be blocked until a manual reset is performed.

The reset time shall be not less than 5 s.

R.7.2.2 Type M CBARs

After tripping of the residual current release, if the assessed earth leakage current is lower than $I_{\Delta ar}$, a type M CBAR shall automatically reclose within the reclosing time declared by the manufacturer.

After tripping of the residual current release, if the assessed earth leakage current is higher than $I_{\Delta ar}$, the automatic reclosing shall be inhibited. In this case, the monitoring shall not be effective for a period of time longer than the monitoring time declared by the manufacturer. After this time, the automatic reclosing function shall be blocked.

The monitoring time shall be less than 1 h.

Compliance is checked by the tests of R.8.4.2.

R.7.2.3 Type TD CBAR

After tripping due to the residual current function, a type TD CBAR shall automatically reclose within the reclosing time-delay declared by the manufacturer, unless it has reached the maximum number of consecutive reclosing operations within the reset time.

Compliance is checked by the tests of R.8.4.3.

NOTE A type TD CBAR will not reclose on a phase-to-phase short-circuit, but can potentially reclose on a phase-to-ground fault.

R.7.2.4 Residual short-circuit making and breaking capacity

CBARs shall make, carry for a specified time and break residual short-circuit currents.

Compliance is checked by the tests of R.8.7.

R.7.2.5 Effects of environmental conditions

CBARs shall operate satisfactorily, taking into account the effects of environmental conditions.

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Compliance is checked by the tests of R.8.8.

R.8 Tests

R.8.1 General conditions

As a complement to Clause 8 and Clause B.8 of this standard, the following additional requirements apply.

Integral CBARs shall meet the test requirements from R.8.2 to R.8.8 except that the tests of R.8.6 only apply to CBARs suitable for isolation.

One sample shall be submitted to the tests of R.8.2, R.8.3 and R.8.4 in sequence.

The tests from R.8.5 to R.8.8 may be made during the test sequences of Clause 8.

External CBARs shall meet the test requirements of R.8.9.

Tests shall be performed in automatic reclosing mode, unless otherwise stated, the CBAR being supplied with the maximum rated voltage and the rated control circuit supply voltage, if applicable.

The CBAR shall be connected as per the manufacturer's instructions.

EMC tests of B.8.12 shall be performed in both automatic re-closing mode and manual re-closing mode.

R.8.2 Verification of the non-reclosing after tripping under over-current conditions

R.8.2.1 Tripping under short-circuit conditions

The circuit-breaker shall be tripped through its short-circuit release by applying a test current higher or equal to 120 % of the short-circuit current setting on one combination of two poles in series chosen at random (see 8.3.3.2.2). In case of adjustable current setting, the test shall be performed at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker short-circuit release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

R.8.2.2 Tripping under overload conditions

The circuit-breaker shall be tripped through its overload release by applying a test current higher than 130 % of the overload current setting and lower than 80 % of the short circuit current setting. This test may be performed at any ambient temperature and in case of adjustable current setting, at any convenient setting. The device shall not reclose automatically after tripping, within twice the reclosing time or reclosing time-delay, as applicable, declared by the manufacturer, or 60 s, whichever is the greater.

For the purpose of this test, the circuit-breaker overload release may be set to any convenient value, and it is acceptable to separate the control circuit supply voltage for the automatic reclosing function, from the main terminals.

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R.8.3 Verification of the non-reclosing after intentional opening

The selector switch being in the "automatic reclosing" position and the control circuit supply voltage normally applied, the circuit-breaker is opened manually. The device shall not reclose automatically after opening. The test duration shall be twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

This test shall be repeated for opening through shunt trip or undervoltage release as applicable, using any convenient rated control voltage variant.

R.8.4 Verification of the automatic reclosing function after tripping on earth fault

R.8.4.1 General

The devices shall be installed as in normal use.

The test circuit shall be in accordance with Figure R.1.

R.8.4.2 Verification of the correct operation of type M CBARs

R.8.4.2.1 In case of continuous residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

The switch S_2 shall be maintained in the closed position for the monitoring time declared by the manufacturer (see R.7.2.2).

The monitoring voltage or current shall comply with the requirements of R.7.1.3.

The CBAR shall not reclose automatically.

At the end of the monitoring time, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

R.8.4.2.2 In case of temporary residual current

The test is made on one pole only chosen at random. For CBARs with multiple settings of the residual operating current, the test shall be carried out at the lowest and highest settings.

The test circuit being calibrated at $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.The CBAR shall trip.

After tripping, the residual current is reduced to the value of $I_{\Delta ar}$ corresponding to the applied voltage.

The CBAR shall reclose automatically within the reclosing time declared by the manufacturer.

The test is repeated as many times as necessary to verify the maximum number of consecutive reclosing operations within the reset time, as declared by the manufacturer. At the end of the test, the CBAR shall be in the blocked state, and no monitoring voltage or current shall be present in the downstream circuit.

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R.8.4.3 Verification of the correct operation of type TD CBARs

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay (Δt) as applicable.

The test circuit being calibrated at $2 \times I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall reclose automatically within the reclosing time-delay, repeated for the maximum number of consecutive reclosings within the reset time, as declared by the manufacturer.

At the end of the test, the CBAR shall be in the blocked state.

R.8.4.4 Verification of the correct operation of the selector switch

The test is made on one pole only chosen at random, with the selector switch in the "manual reclosing" position, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit being calibrated at $2 \times I_{\Delta n,}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2. The CBAR shall trip.

Immediately after tripping, the switch S_2 is re-opened; the CBAR shall not reclose automatically within twice the reclosing time or reclosing time-delay declared by the manufacturer, as applicable, or 60 s, whichever is the greater.

R.8.5 Verification of mechanical endurance

R.8.5.1 External automatic reclosing device combined with a CBR previously tested to Annex B or CBAR previously tested to Annex B

The test circuit is in accordance with Figure R.1.

The test is made on one pole only chosen at random, the CBAR being set at the minimum values of $I_{\Delta n}$ and time-delay, as applicable.

The test circuit is calibrated at $2 \times I_{\Delta n}$. With the switch S_1 and the CBAR in the closed position, the residual current is established by closing the switch S_2.

The CBAR shall trip and shall be reclosed automatically.

The test shall be repeated for one-third of the number of "operations with current" specified in Table 8. No failure to trip or to reclose shall be permitted.

NOTE Depending on the reset time and corresponding maximum number of consecutive reclosing operations, it may be necessary to manually reset the CBAR or inhibit the blocking function.

R.8.5.2 CBAR not previously tested to Annex B

The test of R.8.5.1 may be carried out separately or during the operational performance test of B.8.1.1.1, replacing the operations performed by applying a residual current.

R.8.6 Verification of the isolation function

R.8.6.1 General

This verification only applies to CBARs suitable for isolation.

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The tests of R.8.6.2 and R.8.6.3 shall be performed in all positions of the selector switch and in the blocked state.

R.8.6.2 Leakage current between open contacts

The following requirements apply:

a) Following the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 0,5 mA.

b) Following the test of 8.3.3.6 (Test sequence I, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

c) Following the test of 8.3.4.4 (Test sequence II, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 2 mA.

d) If applicable, following the test of 8.3.5.4 (Test sequence III, verification of dielectric withstand), the leakage current, measured through each pole with the contacts in the open position, at a test voltage of 1,1 U_e, shall not exceed 6 mA.

R.8.6.3 Impulse voltage between open contacts

During the test of 8.3.3.3 (Test sequence I, test of dielectric properties), the test voltage shall be applied between the line terminals being connected together and load terminals being connected together of CBARs with the contacts in the open position and its value shall be as specified in Table 14 of IEC 60947-1:2007.

There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

B.8.10 applies, with the following additional requirements:

The tests shall be performed in automatic reclosing mode, if applicable, with the line voltage (i.e. control circuit supply voltage) connected to the CBAR.

The following additional requirements shall be met after test:

– The CBAR shall comply with the test of B.8.11.4 b) regardless of the operation of the protection devices (fuse, etc.);

– In case of operation of the protection devices (fuse, etc.), this operation shall be shown by the appropriate indication means, if provided. If no indication mean is provided, it shall not be possible to reclose the CBAR, even manually, when the protection devices have operated.

R.8.8 Verification of the automatic reclosing function after the test sequences of Clause B.8

Following each of the verifications of B.8.1.2.1 (verification of the withstand capability to short-circuit currents), a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

Following each of the test sequences B I to B IV of Annex B, a verification of the correct automatic reclosing operation shall be made in accordance with R.8.4.2 or R.8.4.3, as applicable.

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R.8.9 Test items for external type automatic reclosing devices

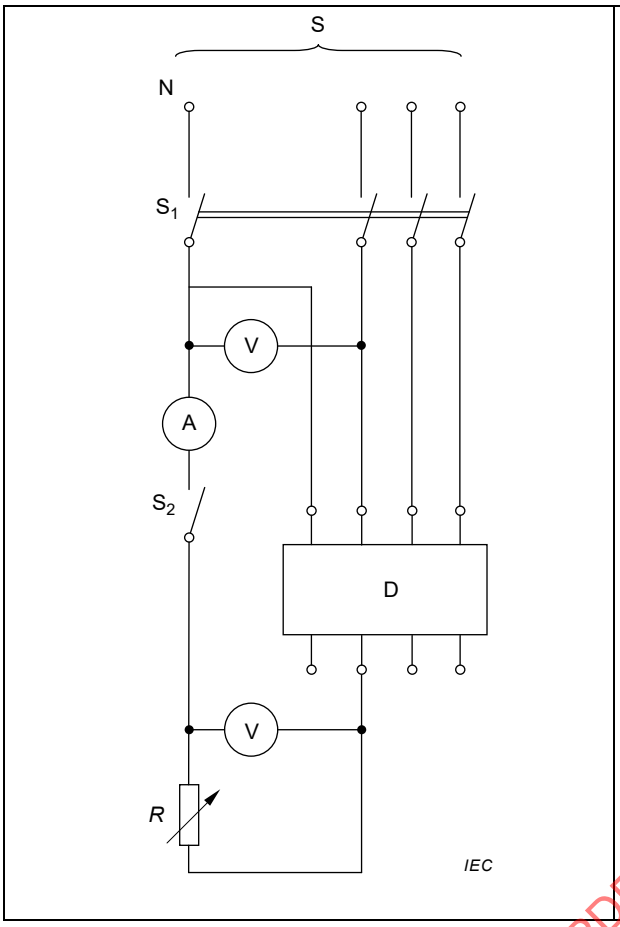
The following test sequences shall be performed on CBARs classified under R.3.1.2, in accordance with Figure R.1.

These tests are applicable to an automatic reclosing device assembled to a CBR and do not replace the tests of Clause B.8 made on the CBR.

Table R.1 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under over-current conditions	R.8.2
	Verification of the non-reclosing after intentional opening	R.8.3
	Verification of the automatic reclosing function after tripping on earth faults	R.8.4
	Verification of mechanical endurance	R.8.5
	Verification of the isolation function	R.8.6
2	Verification of the residual short-circuit making and breaking capacity	R.8.7
3	Rated ultimate short-circuit breaking capacity	8.3.5
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
4	Verification of the effects of environmental conditions	B.8.11
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8
5	Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages	B.8.6
	Verification of electromagnetic compatibility	B.8.12
	Verification of the automatic reclosing function after the test sequence of Clause B.8	R.8.8

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Key:

S = power supply
N = neutral connection
S_1 = multipole switch
S_2 = single-pole switch
V = voltmeter
A = r.m.s. ammeter
D = CBAR under test
R = adjustable resistor

Figure R.1 – Test circuit for the verification of the automatic reclosing functions

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2 This publication was withdrawn.

3 "DB" refers to the IEC on-line database.

4 "DB" refers to the IEC on-line database.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

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Cette version consolidée de la Norme IEC officielle et de son amendement a été préparée pour la commodité de l'utilisateur.

L'IEC 60947-2 édition 5.1 contient la cinquième édition (2016-06) [documents 121A/71/FDIS et 121A/83/RVD], son corrigendum (2016-11) et son amendement 1 (2019-07) [documents 121A/286/FDIS et 121A/302/RVD].

Cette version Finale ne montre pas les modifications apportées au contenu technique par l'amendement 1. Une version Redline montrant toutes les modifications est disponible dans cette publication.

La Norme internationale IEC 60947-2 a été établie par le sous-comité 121A: Appareillages à basse tension, du comité d'études 121 de l'IEC: Appareillage et ensembles d'appareillages basse tension.

Cette cinquième édition constitue une révision technique.

Cette édition inclut les additions techniques majeures suivantes par rapport à l'édition précédente:

- essais pour la vérification de la sélectivité dans l'Annexe A (voir A.5.3),
- essais de courants de charge critiques pour disjoncteurs à courant continu (voir 8.3.9),
- nouvelle Annexe P relative aux disjoncteurs pour utilisation dans des applications photovoltaïques,
- nouvelle Annexe R relative aux disjoncteurs de courant différentiel résiduel avec fonctions de refermeture automatique.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60947, publiées sous le titre général *Appareillage à basse tension*, peut être consultée sur le site web de l'IEC.

Cette Norme internationale doit être utilisée conjointement avec l'IEC 60947-1:2007 et ses Amendement 1:2010 et Amendement 2:2014.

Les dispositions des règles générales qui font l'objet de l'IEC 60947-1 sont applicables à la présente norme lorsque celle-ci le précise. Les articles, paragraphes, tableaux, figures et annexes des règles générales qui sont ainsi applicables sont identifiés par référence à l'IEC 60947-1 et ses amendements le cas échéant, par exemple: 1.2.3 de l'IEC 60947-1:2007, Tableau 4 de l'IEC 60947-1:2007/AMD1:2010, ou Annexe A de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014.

Le comité a décidé que le contenu de la publication de base et de son amendement ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives à la publication recherchée. A cette date, la publication sera

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Le contenu du corrigendum d'octobre 2019 a été pris en considération dans cet exemplaire.

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

1 Généralités

1.1 Domaine d'application et objet

La présente partie de la série IEC 60947 est applicable aux disjoncteurs destinés à être installés et utilisés par des personnes qualifiées ou compétentes, et dont les contacts principaux sont destinés à être reliés à des circuits dont la tension assignée ne dépasse pas 1 000 V en courant alternatif ou 1 500 V en courant continu; elle contient aussi des exigences supplémentaires pour les disjoncteurs à fusibles incorporés.

Les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif mais ne dépassant pas 1 500 V en courant alternatif peuvent également être soumis à essai selon la présente norme.

Elle est applicable quels que puissent être les courants assignés, les méthodes de construction et l'emploi prévu des disjoncteurs.

Les exigences pour les disjoncteurs qui sont aussi prévus pour assurer une protection contre les courants différentiels résiduels font l'objet de l'Annexe B.

Les exigences supplémentaires pour les disjoncteurs à protection électronique contre les surintensités font l'objet de l'Annexe F.

Les exigences supplémentaires relatives aux disjoncteurs pour réseaux IT font l'objet de l'Annexe H.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des disjoncteurs font l'objet de l'Annexe J.

Les exigences pour les disjoncteurs ne satisfaisant pas aux exigences concernant les protections contre les surintensités font l'objet de l'Annexe L.

Les exigences pour les appareils modulaires à courant différentiel résiduel (non intégrés à un appareil de coupure de courant) font l'objet de l'Annexe M.

Les exigences et les méthodes d'essai pour la compatibilité électromagnétique des auxiliaires de disjoncteurs font l'objet de l'Annexe N.

Les exigences et les méthodes d'essai pour les disjoncteurs à courant continu utilisables dans les applications photovoltaïques (PV) font l'objet de l'Annexe P.

Les exigences et les méthodes d'essai pour les disjoncteurs incorporant une protection par courant différentiel résiduel avec fonctions de refermeture automatique font l'objet de l'Annexe R.

Les exigences supplémentaires pour les disjoncteurs utilisés comme démarreurs directs sont données dans l'IEC 60947-4-1, applicable aux contacteurs et aux démarreurs à basse tension.

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Les exigences concernant les disjoncteurs destinés à la protection des installations électriques des bâtiments et à des emplois analogues et prévus pour être utilisés par des personnes non averties figurent dans l'IEC 60898.

Les exigences relatives aux disjoncteurs pour le matériel (par exemple pour les appareils électriques) figurent dans l'IEC 60934.

Des exigences particulières ou supplémentaires peuvent être nécessaires pour certaines applications spécifiques (par exemple: traction, laminoirs, service à bord des navires, circuits en aval de dispositifs d'entraînement à fréquence variable, utilisation dans des atmosphères explosives).

NOTE Les disjoncteurs, objet de la présente norme, peuvent être munis d'appareils provoquant l'ouverture automatique dans des conditions prédéterminées autres que la surintensité et la chute de tension, telles que, par exemple, l'inversion de la puissance ou du courant. La présente norme ne traite pas de la vérification du fonctionnement dans de telles conditions prédéterminées.

La présente norme a pour objet de fixer:

a) les caractéristiques des disjoncteurs;

b) les conditions auxquelles doivent répondre les disjoncteurs concernant:

   1) leur fonctionnement et leur tenue en service normal;

   2) leur fonctionnement et leur tenue en cas de surcharge et en cas de court-circuit, y compris la coordination en service (sélectivité et protection d'accompagnement);

   3) leurs propriétés diélectriques;

c) les essais destinés à vérifier si ces conditions sont remplies et les méthodes à adopter pour ces essais;

d) les informations à marquer sur les appareils ou à fournir avec ceux-ci.

1.2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-14, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60068-2-30, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60228, *Ames des câbles isolés*

IEC 60269-1:2006, *Fusibles basse tension – Partie 1: Exigences générales*

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60947-1:2007, *Appareillage à basse tension – Partie 1: Règles générales*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

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IEC 61000-4-2:2008, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2006, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5:2014, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6:2013, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-11, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61545, *Dispositifs de connexion – Dispositifs pour la connexion des câbles en aluminium dans un organe de serrage en matière quelconque et des câbles en cuivre dans des organes de serrage en aluminium*

IEC 62475:2010, *Techniques des essais à haute intensité – Définitions et exigences relatives aux courants d'essai et systèmes de mesure*

CISPR 11:2015, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
CISPR 11:2015/AMD1:2016

CISPR 32:2015, *Compatibilité électromagnétique des équipements multimédia – Exigences d'émission*

2 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60947-1 ainsi que les suivants s'appliquent.

NOTE Lorsque ces définitions sont identiques à celles du *Vocabulaire Electrotechnique International (VEI)*, IEC 60050-441, la référence à cette publication est donnée entre crochets.

2.1
disjoncteur
appareil mécanique de connexion capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, ainsi que d'établir, de supporter pendant une durée spécifiée et d'interrompre des courants dans des conditions anormales spécifiées du circuit telles que celles du court-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

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2.1.1
taille
terme désignant un groupe de disjoncteurs dont les dimensions extérieures physiques sont communes à une plage de courants assignés

Note 1 à l'article: La taille est exprimée en ampères correspondant au courant assigné le plus élevé du groupe.

Note 2 à l'article: Dans une taille, la largeur de l'appareil peut varier selon le nombre de pôles.

Note 3 à l'article: Cette définition n'implique pas de normalisation dimensionnelle.

2.1.2
différence de construction
différence significative de construction entre des disjoncteurs d'une taille donnée, nécessitant d'effectuer des essais supplémentaires de type

2.2
disjoncteur à fusibles incorporés
combinaison en un seul appareil d'un disjoncteur et de fusibles, un fusible étant placé en série avec chaque pôle du disjoncteur destiné à être relié à un conducteur de phase

[SOURCE: IEC 60050-441:1984, 441-14-22]

2.3
disjoncteur à limitation du courant
disjoncteur qui, à l'intérieur d'une plage de courants spécifiée, empêche le courant coupé limité d'atteindre la valeur crête présumée et qui limite l'énergie limitée (I^2t) à une valeur inférieure à l'énergie limitée d'une demi-période du courant présumé symétrique

Note 1 à l'article: Il peut être fait référence à la valeur crête présumée symétrique ou asymétrique du courant coupé limité.

Note 2 à l'article: Le courant coupé limité (let-through current) est aussi nommé «cut-off current» (voir IEC 60050-441:1984, 441-17-12).

Note 3 à l'article: Les modèles de représentation graphique des caractéristiques de courant coupé limité et d'énergie limitée sont illustrés de la Figure K.2 à la Figure K.5 et les exemples d'utilisation des modèles de la Figure K.6 à la Figure K.7.

2.4
disjoncteur enfichable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts permettant le retrait du disjoncteur

Note 1 à l'article: Certains disjoncteurs peuvent être de type enfichable sur le côté d'alimentation uniquement, les bornes de sortie étant les bornes utilisées habituellement pour le raccordement par conducteurs.

2.5
disjoncteur débrochable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts de sectionnement lui permettant d'être retiré du circuit principal et, en position débrochée, de présenter une distance de sectionnement conforme à des exigences spécifiées

2.6
disjoncteur en boitier moulé
disjoncteur dont le châssis et l'enveloppe sont en matériau isolant moulé et font partie intégrante du disjoncteur

[SOURCE: IEC 60050-441:1984, 441-14-24]

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2.7
disjoncteur à air
disjoncteur dont les contacts s'ouvrent et se ferment dans l'air à la pression atmosphérique

[SOURCE: IEC 60050-441:1984, 441-14-27]

2.8
disjoncteur à vide
disjoncteur dont les contacts s'ouvrent et se ferment dans une enceinte où règne un vide poussé

[SOURCE: IEC 60050-441:1984, 441-14-29]

2.9
disjoncteur à gaz
disjoncteur dont les contacts s'ouvrent et se ferment dans un gaz autre que l'air à une pression égale ou supérieure à la pression atmosphérique

2.10
déclencheur sous courant de fermeture
déclencheur qui permet l'ouverture d'un disjoncteur sans retard intentionnel, pendant une manœuvre de fermeture, si le courant établi dépasse une valeur prédéterminée, et qui est rendu inopérant lorsque le disjoncteur est en position fermée

2.11
déclencheur de court-circuit
déclencheur à maximum de courant destiné à la protection contre les courts-circuits

2.12
déclencheur de court-circuit à retard de courte durée
déclencheur à maximum de courant prévu pour fonctionner au bout d'un retard de courte durée

2.13
interrupteur de défaut
interrupteur auxiliaire ne fonctionnant que lors du déclenchement du disjoncteur auquel il est associé

2.14
disjoncteur à fermeture empêchée
disjoncteur dont chacun des contacts mobiles est empêché de se fermer suffisamment pour être capable de laisser passer le courant si l'ordre de fermeture est donné alors que demeurent maintenues des conditions spécifiées

2.15
pouvoir de coupure (ou de fermeture) en court-circuit
pouvoir de coupure (ou de fermeture) pour lequel les conditions spécifiées comprennent un court-circuit

2.15.1
pouvoir de coupure ultime en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée ne comprennent pas l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

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2.15.2
pouvoir de coupure de service en court-circuit
pouvoir de coupure pour lequel les conditions spécifiées suivant une séquence d'essai spécifiée comprennent l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

2.16
durée d'ouverture
intervalle de temps entre l'instant spécifié de début de la manoeuvre d'ouverture et l'instant de la séparation des contacts d'arc sur tous les pôles

Note 1 à l'article:

– dans le cas d'un disjoncteur actionné directement, l'instant de début de la durée d'ouverture est l'instant de début d'un courant assez fort pour provoquer la manœuvre du disjoncteur;

– dans le cas d'un disjoncteur actionné par toute forme d'énergie auxiliaire, l'instant de début de la durée d'ouverture est l'instant de début de l'application ou du retrait de l'énergie auxiliaire au déclencheur d'ouverture.

Note 2 à l'article: Pour les disjoncteurs, la «durée d'ouverture» est couramment appelée «durée de déclenchement», bien que, à proprement parler, la durée de déclenchement comprenne le délai entre l'instant où commence la durée d'ouverture et celui où la commande de l'ouverture devient irréversible.

[SOURCE: IEC 60947-1:2007, 2.5.39, modifiée – ajout de Notes à l'article.]

2.17
coordination de la protection contre les surintensités

2.17.1
sélectivité lors d'une surintensité
coordination entre les caractéristiques de fonctionnement de plusieurs appareils de protection à maximum de courant de telle façon qu'à l'apparition de surintensités comprises dans des limites données, l'appareil prévu pour fonctionner dans ces limites fonctionne, tandis que le ou les autres ne fonctionnent pas

2.17.2
sélectivité totale
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection sans provoquer le fonctionnement de l'autre appareil de protection

2.17.3
sélectivité partielle
sélectivité lors d'une surintensité dans laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval assure la protection jusqu'à un niveau donné de surintensité sans provoquer le fonctionnement de l'autre appareil de protection

2.17.4
courant limite de sélectivité
I_s
valeur de courant correspondant à l'intersection de la caractéristique totale temps-courant de l'appareil de protection placé en aval avec la caractéristique temps-courant de préarc (pour les fusibles) ou de déclenchement (pour les disjoncteurs) de l'autre appareil de protection

Note 1 à l'article: Le courant limite de sélectivité (voir Figure A.1) est une valeur limite de courant:

– en dessous de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval achève sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité est assurée);

– au-dessus de laquelle, en présence de deux appareils de protection à maximum de courant placés en série, l'appareil de protection aval peut ne pas achever sa manœuvre de coupure en temps voulu pour empêcher l'autre appareil de protection d'amorcer sa manœuvre (c'est-à-dire que la sélectivité n'est pas assurée).

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2.17.5
courant d'intersection
I_B
coordonnée du courant correspondant à l'intersection des courbes donnant les caractéristiques de la durée maximale de coupure en fonction du courant pour deux appareils de protection à maximum de courant placés en série

Note 1 à l'article: Cela s'applique à deux appareils de protection à maximum de courant placés en série pour des durées de fonctionnement ≥ 0,05 s. Pour des durées de fonctionnement < 0,05 s, les deux appareils à maximum de courant placés en série sont considérés comme une association (voir Annexe A).

2.18
caractéristique I^2t d'un disjoncteur
information (généralement une courbe) donnant les valeurs maximales de I^2t correspondant à la durée de coupure en fonction du courant présumé (valeur efficace de la composante périodique en courant alternatif) jusqu'à la valeur maximale du courant présumé correspondant au pouvoir assigné de coupure en court-circuit à la tension correspondante

2.19
durée de réarmement
temps écoulé entre le déclenchement du disjoncteur provoqué par une surintensité et l'instant où les conditions sont atteintes pour qu'il puisse être refermé

2.20
courant assigné instantané de réglage de court-circuit
I_i
valeur assignée du courant provoquant le fonctionnement d'un déclencheur sans retard intentionnel

2.21
courant de réglage de surcharge
I_r
courant de réglage pour un déclencheur de surcharge réglable

Note 1 à l'article: Dans le cas d'un déclencheur de surcharge non réglable, cette valeur est égale au courant assigné I_n.

2.22
automate programmable
AP
système électronique numérique conçu pour un usage en environnement industriel et utilisant une mémoire programmable destinée au stockage interne d'instructions orientées utilisateur pour réaliser des fonctions particulières telles que la logique, le séquencement, le décompte du temps, le comptage et l'arithmétique afin de commander, au moyen d'entrées et de sorties analogiques ou numériques, différents types de machines ou de processus. Un AP ainsi que ses périphériques associés sont conçus de sorte qu'ils peuvent aisément être intégrés dans un système de commande industriel et employés dans toutes leurs fonctions prévues

[SOURCE: IEC 61131-1:2003, 3.5, modifiée – suppression de la note.]

2.23
déclencheur de fermeture
bobine de fermeture
auxiliaire alimenté par une source de tension qui déclenche la fermeture du disjoncteur

Note 1 à l'article: Un déclencheur de fermeture est un appareil auxiliaire du disjoncteur, différent de l'"appareil de fermeture" mentionné dans les figures de l'Annexe A et dans l'IEC 60947-1, qui fait partie du montage d'essai et qui est destiné à établir le courant de court-circuit.

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3 Classification

Les disjoncteurs peuvent être classés:

3.1 Suivant leur catégorie de sélectivité, A ou B (voir 4.4)

3.2 Suivant le milieu de coupure, par exemple:

– coupure à air,
– coupure sous vide,
– coupure à gaz.

3.3 Suivant le type de conception, par exemple:

– construction ouverte,
– construction en boîtier moulé.

3.4 Suivant le mode de commande du mécanisme de manœuvre, c'est-à-dire:

– manœuvre dépendante à main,
– manœuvre indépendante à main,
– manœuvre dépendante à source d'énergie extérieure,
– manœuvre indépendante à source d'énergie extérieure,
– manœuvre à accumulation d'énergie.

3.5 Suivant l'aptitude au sectionnement:

– apte au sectionnement,
– inapte au sectionnement.

3.6 Suivant les possibilités d'entretien:

– conçu pour être entretenu,
– non conçu pour être entretenu.

3.7 Suivant le mode d'installation, par exemple:

– fixe,
– enfichable,
– débrochable.

3.8 Suivant le degré de protection procuré par l'enveloppe (voir 7.1.12 de l'IEC 60947-1:2007).

4 Caractéristiques des disjoncteurs

4.1 Enumération des caractéristiques

Les caractéristiques d'un disjoncteur doivent, selon le cas, être indiquées de la façon suivante:

– type du disjoncteur (4.2),
– valeurs assignées et valeurs limites du circuit principal (4.3),
– catégories de sélectivité (4.4),
– circuits de commande (4.5),

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– circuits auxiliaires (4.6),
– déclencheurs (4.7),
– fusibles incorporés (disjoncteurs à fusibles incorporés) (4.8).

4.2 Type du disjoncteur

Les éléments suivants doivent être indiqués:

– le nombre de pôles,
– la nature du courant (courant alternatif ou courant continu) et, dans le cas du courant alternatif, le nombre de phases et la fréquence assignée.

4.3 Valeurs assignées et valeurs limites du circuit principal

4.3.1 Généralités

Les valeurs assignées relatives à un disjoncteur doivent être indiquées conformément aux 4.3.2 à 4.4, mais il n'est pas nécessaire de spécifier toutes les valeurs assignées énumérées.

4.3.2 Tensions assignées

4.3.2.1 Tension d'emploi assignée (U_e)

Le paragraphe 4.3.1.1 de l'IEC 60947-1:2007 est applicable avec le développement suivant:

– Disjoncteurs répondant au point a) de la Note 2 (de l'IEC 60947-1 :2007):

U_e est généralement exprimée par la tension entre phases.

NOTE 1 Au Canada et aux Etats-Unis, la tension assignée d'emploi U_e est exprimée par:

a) la tension entre phases et la terre, ainsi que par la tension entre phases (par exemple 277 V/480 V) pour des réseaux triphasés à quatre fils et neutre mis à la terre,

b) la tension entre phases (par exemple 480 V) pour des réseaux triphasés, à trois fils, non reliés à la terre ou reliés à la terre par une impédance.

Les disjoncteurs pour systèmes non reliés à la terre ou pour systèmes reliés à la terre par une impédance requièrent des essais supplémentaires conformément à l'Annexe H.

– Disjoncteurs répondant au point b) de la Note 2:

Ces disjoncteurs demandent des essais supplémentaires conformément à l'Annexe C.

U_e doit s'exprimer par la tension entre phases, précédée de la lettre C.

NOTE 2 Dans la pratique actuelle au Canada et aux Etats-Unis, les disjoncteurs répondant au point b) de la Note 2 (de l'IEC 60947-1 :2007) ne sont identifiés que par la tension entre phases.

4.3.2.2 Tension d'isolement assignée (U_i)

Le paragraphe 4.3.1.2 de l'IEC 60947-1:2007 est applicable.

4.3.2.3 Tension assignée de tenue aux chocs (U_{imp})

Le paragraphe 4.3.1.3 de l'IEC 60947-1:2007 est applicable.

4.3.3 Courants

4.3.3.1 Courant thermique conventionnel à l'air libre (I_{th})

Le paragraphe 4.3.2.1 de l'IEC 60947-1:2007 est applicable.

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4.3.3.2 Courant thermique conventionnel sous enveloppe (I_{the})

Le paragraphe 4.3.2.2 de l'IEC 60947-1:2007 est applicable.

4.3.3.3 Courant assigné (I_n)

Pour les disjoncteurs, le courant assigné est le courant assigné ininterrompu (I_u) (voir 4.3.2.4 de l'IEC 60947-1:2007) et a la même valeur que le courant thermique conventionnel à l'air libre (I_{th}).

4.3.3.4 Courant assigné des disjoncteurs tétrapolaires

Le paragraphe 7.1.9 de l'IEC 60947-1:2007 est applicable.

4.3.4 Fréquence assignée

Le paragraphe 4.3.3 de l'IEC 60947-1:2007 est applicable.

4.3.5 Service assigné

Les services assignés considérés comme normaux sont:

– le service de huit heures (voir le 4.3.4.1 de l'IEC 60947-1:2007),
– le service ininterrompu (voir le 4.3.4.2 de l'IEC 60947-1:2007).

4.3.6 Caractéristiques de court-circuit

4.3.6.1 Pouvoir assigné de fermeture en court-circuit (I_{cm})

Le pouvoir assigné de fermeture en court-circuit d'un disjoncteur est la valeur de pouvoir de fermeture en court-circuit fixée pour ce disjoncteur par le fabricant pour la tension assignée d'emploi, à la fréquence assignée et pour un facteur de puissance spécifié en courant alternatif, ou une constante de temps spécifiée en courant continu. Il s'exprime par la valeur maximale de crête du courant présumé.

En courant alternatif, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur au produit de son pouvoir assigné de coupure ultime en court-circuit multiplié par le facteur *n* figurant au Tableau 2 (voir 4.3.6.3).

En courant continu, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur ne doit pas être inférieur à son pouvoir assigné de coupure ultime en court-circuit.

Un pouvoir assigné de fermeture en court-circuit implique que le disjoncteur doit être capable d'établir le courant correspondant à ce pouvoir assigné pour une tension appliquée appropriée à la tension assignée d'emploi.

4.3.6.2 Pouvoirs assignés de coupure en court-circuit

4.3.6.2.1 Généralités

Les pouvoirs assignés de coupure en court-circuit d'un disjoncteur sont les valeurs de pouvoir de coupure en court-circuit assignées par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans des conditions spécifiées.

Un pouvoir assigné de coupure en court-circuit exige que le disjoncteur doit pouvoir couper tout courant de court-circuit de valeur inférieure ou égale à ce pouvoir assigné de coupure, à une tension de rétablissement à fréquence industrielle correspondant aux valeurs spécifiées pour la tension d'essai et:

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– en courant alternatif, à tout facteur de puissance supérieur ou égal à celui du Tableau 11 (voir 8.3.2.2.4),

– en courant continu, à toute constante de temps inférieure ou égale à celle du Tableau 11 (voir 8.3.2.2.5).

Aucun pouvoir de coupure en court-circuit n'est garanti pour des tensions de rétablissement à fréquence industrielle supérieures aux valeurs spécifiées pour la tension d'essai (voir 8.3.2.2.6).

En courant alternatif, le disjoncteur doit être capable de couper un courant présumé correspondant à son pouvoir assigné de coupure en court-circuit et le facteur de puissance correspondant donné au Tableau 11, quelle que soit la valeur de la composante continue correspondante, en admettant que la composante périodique est constante.

Les pouvoirs assignés de coupure en court-circuit sont définis comme suit:

– pouvoir assigné de coupure ultime en court-circuit,

– pouvoir assigné de coupure de service en court-circuit.

4.3.6.2.2 Pouvoir assigné de coupure ultime en court-circuit (I_{cu})

Le pouvoir assigné de coupure ultime en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure ultime en court-circuit (voir 2.15.1) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.5. Il est exprimé comme valeur du courant de coupure présumé, en kA (valeur efficace de la composante alternative dans le cas du courant alternatif).

4.3.6.2.3 Pouvoir assigné de coupure de service en court-circuit (I_{cs})

Le pouvoir assigné de coupure de service en court-circuit d'un disjoncteur est la valeur du pouvoir de coupure de service en court-circuit (voir 2.15.2) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi, dans les conditions spécifiées en 8.3.4. Il est exprimé comme valeur du courant de coupure présumé, en kA, ou comme pourcentage de I_{cu} (par exemple I_{cs} = 25 % I_{cu}).

I_{cs} doit être au moins égal à 25 % de I_{cu}.

Tableau 1 (vide)

4.3.6.3 Relation normale entre les pouvoirs de fermeture et de coupure en court-circuit des disjoncteurs à courant alternatif et les facteurs de puissance correspondants

La relation normale entre le pouvoir de coupure en court-circuit et le pouvoir de fermeture en court-circuit est donnée par le Tableau 2.

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Tableau 2 – Rapport *n* entre le pouvoir de fermeture en court-circuit et le pouvoir de coupure en court-circuit et le facteur de puissance correspondant (pour les disjoncteurs à courant alternatif)

Pouvoir de coupure en court-circuit kA eff	Facteur de puissance	Valeur minimale exigée de *n* $n = \frac{\text{pouvoir de fermeture en court - circuit}}{\text{pouvoir de coupure en court - circuit}}$
$I \leq 1,5$	0,95	1,41
$1,5 < I \leq 3$	0,9	1,42
$3 < I \leq 4,5$	0,8	1,47
$4,5 < I \leq 6$	0,7	1,53
$6 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

Les pouvoirs assignés de fermeture et de coupure en court-circuit ne sont valables que si le disjoncteur est manœuvré selon les exigences de 7.2.1.1 et 7.2.1.2.

Pour des exigences spéciales, le fabricant peut fixer une valeur de pouvoir assigné de fermeture en court-circuit supérieure à celle exigée dans le Tableau 2. Les essais de vérification de ces valeurs assignées doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

4.3.6.4 Courant assigné de courte durée admissible (I_{cw})

Le courant assigné de courte durée admissible d'un disjoncteur est la valeur de courant de courte durée admissible fixée pour ce disjoncteur par le fabricant dans les conditions d'essai spécifiées en 8.3.6.3.

En courant alternatif, la valeur de ce courant est la valeur efficace de la composante périodique du courant présumé de court-circuit, étant par hypothèse constante pendant le retard de courte durée.

Le retard de courte durée associé au courant assigné de courte durée admissible doit être d'au moins 0,05 s, les valeurs préférentielles étant les suivantes:

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

Le courant assigné de courte durée admissible ne doit pas avoir une valeur moindre que les valeurs figurant au Tableau 3.

Tableau 3 – Valeurs minimales du courant assigné de courte durée admissible

Courant assigné I_n A	Courant assigné de courte durée admissible I_{cw} – Valeurs minimales kA
$I_n \leq 2\,500$	12 I_n ou 5 kA, selon la valeur la plus élevée
$I_n > 2\,500$	30 kA

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4.4 Catégories de sélectivité

Les disjoncteurs conformes à la présente norme sont divisés en deux catégories de sélectivité:

– **catégorie de sélectivité B** comprenant les disjoncteurs assurant la sélectivité en ayant un courant assigné de courte durée admissible et un retard de courte durée associé conformes à 4.3.6.4.

  La sélectivité des disjoncteurs de catégorie de sélectivité B n'est pas nécessairement assurée jusqu'au pouvoir de coupure ultime en court-circuit (par exemple, en cas de fonctionnement d'un déclencheur instantané), mais elle l'est au moins jusqu'à la valeur spécifiée au Tableau 3.

– **catégorie de sélectivité A** comprenant tous les autres disjoncteurs.

  Ces disjoncteurs peuvent assurer la sélectivité dans des conditions de court-circuit par d'autres moyens.

  Un disjoncteur de catégorie de sélectivité A peut avoir un retard de courte durée intentionnel avec un courant de courte durée admissible inférieur à celui spécifié en 4.3.6.4. Dans ce cas, les essais comprennent la séquence d'essai IV (voir 8.3.6) au courant assigné de courte durée admissible.

L'attention est attirée sur les différences entre les essais s'appliquant aux deux catégories de sélectivité (voir Tableau 9 et 8.3.4, 8.3.5, 8.3.6 et 8.3.8).

Tableau 4 (vide)

4.5 Circuits de commande

4.5.1 Circuits de commande électriques

Le paragraphe 4.5.1 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 est applicable, avec le complément suivant:

Si la tension assignée d'alimentation de commande est différente de celle du circuit principal, il est recommandé de choisir sa valeur parmi celles du Tableau 5.

Tableau 5 – Valeurs préférentielles de la tension assignée d'alimentation de commande si elle est différente de celle du circuit principal

Courant continu V	Courant alternatif monophasé V
24 – 48 – 110 – 125 – 220 – 250	24 – 48 – 110 – 127 – 220 – 230

4.5.2 Circuits de commande à air comprimé (pneumatiques ou électropneumatiques)

Le paragraphe 4.5.2 de l'IEC 60947-1:2007 est applicable.

4.6 Circuits auxiliaires

Le paragraphe 4.6 de l'IEC 60947-1:2007 est applicable.

4.7 Déclencheurs

4.7.1 Types

Pour les besoins de la présente norme, les types suivants de déclencheurs sont considérés:

1) déclencheur shunt,

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2) déclencheur à maximum de courant:
   a) instantané,
   b) à retard indépendant,
   c) à temps inverse:
      – indépendant de la charge préalable,
      – dépendant de la charge préalable (par exemple: déclencheur du type thermique).

NOTE 1 Le terme «déclencheur de surcharge» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les surcharges (voir 2.4.30 de l'IEC 60947-1:2007). Le terme «déclencheur de court-circuit» est employé pour désigner des déclencheurs à maximum de courant destinés à la protection contre les courts-circuits (voir 2.11).

NOTE 2 Le terme «déclencheur réglable», utilisé dans la présente norme, comprend aussi les déclencheurs interchangeables.

3) déclencheur à minimum de tension (déclencheur d'ouverture),
4) déclencheur de fermeture;
5) autres déclencheurs.

4.7.2 Caractéristiques

Les caractéristiques suivantes doivent être considérées:

1) déclencheur shunt et déclencheur à minimum de tension (déclencheurs d'ouverture), et déclencheur de fermeture:
   – tension assignée du circuit de commande (U_c),
   – nature du courant,
   – fréquence assignée, dans le cas du courant alternatif.
2) déclencheur à maximum de courant:
   – courant assigné (I_n),
   – nature du courant,
   – fréquence assignée, dans le cas du courant alternatif,
   – courant de réglage (ou plage de réglage),
   – temps de réglage (ou plage de réglage) le cas échéant.

Le courant assigné d'un déclencheur à maximum de courant est la valeur du courant (valeur efficace dans le cas du courant alternatif) correspondant au courant de réglage maximal qu'il doit être capable de supporter dans les conditions d'essai spécifiées en 8.3.2.5 sans que l'échauffement dépasse les valeurs spécifiées au Tableau 7.

4.7.3 Courant de réglage des déclencheurs à maximum de courant

Pour les disjoncteurs équipés de déclencheurs réglables (voir Note 2 de 4.7.1, point 2)), le courant de réglage (ou la plage des courants de réglage, le cas échéant) doit être marqué ou affiché sur le déclencheur ou sur son échelle de réglage. L'indication ou l'affichage peut être donné(e) soit directement en ampères, soit en multiples de la valeur du courant. Des moyens doivent être disponibles auprès du fabricant pour lire l'affichage indépendamment de l'état du disjoncteur.

Pour les disjoncteurs équipés de déclencheurs non réglables, l'indication peut figurer sur le disjoncteur. Si les caractéristiques de fonctionnement du déclencheur de surcharge satisfont aux exigences du Tableau 6, il suffit d'indiquer sur le disjoncteur son courant assigné (I_n).

Pour les déclencheurs indirects fonctionnant à l'aide d'un transformateur de courant, les indications peuvent se rapporter soit au courant au primaire du transformateur de courant qui

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les alimente, soit au courant de réglage du déclencheur de surcharge. Dans l'un et l'autre cas, le rapport de transformation du transformateur de courant doit être indiqué.

Sauf spécification contraire,

– la valeur de fonctionnement des déclencheurs de surcharge autres que ceux du type thermique est indépendante de la température de l'air ambiant dans les limites de – 5 °C à + 40 °C;
– pour les déclencheurs du type thermique, les valeurs indiquées correspondent à une température de référence de + 30 °C ± 2 °C. Le fabricant doit être en mesure de préciser l'influence des variations de la température de l'air ambiant (voir 7.2.1.2.4, point b)).

4.7.4 Réglage du temps de déclenchement des déclencheurs à maximum de courant

Le temps de déclenchement doit être défini comme suit, selon le type de déclencheur à maximum de courant:

1) Déclencheurs à maximum de courant à retard défini

   Le retard de ces déclencheurs est indépendant de la surintensité. Le réglage du temps de déclenchement doit être défini comme égal à la valeur en secondes de la durée d'ouverture du disjoncteur si le retard n'est pas réglable, ou aux valeurs extrêmes de la durée d'ouverture si le retard est réglable.

2) Déclencheurs à maximum de courant à temps inverse

   Le retard de ces déclencheurs dépend de la surintensité.

   Les caractéristiques temps/courant doivent être données sous forme de courbes fournies par le fabricant. Celles-ci doivent indiquer comment la durée d'ouverture, à partir de l'état froid, varie en fonction du courant dans la plage de fonctionnement du déclencheur. Le fabricant doit indiquer, par des moyens convenables, les tolérances applicables à ces courbes.

   Ces courbes doivent être données pour chacune des valeurs extrêmes du courant de réglage et, si le temps de réglage donné est réglable, il est recommandé qu'elles soient également données pour chacune des valeurs extrêmes du temps de réglage.

   Il est recommandé de porter le courant en abscisses et le temps en ordonnées, en utilisant des échelles logarithmiques. De plus, en vue de faciliter l'étude de la coordination des divers types de protection contre les surintensités, il est recommandé de porter le courant en multiples du courant de réglage et le temps en secondes en utilisant les échelles normalisées données dans les feuilles de courbe normale décrites en 5.6.1 de l'IEC 60269-1:2006.

4.8 Fusibles incorporés (disjoncteurs à fusibles incorporés)

Le paragraphe 4.8 de l'IEC 60947-1:2007/AMD1:2010 est applicable.

Le fabricant doit fournir les informations nécessaires.

5 Informations sur le matériel

5.1 Nature des informations

Le paragraphe 5.1 de l'IEC 60947-1:2007 est applicable, dans la mesure où il est approprié pour un modèle particulier.

En supplément le fabricant doit, sur demande, fournir les informations concernant la puissance dissipée typique pour les différentes tailles (voir 2.1.1). Voir Annexe G.

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