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



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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

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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. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2016 and its Amendment 1: 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) suitability for isolation (see Clause 1);
b) removal of the classification according to the interrupting medium, according to the design, according to the suitability for isolation (see Clause 4);
c) adjustment of current settings with an external device connectable to the release (see 5.7.3);
d) requirements for circuits with protective separation (see 8.2.3.8);
e) additional tests for ground-fault overcurrent releases (see 9.3.4.2.5);
f) additional tests concerning dielectric properties in tripped position (see 9.3.4.3);
g) use of DC voltage for dielectric tests (see 9.3.4.6.2 and 9.4.6);
h) tests of individual pole breaking capacity under phase-to-neutral AC voltage (see 9.3.11);
i) improvement of measurement of power loss in Annex G;
j) changes in EMC tests (see Annex J);
k) introduction of CBI class W in Annex L.

The text of this International Standard is based on the following documents:

Draft	Report on voting
121A/608/FDIS	121A/621/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 60947-1:2020.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this document, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2020.

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The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

~~1 General~~

1 Scope ~~and object~~

This document 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 AC or 1 500 V DC; 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.~~

This document also applies to circuit-breakers with ratings at or below 1 000 V AC, additionally having one or more ratings above 1 000 V AC but not exceeding 1 500 V AC.

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

Circuit-breakers per this document are suitable for isolation.

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

Additional requirements for circuit-breakers intended for connection of aluminium conductors are contained in Annex D.

The additional requirements for circuit-breakers with electronic overcurrent 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 overcurrent 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 for instantaneous trip circuit-breakers are contained in Annex O.

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

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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~~ overcurrent protection for household and similar installations, and designed for use by uninstructed persons, are contained in IEC 60898 series.

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~~ can be ~~necessary~~ applicable.

NOTE 1 Circuit-breakers can have dedicated accessories.

NOTE 2 Circuit-breakers which are dealt with in this document can be provided with devices for automatic opening under predetermined conditions other than those of overcurrent and undervoltage as, for example, reversal of power or current. This document does not deal with the verification of operation under such pre-determined conditions.

The object of this document is to state:

a) the characteristics of circuit-breakers;

b) the requirements for circuit-breakers with reference to:

   1) operation and behaviour in normal service;

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

   3) dielectric properties;

   4) requirements on electromagnetic compatibility, where applicable;

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~~ circuit-breakers.

NOTE 3 For cybersecurity requirements, see IEC TS 63208.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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*~~

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IEC 60664-1:~~2007~~2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-1:~~2007~~2020, *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~~2020, *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 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:~~2013~~2023, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11:2020, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

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

IEC 61545:1996, *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 11:2015/AMD2:2019

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1:2020, 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.

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ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified ~~time~~ duration and breaking currents under specified abnormal circuit conditions such as those of short-circuit

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

3.1.1
frame size
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~~ can vary according to the number of poles.

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

3.1.2
construction break
significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing

3.2
integrally fused circuit-breaker
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~~ line conductor

[SOURCE: IEC 60050-441:1984, 441-14-22, modified – “phase” replaced with “line”.]

3.3
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~~ can 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.

3.4
plug-in circuit-breaker
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~~ can be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

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3.5
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]~~

~~**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~~

3.6
making-current release
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

3.7
short-circuit release
overcurrent release intended for protection against short circuits

3.8
short-time delay short-circuit release
overcurrent release intended to operate at the end of the short-time delay

3.9
alarm switch
auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

3.10
circuit-breaker with lock-out device preventing closing
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

3.11
short-circuit breaking (or making) capacity
breaking (or making) capacity for which the prescribed conditions include a short circuit

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3.11.1
ultimate short-circuit breaking capacity
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

3.11.2
individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage
ultimate short-circuit breaking capacity which is determined for an individual pole at the phase-to-neutral AC voltage

3.11.3
service short-circuit breaking capacity
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

3.12
opening time
<of a mechanical switching device> 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.~~ IEC 60947-1:2020, 3.7.39, modified – modification of Note 1 to entry and addition of Note 2 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~~

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~~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).~~

3.13
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 (RMS symmetrical for AC) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

3.14
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

3.15
~~**rated** **instantaneous short-circuit current setting**~~
I_i
~~rated value of the current causing the operation of a release without any intentional time-delay~~

current setting of a short-circuit release, above which a current causes its operation without any intentional time-delay

Note 1 to entry: I_i can be non-adjustable

3.16
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.

3.17
short-time pick-up current setting
I_{sd}
current setting of a short-circuit release, above which a current causes its operation with an intentional time-delay (t_{sd})

3.18
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

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Note 1 to entry: 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.]

3.19
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.

4 Classification

~~Circuit-breakers may be classified:~~

4.1 According to the selectivity category, A or B (see 5.4)

~~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.~~

4.2 According to the method of controlling the operating mechanism:

– 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.~~

4.3 According to the provision for maintenance:

– maintainable;
– non-maintainable.

4.4 According to the method of installation:

– fixed;
– plug-in;
– withdrawable.

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4.5 According to the degree of protection provided by the enclosure (see 8.1.12 of IEC 60947-1:~~2007~~2020)

5 Characteristics of circuit-breakers

5.1 Summary of characteristics

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

– type of circuit-breaker (5.2);
– rated and limiting values of the main circuit (5.3);
– selectivity categories (5.4);
– control circuits (5.5);
– auxiliary circuits (5.6);
– releases (5.7);
– integral fuses (integrally fused circuit-breakers) (5.8).

5.2 Type of circuit-breaker

The following shall be stated:

– number of poles;
– kind of current (AC or DC) and, in the case of AC, number of phases and rated frequency.

5.3 Rated and limiting values of the main circuit

5.3.1 General

The rated values established of a circuit-breaker shall be stated in accordance with 5.3.2 to 5.4, but it is not necessary to ~~establish all the rated values listed~~ state I_{th} (5.3.3.1), I_{the} (5.3.3.2), rated frequency (5.3.4) in case of a DC only circuit-breaker, rated duty (5.3.5).

5.3.2 Rated voltages

5.3.2.1 Rated operational voltage (U_e)

Subclause 5.3.1.1 of IEC 60947-1:~~2007~~2020 applies with the following amplification:

– circuit-breakers covered by 5.3.1.1 item a) of IEC 60947-1:~~2007~~2020.

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 5.3.1.1 item b) of IEC 60947-1:2020.

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 5.3.1.1 item b) of IEC 60947-1:~~2007~~2020 are identified by the voltage between phases only.

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5.3.2.2 Rated insulation voltage (U_i)

Subclause 5.3.1.2 of IEC 60947-1:~~2007~~2020 applies.

5.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:~~2007~~2020 applies.

5.3.3 Currents

5.3.3.1 Conventional free air thermal current (I_{th})

Subclause 5.3.2.1 of IEC 60947-1:~~2007~~2020 applies.

5.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:~~2007~~2020 applies.

5.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 5.3.2.4 of IEC 60947-1:~~2007~~2020) 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.~~

5.3.4 Rated frequency

Subclause 5.3.3 of IEC 60947-1:~~2007~~2020 applies.

5.3.5 Rated duty

The rated duties considered as normal are:

– the eight-hour duty (see 5.3.4.1 of IEC 60947-1:~~2007~~2020),
– the uninterrupted duty (see 5.3.4.2 of IEC 60947-1:~~2007~~2020).

5.3.6 Short-circuit characteristics

5.3.6.1 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 AC, or time constant for DC. It is expressed as the maximum prospective peak current.

For AC, 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 1 (see 5.3.6.3).

For DC, 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.

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5.3.6.2 Rated short-circuit breaking capacities

5.3.6.2.1 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.

NOTE A circuit-breaker in accordance with this document is able to break line-to-line, line-to-earth, line-to-neutral (AC) and line-to-mid-point (DC) short-circuits

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 AC, at any power factor not less than ~~that of Table 11~~ those required in 9.3.3.2.4;

– for DC, with any time constant not greater than ~~that of Table 11~~ those required in 9.3.3.2.5.

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 9.3.3.2.6), no short-circuit breaking capacity is guaranteed.

For AC, 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~~ 9.3.3.2.4, irrespective of the value of the inherent DC component, on the assumption that the RMS value of the AC component of the prospective current is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;

– rated service short-circuit breaking capacity.

5.3.6.2.2 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 3.11.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.6. It is expressed as the value of the prospective breaking current, in kA (RMS value of the AC component in the case of AC).

5.3.6.2.3 Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1})

The rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage of a circuit-breaker is the value of individual pole breaking capacity at phase-to-neutral voltage assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.11. It is expressed as a value of the prospective breaking current, in kA (RMS value of the AC component).

5.3.6.2.4 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 3.11.3) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.5. 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)~~

5.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor for AC circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 1.

Table 1 – Ratio n between short-circuit making capacity and short-circuit breaking capacities and related power factor for AC circuit-breakers

Short-circuit breaking capacity kA RMS I	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 8.2.1.1 and 8.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 1. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

5.3.6.4 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 9.3.7.3.

NOTE 1 The rated short-time withstand current is not influenced by a change of a trip unit.

NOTE 2 The attainable time selectivity in an application depends on the actual short-time pick-up current setting (I_{sd}) and the intentional time delay (t_{sd}) of the trip unit.

For AC, the value of this current is the RMS value of the AC 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 2.

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Table 2 – 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

5.4 Selectivity categories

Circuit-breakers according to this document 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 5.3.6.4.

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 2.

– **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 5.3.6.4. In that case, the tests shall include test sequence IV (see 9.3.7) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two selectivity categories (see Table 10 and 9.3.5, 9.3.6, 9.3.7 and 9.3.9).

~~**Table 4 (void)**~~

5.5 Control circuits

5.5.1 Electrical control circuits

Subclause 5.5.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies, with the following addition:

If the rated control circuit supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 3.

Table 3 – Preferred values of the rated control circuit 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

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

Subclause 5.5.2 of IEC 60947-1:~~2007~~2020 applies.

5.6 Auxiliary circuits

Subclause 5.6 of IEC 60947-1:~~2007~~2020 applies.

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5.7 Releases

5.7.1 Types

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

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

NOTE 1 The term "overload release" is used to identify overcurrent releases intended for protection against overloads (see 3.6.31 of IEC 60947-1:~~2007~~2020). The term "short-circuit release" is used to identify overcurrent releases intended for protection against short circuits (see 3.7); it includes the short-time delay short-circuit release (see 3.8).

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

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

5.7.2 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 AC
2) overcurrent release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if AC;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

The rated current of an overcurrent release is the value of current (RMS if AC) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 9.3.3.5, without the temperature-rise exceeding the values specified in Table 6.

5.7.3 Current setting of overcurrent 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 adjustable releases (see Note 2 to 5.7.1, item 2), the current settings shall be marked on the release, or displayed on the release's display, or displayed on an external device's display connectable to the release. The settings may be either directly in

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amperes or as a multiple of the current value. Means shall be provided by the manufacturer to read the display regardless of the status of the circuit-breaker. When applicable, the manufacturer shall specify the characteristics of the external device.

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 5, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

The current settings may be adjusted through an external (local or remote) device connectable to the release, in which case either local setting indications shall not be exceeded, or a local indication shall show that the settings are controlled remotely. The manufacturer shall provide means to the testing laboratory to ensure settings do not change during type tests.

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 in the literature (see 8.2.1.2.4, item b)).

5.7.4 Tripping time setting of overcurrent releases

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

1) Definite time-delay overcurrent releases

   The time-delay of such releases is independent of the overcurrent. 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 overcurrent releases

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

   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 overcurrent 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.

5.8 Integral fuses (integrally fused circuit-breakers)

Subclause 5.8 of IEC 60947-1:~~2007/AMD1:2010~~2020 applies, replacing "SCPD" with "integral fuse".

~~The manufacturer shall provide the necessary information.~~

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6 Product information

6.1 Nature of the information

Subclause 6.1 of IEC 60947-1:~~2007~~2020 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 3.1.1). See Annex G.

For the glossary of symbols and graphical representation of characteristics, see Annex K.

6.2 Marking

Each circuit-breaker shall be marked in a durable manner; data to be provided and corresponding locations are indicated in Table 4.

Table 4 – 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~~S00287:2001-07 combined with IEC 60617-~~S00219~~S00220:2001-07)	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 8.1.6.1 of IEC 60947-1:~~2007~~2020)	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 this document	Marked
2.4	selectivity category A or B	Marked
2.5	rated operational voltage(s) U_e (see 5.3.2.1 and, where applicable, Annex H)	Marked
2.6	~~unsuitability for IT systems, if applicable, with the symbol~~  ~~(IEC 60417-6363:2016-07)~~ Indication that the circuit-breaker is not suitable for IT systems at all rated voltages with the symbol  (IEC 60417-6363:2016-07). For any exception for specific rated voltages, see H.5.	Marked
2.7	rated impulse withstand voltage (U_{imp})	Marked
2.8	value (or range) of the rated frequency, and/or the indication "DC" (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 individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}), at the corresponding rated voltage (U_e), if different from I_{cu}	Marked
2.12	rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B	Marked
2.13	range of the current setting (I_r) of the adjustable overload release	Marked [a]
2.14	value or range (when adjustable) of the short-time pick-up current setting (I_{sd}) of the release and its intended time-delay (t_{sd}), when applicable	Marked [a]
2.15	range of the ground-fault current (I_g) of the adjustable release, when applicable	Marked [a]
2.16	range of the ~~rated~~ instantaneous short-circuit current setting (I_i), for adjustable releases	Marked [a]

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Item	Information	~~Marking~~ Location
2.17	reference temperature for non-compensated thermal releases, if different from 30 °C	Marked
2.18	terminals identification, according to 8.1.8.4 of IEC 60947-1:~~2007~~2020	Marked
2.19	Identification of line and load terminals, if applicable	Marked
2.20	neutral pole terminals, if applicable, by the letter N	Marked
2.21	protective earth terminal, where applicable, by the symbol (IEC 60417-5019:2006-08)  (see 8.1.10.3 of IEC 60947-1:~~2007~~2020)	Marked
3.1	rated short-circuit making capacity (I_{cm}) at the corresponding rated voltage (U_e), if higher than the minimum values specified in 5.3.6.1	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 (see 7.1.3.2 of IEC 60947-1:2020)	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~~2020)	Literature
3.6	when applicable, 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~~2020, 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, when applicable, for temperatures higher than the reference temperature	Literature
3.13	influence of ambient temperature, if applicable, on the tripping performance of the overcurrent release (see 5.7.3)	Literature
3.14	current derating for terminals and connections, if applicable	Literature
3.15	method and diagram of series connection of poles (as necessary for each rating) for DC circuit-breakers	Literature
3.16	type of ground-fault detection function (see T.4 of IEC 60947-1:2020)	Literature
3.17	value of the instantaneous short-circuit current setting (I_i), for non-adjustable releases	Literature
3.18	number of poles	Literature
3.19	further information concerning aluminum conductors (see D.5.2)	Literature
4.1	for closing releases (see 3.19) and/or motor-operators, rated control circuit voltage, kind of current and rated frequency for AC	Aux
4.2	rated control circuit voltage of the shunt release and/or of the undervoltage release (or of the no-voltage release), kind of current and rated frequency for AC	Aux
4.3	rated current of indirect overcurrent releases (see 5.7.3)	Aux
4.4	number and type of auxiliary contacts, rated operational currents at the rated operational voltages, and rated frequency for AC	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.~~ Where applicable, settings of I_r, I_i, I_{sd} and I_g may be displayed on the display of the release or of an external device instead of being marked (see 5.7.3).

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6.3 Instructions for installation, operation and maintenance

Subclause 6.3 of IEC 60947-1:~~2007/AMD2:2014~~2020 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.

7 Normal service, mounting and transport conditions

Clause 7 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies with the following addition:

Pollution degree (see 7.1.3.2 of IEC 60947-1:~~2007~~2020).

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

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 8.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies with the following modifications:

a) Where, in 8.1.2.2 of IEC 60947-1:2020, 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 and 850 °C for the other circuits.

NOTE 1 "Other circuits" cover control circuits (see 5.5), auxiliary circuits (see 5.6) and releases (see 5.7)

b) The requirements of 8.1.2 of IEC 60947-1:2020 do not apply to parts with a mass lower than 2 g (insignificant mass, in accordance with 3.14 of IEC 60695-2-11:2021). For products containing more than one small part, the total mass of non-tested parts located within 3 mm of each other shall not exceed 10 g.

NOTE 2 This distance of 3 mm is defined in 30.2 of IEC 60335-1:2020.

When aluminium conductors are to be used, Annex D applies.

NOTE 3 Guidance for the development of embedded software is offered in IEC TR 63201.

~~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.~~

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8.1.2 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.

8.1.3 ~~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.~~

Subclause 8.1.7 of IEC 60947-1:2020 applies.

For additional requirements concerning performance, see 8.2.6.

NOTE In the UK, for circuit-breakers with plug-in line and load connections, isolation is achieved by complete removal of the circuit-breaker from the fixed connecting contacts.

8.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:~~2007~~2020 and in Table 15 of IEC 60947-1:~~2007/AMD1:2010~~2020.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:~~2007~~2020, clearances shall be obtained from Table F.2 of IEC 60664-1:~~2007~~2020.

8.1.5 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 9.3.3.6.1, item b).

8.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 3.1.2) if any one of the following features are not the same:

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– 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 overcurrent 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, or rendering the central pole inaccessible;
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.).

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

Subclause 8.1.9 of IEC 60947-1:~~2007~~2020 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.~~

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

Annex S of IEC 60947-1:~~2007~~2020 applies. For the purposes of this document, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 Closing

8.2.1.1.1 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.

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8.2.1.1.2 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.

8.2.1.1.3 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.

8.2.1.1.4 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 circuit supply voltage, and, when AC, at the rated frequency.

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

At 85 % of the rated control circuit supply voltage, the closing operation shall be performed ~~when the current established by~~ to establish a current through 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.

8.2.1.1.5 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.

8.2.1.1.6 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 circuit 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.

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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.

8.2.1.2 Opening

8.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 3.6.24 of IEC 60947-1:~~2007~~2020) 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.

8.2.1.2.2 Opening by undervoltage releases

Subclause 8.2.1.3 of IEC 60947-1:~~2007~~2020 applies.

8.2.1.2.3 Opening by shunt releases

Subclause 8.2.1.4 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

8.2.1.2.4 Opening by overcurrent releases

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker ~~with an accuracy~~ within a tolerance 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 overcurrent coordination, the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 3.7.21 of IEC 60947-1:~~2007~~2020) as a function of prospective current (RMS symmetrical for AC currents);

– I^2t characteristics (see 3.13) for circuit-breakers of selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 9.3.6.1).

When applicable, the conformity with this information ~~may~~ shall be checked during the relevant type tests in test sequences II and III (see 9.3.5 and 9.3.6).

NOTE 1 It is possible to provide other forms of data to verify coordination 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~~ within a tolerance 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 5.

At the reference temperature (see 5.7.3) and at 1,05 times the current setting (see 3.6.38 of IEC 60947-1:~~2007~~2020), i.e. with the conventional non-tripping current (see 3.7.30 of IEC 60947-1:~~2007~~2020), the ~~opening~~ overload release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 3.7.30 of IEC 60947-1:~~2007~~2020) 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

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3.7.31 of IEC 60947-1:~~2007~~2020), 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 5 – Characteristics of the opening operation of inverse time-delay overcurrent 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 5 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.

c) Opening under ground-fault conditions

The ground-fault overcurrent release shall cause tripping of the circuit-breaker within the tolerance corresponding to the type of detection function (CI-A or CI-B) according to T.4 of IEC 60947-1:2020, for all values of the current setting of the ground-fault overcurrent release.

Ground-fault overcurrent releases may have an intentional time-delay, but the break time shall not exceed the tripping time values indicated in Table T.1 of IEC 60947-1:2020.

NOTE 3 Ground-fault overcurrent releases can have sensors internal or external to the circuit-breaker.

8.2.2 Temperature-rise

8.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 9.3.3.5, shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.4.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.5.5 and 9.3.7.4.

8.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 6 are applicable only if the ambient air temperature remains within the limits given in 7.1.1 of IEC 60947-1:~~2007/AMD2:2014~~2020.

8.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the overcurrent releases that may be associated with it, shall be capable of carrying its rated current I_n, under the conditions of Clause 9, without the temperature-rises exceeding the limits specified in Table 6.

8.2.2.4 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 5.3.5, and also the temperature-rise tests under the test conditions specified in 9.3.3.5, to be made without the temperature-rises exceeding the limits specified in Table 6.

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The requirements of this subclause shall be verified on a new ~~circuit-breaker~~ sample. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 9.3.4.7.

8.2.2.5 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 6 when tested in accordance with 9.3.3.5.

Table 6 – 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~~ shall 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 9.	

8.2.3 Dielectric properties

8.2.3.1 General

Subclauses 8.2.3.1 a) and 8.2.3.1 b) of IEC 60947-1:~~2007~~2020 apply.

Type tests shall be made in accordance with 9.3.4.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 9.3.4.6.

Routine tests shall be made in accordance with 9.4.6.

8.2.3.2 Impulse withstand voltage

Subclause 8.2.3.2 of IEC 60947-1:~~2007~~2020 applies.

For circuit-breakers rated above 1 000 V AC, 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 AC.

NOTE Table 1 of IEC TS 62993:2017 provides rated impulse voltage values above 1 000 V AC.

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8.2.3.3 Power-frequency or DC 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.

8.2.3.4 Clearances

Subclause 8.2.3.4 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

8.2.3.5 Creepage distances

Subclause 8.2.3.5 of IEC 60947-1:~~2007~~2020 applies.

8.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 9.3.3.4.1, item 3) of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020, or DC tests (test voltages for DC tests are under consideration).

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

8.2.3.7 Spacing between separate circuits

Subclause 8.2.3.7 of IEC 60947-1:~~2007~~2020 applies.

8.2.3.8 Requirements for circuits with protective separation

Annex N of IEC 60947-1:2020 applies.

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

8.2.4.1 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 9.3.4.5.

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

8.2.4.2 Operational performance capability

Subclause 8.2.4.2 of IEC 60947-1:~~2007~~2020 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 7:

– for the test of operational performance without current in the main circuit under the test conditions specified in 9.3.4.4.3;
– for the test of operational performance with current in the main circuit under the test conditions specified in 9.3.4.4.4.

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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 7 – 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.

8.2.5 Ability to make and break under short-circuit conditions

Subclause 8.2.5 of IEC 60947-1:~~2007~~2020 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 5.3.6.1 and 5.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 5.3.6.2.

The rated short-time withstand current shall be in accordance with 5.3.6.4.

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**~~

8.2.6 ~~Additional requirements for circuit-breakers suitable~~ Requirements for isolation

Subclause 8.2.7 of IEC 60947-1:2020 applies and tests shall be made in accordance with 9.3.4.3, 9.3.4.6, 9.3.4.10, 9.3.5.4, 9.3.6.4 and 9.3.8.8, as applicable.

8.2.7 Specific requirements for integrally fused circuit-breakers

NOTE For the coordination between circuit-breakers and separate fuses associated in the same circuit, see 8.2.8.

An integrally fused circuit-breaker shall comply with this document in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 9.3.8).

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

For all overcurrents 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 a

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circuit-breaker with lock-out device preventing closing (see 3.10), 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.

8.2.8 Coordination between a circuit-breaker and another short-circuit protective device

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

8.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

9 Tests

9.1 Kind of tests

9.1.1 General

Subclause 9.1 of IEC 60947-1:~~2007~~2020 applies, with the following additions:

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

– type tests (see 9.3);
– routine tests (see 9.4);
– special tests (see 9.5).

For items subject to agreement between manufacturer and user, see Annex E.

9.1.2 Type tests

Type tests include the tests listed in Table 8.

Table 8 – Type tests

Test	Subclause
Temperature-rise	9.3.3.5
Tripping limits and characteristics	9.3.4.2
Dielectric properties	9.3.4.3
Operational performance capability	9.3.4.4
Overload performance (where applicable)	9.3.4.5
Short-circuit breaking capacities	9.3.5 and 9.3.6
Short-time withstand current (where applicable)	9.3.7
Performance of integrally fused circuit-breakers	9.3.8
Critical DC load current	9.3.10
Individual pole short-circuit breaking capacity at phase-to-neutral AC voltage (where applicable)	9.3.11

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

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9.1.3 Routine tests

Routine tests comprise the tests listed in 9.4.

9.1.4 Special tests

Special tests comprise the tests listed in 9.5.

9.2 Compliance with constructional requirements

Subclause 9.2 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies.

9.3 Type tests

9.3.1 General

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 (9.3.4 to 9.3.9);
– test conditions applicable to temperature-rise tests (9.3.3.5);
– test conditions applicable to short-circuit tests (9.3.3.6).

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 Table 9, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

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Table 9 – Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	9.3.3.1
Arrangement of circuit-breakers for short-circuit tests	9.3.3.6.1
Frequency	9.3.3.2.3
Power factor	9.3.3.2.4
Records (interpretation of)	9.3.3.6.6
Recovery voltage	9.3.3.2.6
Short-circuit test circuits	9.3.3.6.2
Short-circuit test procedure	9.3.3.6.4
Temperature-rise test	9.3.3.5
Time constant	9.3.3.2.5
Tolerances	9.3.3.2.2
Tests (for overall schema of test sequences, see Table 10)	**Subclause**
Critical DC load current	9.3.10
Dielectric properties	9.3.4.3
Dielectric withstand (verification)	9.3.4.6 – 9.3.5.4 – 9.3.6.4 – 9.3.7.6 – 9.3.8.4 – 9.3.8.8 – 9.3.9.6
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	9.3.4.10
Integrally fused circuit-breakers (short-circuit tests)	9.3.8.2 – 9.3.8.6 – 9.3.8.7
Operational performance capability	9.3.4.4 – 9.3.5.3 – 9.3.5.5
Overload performance	9.3.4.5
Overload releases (verification)	9.3.4.8 – 9.3.5.6 – 9.3.6.2 – 9.3.6.5 – 9.3.7.2 – 9.3.7.7 – 9.3.8.5 – 9.3.8.9 – 9.3.9.2 – 9.3.9.8
Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	9.3.11
Service short-circuit breaking capacity	9.3.5.2 – 9.3.9.4
Short-circuit breaking capacity test at maximum short-time withstand current	9.3.7.5
Short-time withstand current	9.3.7.3 – 9.3.9.3
Temperature-rise (verification)	9.3.4.7 – 9.3.5.5 – 9.3.7.4 – 9.3.8.3 – 9.3.9.7
Tripping limits and characteristics	9.3.4.2
Ultimate short-circuit breaking capacity	9.3.6.3
Withdrawable circuit-breakers (additional tests)	9.3.4.4.5

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9.3.2 Test sequences

9.3.2.1 General

Type tests are grouped together in a number of sequences, as shown in Table 10.

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

9.3.2.2 Tests omitted from sequence I and made separately

With reference to 9.1.1 of IEC 60947-1:~~2007~~2020, the following tests of test sequence I (see 9.3.4) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (9.3.4.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 9.3.4.2.3 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 (9.3.4.3);

– test of under-voltage releases of 9.3.4.4.2.3 and 9.3.4.4.3 to verify the requirements of 8.2.1.3 of IEC 60947-1:~~2007~~2020, and tests of under-voltage releases at alternative frequencies (see 9.3.3.1);

– test of shunt releases of 9.3.4.4.2.4 and 9.3.4.4.3 to verify the requirements of 8.2.1.4 of IEC 60947-1:~~2007/AMD2:2014~~2020, and tests of shunt releases at alternative frequencies (see 9.3.3.1);

– additional tests for operational performance capability without current for withdrawable circuit-breakers (9.3.4.4.5).

9.3.2.3 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 11.

Table 10 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (9.3.4)	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 (9.3.5)	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 (9.3.6)	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

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Test sequence	Applicable to	Tests
IV Rated short-time withstand current (9.3.7)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with an assigned short-time withstand current (see 5.4)	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 (9.3.8)	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 (9.3.9)	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
VII Critical DC load current (9.3.10)	Circuit-breakers with DC ratings	Critical DC load current tests
VIII Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (9.3.11)	AC circuit-breakers, when applicable (see 9.3.11.1)	Verification of overload releases Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}) Verification of dielectric withstand Verification of overload releases
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 11.

[b] Except where Sequence VI is applied.

[c] Except
- where $I_{cs} = I_{cu}$ (but see 9.3.6),
- where sequence VI is applied,
- for integrally fused circuit-breakers.

[d] See note to 9.3.6.1

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Table 11 – 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 5.4).

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9.3.2.4 Alternative test programmes for AC circuit-breakers having a different number of poles

These alternative test programmes may only be applied to AC ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 10, 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 10. 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 10 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 13 shall be carried out on the other variants.
– Programme 2: The applicable test sequences according to Table 10 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 14 shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated in Table 12.

Table 12 – Alternative test programmes for AC circuit-breakers

	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 10 □ tested per Table 13 ○ tested per Table 14 – no test required								
[a] Construction 1 is the construction which covers the max rating.									

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Table 13 – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 9.3.2.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	9.3.4.2	Test of tripping limits and characteristics		
	9.3.4.2.1	General	X	X
	9.3.4.2.2	Short-circuit releases	X[a]	X[e]
	9.3.4.2.3 a)[i] or 9.3.4.2.3 b)[i] (as applicable)	Overload releases: – instantaneous/definite time-delay or – inverse time-delay	X	X[e]
	9.3.4.2.4	Additional test for definite time-delay releases:		
	9.3.4.3	Dielectric properties	X	X
	9.3.4.4	Mechanical operation and operational performance capability		
	9.3.4.4.1	General	X	X
	9.3.4.4.2	Construction and mechanical operation	X[d]	X[d, e]
	9.3.4.4.3	Operational performance capability without current	X	X
	9.3.4.4.4	Operational performance capability with current	X	X
	9.3.4.4.5	Withdrawable circuit-breakers	X	
	9.3.4.5	Overload performance	X	X
	9.3.4.6	Verification of dielectric withstand	X	X
	9.3.4.7	Verification of temperature-rise	X	X
	9.3.4.8	Verification of overload releases		
	9.3.4.9	Verification of undervoltage and shunt releases	X	X
	9.3.4.10	Verification of the main contact position	X	X
II	9.3.5	Rated service short-circuit breaking capacity		
III	9.3.6[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	9.3.7	Rated short-time withstand current	X 4th pole and adjacent pole only (see 9.3.3.6.4)	
V	9.3.8	Performance of integrally fused circuit-breakers	X	X
VI	9.3.9	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.

[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 10).

[c] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (9.3.4.4.2.3) and shunt releases (9.3.4.4.2.4).

[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~~ shall be tested according to Table 13.

[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 3.1.2 and 8.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.

~~[i] Vacant.~~

~~[j] Vacant.~~

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

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Table 14 – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 9.3.2.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[e]	Applicability to 1-pole or 2-pole variants[e]
I	9.3.4.2	Test of tripping limits and characteristics		
	9.3.4.2.1	General		X
	9.3.4.2.2	Short-circuit releases		X [d]
	9.3.4.2.3 a)[f] or 9.3.4.2.3 b)[f] (as applicable)	Overload releases: – instantaneous/definite time-delay or – inverse time-delay		X[d]
	9.3.4.2.4	Additional test for definite time-delay releases		
	9.3.4.3	Dielectric properties	X	X
	9.3.4.4	Mechanical operation and operational performance capability		
	9.3.4.4.1	General	X	X
	9.3.4.4.2	Construction and mechanical operation		X[c, d]
	9.3.4.4.3	Operational performance capability without current	X	X
	9.3.4.4.4	Operational performance capability with current	X	X
	9.3.4.4.5	Withdrawable circuit-breakers		
	9.3.4.5	Overload performance	X	X
	9.3.4.6	Verification of dielectric withstand	X	X
	9.3.4.7	Verification of temperature-rise	X	X
	9.3.4.8	Verification of overload releases		
	9.3.4.9	Verification of undervoltage and shunt releases	X	X
	9.3.4.10	Verification of the main contact position	X	X
II	9.3.5	Rated service short-circuit breaking capacity		
III	9.3.6[a, b]	Rated ultimate short-circuit breaking capacity	X	X
IV	9.3.7	Rated short-time withstand current		
V	9.3.8	Performance of integrally fused circuit-breakers	X	X
VI	9.3.9	Combined test sequence		
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.~~

[a~~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 10).

[~~c~~b] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[~~d~~c] Without verification tests of undervoltage releases (9.3.4.4.2.3) and shunt releases (9.3.4.4.2.4).

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

~~[f] Vacant.~~

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

~~[h] Vacant.~~

~~[i] Vacant.~~

~~[j] Vacant.~~

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

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9.3.3 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.~~

9.3.3.1 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 15 and, where applicable, for the alternative test programmes in Table 13 and Table 14 (see 9.3.2.4).

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

Unless otherwise specified, tests ~~are to~~ shall 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 3.1.2 and 8.1.6) within the frame size, further samples shall be tested in accordance with Table 13 and/or Table 15 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 AC, 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 undervoltage and shunt releases (see 8.2.1 of IEC 60947-1: ~~2007/AMD2:2010~~2020 and 8.2.2.7 of IEC 60947-1:~~2007~~2020).

If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 8.2.1.1.4. 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 3.6.12 of IEC 60947-1:~~2007~~2020), 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.

Unless otherwise stated, the connections of the complete circuit-breaker, and of the separate release (when applicable, see 9.3.4.2.1), shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Table 9 of IEC 60947-1:2020 with a minimum cross section of 1 mm^2, Table 10 of IEC 60947-1:2020, Table 11 of IEC 60947-1:2020) and of length according to 9.3.3.3.4 of IEC 60947-1:2020. In case of aluminium conductors, their cross sections shall be in accordance with Table D.7 or Table D.8, as applicable.

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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 9.3.6, at U_e max, and corresponding I_{cu}, with release settings at maximum (see footnote [a] of Table 15).

b) a temperature-rise test according to the general conditions of 9.3.3.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 5.3.3.2). The temperature-rises shall meet the requirements of 8.2.2 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 9.3.4.1.2, item d) of IEC 60947-1:~~2007~~2020) 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 Table 4, item 3.11).

Unless otherwise stated, all tests shall be performed with forward connections.

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 15 – Number of samples for test

Test sequence	Number of marked U_e or I_{cw} [p] ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temperature-rise verification	Foot-notes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 9.3.4		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}) and VIII (I_{cu1})	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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Test sequence	Number of marked U_e or I_{cw} [p] ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Tempe-rature-rise verifica-tion	Foot-notes
	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
VI (combined)	See test sequence II															
VII (I_{crit})	X	X	X	X	X	1	1		X	U_e max DC	X					g
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 15 applies to the test programmes of Table 10. In the case of the alternative test programmes (see 9.3.2.4), Table 13 and Table 14 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.~~

[e] Test at the maximum kVA rating (I_{cu} or I_{cs}, as applicable, multiplied by the corresponding U_e intermediate). This sample is omitted if another sample has previously been tested under the same conditions.

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

[g] In the case of one or more construction breaks (see 3.1.2 and 8.1.6) 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 ($I_{cw}^2 t$; where "t" is the corresponding short-time delay, see 5.3.6.4). 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 with sequence II ($I_{cu} = I_{cs}$, see 9.3.6).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced with sequence II ($I_{cu} = I_{cs}$, see 9.3.6) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 9.3.9), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 5.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced with sequence IV ($I_{cu} = I_{cw}$, see 9.3.6).

[n] This sample is only required when sequence III is replaced with sequence IV ($I_{cu} = I_{cw}$, see 9.3.6).

[p] Read "U_e" for all test sequences except test sequence IV. Read "I_{cw}" for test sequence IV.

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9.3.3.2 Test quantities

9.3.3.2.1 Values of test quantities

Subclause 9.3.2.2.1 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.2.2 Tolerances on test quantities

Subclause 9.3.2.2.2 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.2.3 Frequency of the test circuit for AC

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 %.

9.3.3.2.4 Power factor of the test circuit

Subclause 9.3.4.1.3 of IEC 60947-1:~~2007~~2020 applies with the following modification:

Table 16 of IEC 60947-1:~~2007~~2020 is replaced by Table 16 of this document.

Table 16 – 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		

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9.3.3.2.5 Time constant of the test circuit

Subclause 9.3.4.1.4 of IEC 60947-1:~~2007~~2020 applies with the following modification:

Table 16 of IEC 60947-1:~~2007~~2020 is replaced by Table 16 of this document.

9.3.3.2.6 Power-frequency recovery voltage

Subclause 9.3.2.2.3, item a) of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

9.3.3.2.7 Ripple of the test current for DC

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

9.3.3.3 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 document 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.

9.3.3.4 Test reports

Subclause 9.3.2.4 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 8.2.2.

Subclause 9.3.3.3 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies, except 9.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 9.3.3.1.

During the temperature-rise test of sequence I (see 9.3.4.7) 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 AC circuit-breakers, a test shall first be carried out on the 3-phase poles; for the neutral pole, the additional single-phase test of 9.3.3.3.4 of IEC 60947-1:~~2007~~2020 applies only when there is a construction break between the neutral pole and the phase poles (see 8.1.6), in which case the test current is the rated current of the neutral pole.

DC circuit-breakers shall be connected in accordance with manufacturer's instructions. The details of the connections shall be stated in the test report.

9.3.3.6 Test conditions for short-circuit tests

9.3.3.6.1 General requirements

Subclause 9.3.4.1.1 of IEC 60947-1:~~2007~~2020 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 9.3.3.1.

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.

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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~~ can 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 9.3.3.6.4).

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 overcurrent releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without overcurrent 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 circuit supply voltage of the release (see 8.2.1.2.3), 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 15.

9.3.3.6.2 Test circuit

Subclause 9.3.4.1.2 of IEC 60947-1:~~2007/AMD1:2010~~2020 applies.

9.3.3.6.3 Calibration of the test circuit

Subclause 9.3.4.1.5 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.6.4 Test procedure

9.3.3.6.4.1 General

Subclause 9.3.4.1.6 of IEC 60947-1:~~2007~~2020 applies, with the following addition.

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

After calibration of the test circuit in accordance with 9.3.3.6.3, 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 10 (see 9.3.2).

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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 9.3.3.3.4, Tables 9 and 10 of IEC 60947-1:~~2007~~2020) 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 9.3.4.2.3 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 9.3.5.2, 9.3.6.3, 9.3.7.5 and 9.3.8.7.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 9.3.2.4.

9.3.3.6.4.3 Additional tests on four-pole circuit-breakers

Additional sequences of operations on one or more new samples, in accordance with Table 15, 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 9.3.3.6.4.2 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~~2020 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 9.3.2.4. When programme 1 is chosen, this subclause applies to the four-pole samples listed in Table 13.

9.3.3.6.4.4 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 3.14), 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 3.7.18 of IEC 60947-1:~~2007~~2020) during these tests may be recorded in the test report (see 8.2.1.2.4, item a)).

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

Subclause 9.3.4.1.7 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.6.6 Interpretation of records

Subclause 9.3.4.1.8 of IEC 60947-1:~~2007~~2020 applies.

9.3.3.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 9.3.5.2, 9.3.6.3, 9.3.7.5, 9.3.8.2, 9.3.8.7, 9.3.9.4, 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.

9.3.4 Test sequence I: General performance characteristics

9.3.4.1 General

This test sequence applies to all circuit-breakers and comprises the tests in Table 17.

Table 17 – Tests of test sequence I

Test	Subclause
Tripping limits and characteristics	9.3.4.2
Dielectric properties	9.3.4.3
Mechanical operation and operational performance capability	9.3.4.4
Overload performance (where applicable)	9.3.4.5
Verification of dielectric withstand and leakage current	9.3.4.6
Verification of temperature-rise	9.3.4.7
Verification of overload releases	9.3.4.8
Verification of undervoltage and shunt releases (if applicable)	9.3.4.9
Verification of main contact position ~~(for circuit-breakers suitable for isolation)~~	9.3.4.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

See 9.3.2 for tests that may be omitted from the sequence and made on separate samples.

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9.3.4.2 Test of tripping limits and characteristics

9.3.4.2.1 General

Subclause 9.3.3.2 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 9.3.3.5).

When the overcurrent 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 9.3.3.1. 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 overcurrent 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 5.7.2).

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 9.3.3.3.4 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020. 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~~ suitable voltage.

9.3.4.2.2 Short-circuit releases

The operation of short-circuit releases (see 5.7.1 item 2) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For AC tests, the test currents shall have no asymmetry. For DC 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 3.6.25 of IEC 60947-1:2020). Alternatively, in the case of a circuit-breaker having also a short-time delay short-circuit release (see 3.8), the current shall be maintained during the non-tripping duration stated by the manufacturer instead of 0,2 s (if the short-time delay short-circuit release is adjustable, the time-delay shall be adjusted to its maximum setting value for this test);

NOTE The alternate proposal intends to avoid the unwanted tripping of the short-time delay short-circuit release during the test of the instantaneous release.

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

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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 3.15);
– 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:

– within 0,2 s in the case of instantaneous releases (see 3.15);
– 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 9.3.4.2.4.

9.3.4.2.3 Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 5.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For AC tests, the test currents shall have no asymmetry. For DC 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 9.3.4.2.4.

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 3.15),
– 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 3.15),
– 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 9.3.4.2.1), the test current for this release shall have a value equal to 1,2 times 110 % of the current setting.

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b) Inverse time-delay releases

The operating characteristics of inverse time-delay overload releases shall be verified in accordance with the performance requirements of 8.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see 9.3.4.2.1), the test currents for this release shall be those given in Table 5 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 5.7.3 and Table 4 item 2.17), 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 7.1.1 of IEC 60947-1:~~2007/AMD2:2014~~2020), the release being energized on all phase poles.

An additional test, at a current value equal to ~~be agreed between manufacturer and user~~ or greater than two times the current setting, 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 9.3.6.2, 9.3.6.5, 9.3.7.2, 9.3.7.7, 9.3.8.5, 9.3.8.9, 9.3.9.2 and 9.3.9.8).

9.3.4.2.4 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 9.3.4.2.1), 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;

– in the case of ground-fault overcurrent releases, on one pole chosen at random, and with the test setup described in 9.3.4.2.5.

The measured time-delay 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.

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b) Non-tripping duration

This test is made under the same conditions as for the test of item a) above for overload, short-circuit and ground-fault overcurrent-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,

– in the case of short-circuit or overload releases, the current is reduced to the value corresponding to the overload current setting (I_r);

– in the case of ground-fault overcurrent releases, the current is reduced to 75 % of the ground-fault current setting (I_g);

and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

9.3.4.2.5 Additional tests for ground-fault overcurrent releases

Annex T of IEC 60947-1:2020 applies, replacing "relay" by "release" when applicable, with the following additions.

Definite time-delay releases shall comply with the requirements of 9.3.4.2.4.

All tests shall be performed on one pole chosen at random.

For AC tests, the test current shall have no asymmetry. For DC tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

If the circuit-breaker is provided with a ground-fault I^2t characteristic (see Figure K.1), this I^2t characteristic shall be disabled for the tests.

9.3.4.3 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.~~

Subclause 9.3.3.4.1 of IEC 60947-1:2020 applies, with the following additions:

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(i) with reference to 9.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2020: the normal positions of operation include the tripped position, if any;

(ii) with reference to 9.3.3.4.1, item 3 c), of IEC 60947-1:2020: for the purposes of this document circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) for circuit-breakers having an operational voltage greater than 50 V, the leakage current, measured through each pole with the circuit-breaker in the open position and in the tripped position (if any), at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(iv) circuit-breakers having a rated insulation voltage greater than 1 000 V AC shall be tested at a voltage of U_i + 1 200 V AC RMS or 2 U_i whichever is the greater;

(v) withdrawable circuit-breakers (see 8.1.2) shall be subject to verification of impulse withstand voltage, as per 9.3.3.4.1, item 2) b) of IEC 60947-1:2020. The test voltage shall be selected from Table 14 of IEC 60947-1:2020, and shall be applied between the withdrawable unit's isolating contacts, in the disconnected position. Acceptance criteria are as per 9.3.3.4.1, item 2) d) of IEC 60947-1:2020.

9.3.4.4 Tests of mechanical operation and of operational performance capability

9.3.4.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 9.3.3.1 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 circuit 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 9.3.4.4.2, 9.3.4.4.3 and 9.3.4.4.4 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 9.3.4.4.2 and 9.3.4.4.3 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.

9.3.4.4.2 Construction and mechanical operation

9.3.4.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 8.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 8.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

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9.3.4.4.2.2 Mechanical operation

Tests shall be made as specified in 9.3.4.4.1 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 8.2.1.1.4.

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 8.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control circuit 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.

9.3.4.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 8.2.1.3 of IEC 60947-1:~~2007~~2020. 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 circuit 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 circuit 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 circuit 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 9.3.4.7.

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

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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 circuit 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 circuit 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 circuit supply voltage for 4 h without impairing its functions.

9.3.4.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 8.2.1.4 of IEC 60947-1:~~2007/AMD2:2014~~2020. 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 circuit 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 circuit supply voltages, the test voltage shall be 70 % of the minimum rated control circuit supply voltage.

9.3.4.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 9.3.3.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 7; 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 (column 3 of Table 7) shall be closing/tripping operations, with the shunt release energized at maximum rated control circuit supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles (column 3 of Table 7) shall be closing/tripping operations at the minimum rated control circuit 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 circuit 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 6.

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

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9.3.4.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 9.3.3.1, the test circuit being in accordance with 9.3.3.5.2 of IEC 60947-1:2020.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 7.

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 16, the tolerance being in accordance with 9.3.3.2.2.

Tests on AC 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 circuit 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 6.

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

9.3.4.4.5 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.

9.3.4.5 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 9.3.3.1, and the test circuit in accordance with 9.3.3.5.2 of IEC 60947-1:~~2007~~2020.

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 18 (see also 9.3.2.2.3 a) of IEC 60947-1:~~2007/AMD2:2014~~2020).

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.

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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~~ suitable 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 7. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced ~~sufficiently~~ so that the circuit-breaker ~~may~~ can 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 18, at the power factor or time constant, as applicable, in accordance with Table 16, the tolerances being in accordance with 9.3.3.2.2.

Table 18 – 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 AC 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.

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

The number of manual and automatic operations, the on durations and, if different from that indicated in Table 7, the operating rate shall be stated in the test report.

9.3.4.6 Verification of dielectric withstand and leakage current

9.3.4.6.1 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.

9.3.4.6.2 Test voltage for dielectric withstand

Subclause 9.3.3.4.1, item 4) b), of IEC 60947-1:~~2007/AMD1:2010~~2020 applies with the following modification.

The test voltage shall be AC in case of an AC circuit-breaker, DC in case of a DC circuit-breaker.

The test voltage for an AC circuit-breaker shall be 2 U_e with a minimum of 1 000 V RMS. Only if an AC test voltage cannot be applied to the AC circuit-breaker, for example due to EMC filter

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components, the test shall be conducted using a DC test voltage of 2 U_e × 1,415 with a minimum of 1 415 V DC.

The test voltage for a DC circuit-breaker shall be 2 U_e with a minimum of 1 415 V DC.

For dielectric tests involving the main circuit, the value of U_e referred to in this subclause is that at which the preceding switching and/or short-circuit tests have been conducted.

9.3.4.6.3 Application of the test voltage for dielectric withstand

The test voltage shall be applied for 5 s in accordance with 9.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:~~2007~~2020 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 9.3.3.4.1, item 1), of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 is not required. For the purposes of this document, 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.~~

9.3.4.6.4 Acceptance criteria for dielectric withstand

Subclause 9.3.3.4.1, item 3) d), of IEC 60947-1:~~2007~~2020 applies.

9.3.4.6.5 Leakage current measurement

The leakage current shall be measured in open position only, in accordance with 9.3.4.3, item (iii), except that the leakage current shall not exceed 2 mA. The corresponding test voltage shall be applied for 5 s.

9.3.4.7 Verification of temperature-rise

Following the test according to 9.3.4.6, a temperature-rise test shall be made at the conventional thermal current according to 9.3.3.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 6.

9.3.4.8 Verification of overload releases

Immediately following the test according to 9.3.4.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 8.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. If applicable, ground-fault overcurrent releases shall be deactivated during the test.

Alternatively, this test may be made using a 3-phase supply.

This test may be made at any ~~convenient~~ suitable voltage.

The operating time shall not exceed the conventional tripping time.

With the manufacturer's consent, a time interval between the tests of 9.3.4.7 and 9.3.4.8 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.

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9.3.4.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 9.3.4.4.2.3 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 rated control circuit supply voltage and shall operate at 35 % of the maximum rated control circuit supply voltage.

Circuit-breakers fitted with shunt releases shall be subjected to the test of 9.3.4.4.2.4, 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 circuit supply voltage.

9.3.4.10 Verification of the main contact position

~~For circuit-breakers suitable for isolation (see 3.5),~~ Following the verification of 9.3.4.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 9.2.6 of IEC 60947-1:~~2007/AMD1:2010~~2020. For the first criterion of 9.2.6.3.1 of IEC 60947-1:2020 (actuator being left free), Figure 2 applies for the application of the test force (see 9.2.6.2.1 of IEC 60947-1:2020).

NOTE For circuit-breakers in accordance with this document, the operating handle of which moves rotating around an axis, the term "extremity" in 9.2.6.2.1 of IEC 60947-1:2020 is the maximum lever arm length perpendicular to this axis.

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

9.3.5.1 General

Except when the test sequence VI (combined) applies (see 9.3.9), this test sequence applies to all circuit-breakers and comprises the tests in Table 19.

Table 19 – Tests of test sequence II

Test	Subclause
Rated service short-circuit breaking capacity	9.3.5.2
Verification of operational performance capability	9.3.5.3
Verification of dielectric withstand and leakage current	9.3.5.4
Verification of temperature-rise	9.3.5.5
Verification of overload releases	9.3.5.6

For the case where $I_{cs} = I_{cu}$, see 9.3.6.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

9.3.5.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 9.3.3, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 5.3.6.2.4.

The power factor for this test shall be according to Table 16, 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.

9.3.5.3 Verification of operational performance capability

Following the test according to 9.3.5.2, the operational performance capability shall be verified in accordance with 9.3.4.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 9.3.5.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 7.

This verification need not be made where, for a given frame size, the test of 9.3.5.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 15.

9.3.5.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.5.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

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

9.3.5.5 Verification of temperature-rise

Following the test according to 9.3.5.4, the temperature-rise at the main terminals shall be verified in accordance with 9.3.3.5. The temperature-rise shall not exceed the values given in Table 6.

This verification need not be made where, for a given frame size, the test of 9.3.5.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

9.3.5.6 Verification of overload releases

Immediately following the test according to 9.3.5.5, the operation of overload releases shall be verified in accordance with 9.3.4.8.

With the manufacturer's consent, a time interval between the tests of 9.3.5.5 and 9.3.5.6 may occur.

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

9.3.6.1 General

Except where the test sequence VI (combined) applies (see 9.3.9), 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 2 (5.3.6.4); 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 15) and the following verifications shall additionally be made in test sequence II:

– the verification of 9.3.6.2, at the beginning of the test sequence;
– the verification of 9.3.6.5, at the end of the test sequence.

This test sequence comprises the tests in Table 20.

Table 20 – Tests of test sequence III

Test	Subclause
Verification of overload releases	9.3.6.2
Rated ultimate short-circuit breaking capacity	9.3.6.3
Verification of dielectric withstand and leakage current	9.3.6.4
Verification of overload releases	9.3.6.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

9.3.6.2 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~~ suitable voltage. If applicable, ground-fault overcurrent releases shall be deactivated during the test; alternatively, each pole shall be tested in series with 2 other poles connected in parallel.

This test is omitted for electronic trip units.

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 9.3.3.3.4 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020. 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.

9.3.6.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 9.3.6.2, 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 9.3.3.

The sequence of operations shall be:

O – *t* – CO

9.3.6.4 Verification of dielectric withstand and leakage current

~~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.~~

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Following the test according to 9.3.6.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6 ~~For circuit-breakers suitable for isolation~~, except that the leakage current shall not exceed 6 mA.

9.3.6.5 Verification of overload releases

Following the test according to 9.3.6.4, the operation of overload releases shall be verified in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature~~, on a pole singly~~.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

9.3.7 Test sequence IV: Rated short-time withstand current

9.3.7.1 General

Except where the test sequence VI (combined) applies (see 9.3.9), this test sequence applies to circuit-breakers with a rated short-time withstand current (see 5.4); it comprises the tests in Table 21.

Table 21 – Tests of test sequence IV

Test	Subclause
Verification of overload releases	9.3.7.2
Rated short-time withstand current	9.3.7.3
Verification of temperature-rise	9.3.7.4
Short-circuit breaking capacity at maximum short-time withstand current	9.3.7.5
Verification of dielectric withstand and leakage current	9.3.7.6
Verification of overload releases	9.3.7.7

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 15.

9.3.7.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

9.3.7.3 Test of rated short-time withstand current

Subclause 9.3.4.3 of IEC 60947-1:~~2007~~2020 applies with the following addition:

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

9.3.7.4 Verification of temperature-rise

Following the test according to 9.3.7.3, the temperature-rise at the main terminals shall be verified according to 9.3.3.5. The temperature-rise shall not exceed the value given in Table 6.

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With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (9.3.7.6). This verification need not be made where, for a given frame size, the test of 9.3.8.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

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

Following the test according to 9.3.7.4, a short-circuit test shall be made with the following sequence of operations:

O – *t* – CO

under the general conditions of 9.3.3, with a value of prospective current equal to that of the short-time withstand current test (see 9.3.7.3) 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 3.6), 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 9.3.3.6.4.3.

9.3.7.6 Verification of dielectric withstand and leakage current

Following the test carried out according to 9.3.7.5, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

9.3.7.7 Verification of overload releases

Following the test according to 9.3.7.6, the operation of overload releases shall be verified in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature~~, on a pole singly~~.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

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

9.3.8.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the tests in Table 22.

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Table 22 – Tests of test sequence V

	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	9.3.8.2
	Verification of temperature-rise	9.3.8.3
	Verification of dielectric withstand and leakage current	9.3.8.4
Stage 2	Verification of overload releases	9.3.8.5
	Short-circuit at 1,1 times take-over current	9.3.8.6
	Short-circuit at ultimate short-circuit breaking capacity	9.3.8.7
	Verification of dielectric withstand and leakage current	9.3.8.8
	Verification of overload releases	9.3.8.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 9.3.8.2 to 9.3.8.4;
– Stage 2 comprises the tests according to 9.3.8.5 to 9.3.8.9.

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 9.3.8.4 may be omitted.

The test according to 9.3.8.3 need only be made if $I_{cs} > I_s$.

Tests according to 9.3.8.2, 9.3.8.6 and 9.3.8.7 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 15.

9.3.8.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 9.3.3, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer.

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.

9.3.8.3 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, 9.3.5.2, in which case the test of 9.3.8.2 is more severe.

Following the test according to 9.3.8.2, the temperature-rise at the main terminals shall be verified, in accordance with 9.3.3.5.

The temperature-rise shall not exceed the value given in Table 6.

9.3.8.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.8.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

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9.3.8.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

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

Following the test according to 9.3.8.5, a short-circuit test is made under the same general conditions as in 9.3.8.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer.

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 three of the fuses for a four-pole circuit-breaker;
– at least two of the fuses for a three-pole circuit-breaker;
– at least one of the fuses for a two-pole circuit-breaker;
– the fuse for a one-pole circuit-breaker;

shall have blown.

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

Following the test according to 9.3.8.6, a short-circuit test is made under the same general conditions as in 9.3.8.2, 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.

9.3.8.8 Verification of dielectric withstand and leakage current

Following the test according to 9.3.8.7 and with a new set of fuses fitted, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

9.3.8.9 Verification of overload releases

Following the test according to 9.3.8.8, the operation of overload releases shall be verified in accordance with 9.3.6.2 except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature~~, on a pole singly~~.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

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9.3.9 Test sequence VI: Combined test sequence

9.3.9.1 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; or

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 tests of Table 23.

Table 23 – Tests of test sequence VI

Test	Subclauses
Verification of overload releases	9.3.9.2
Rated short-time withstand current	9.3.9.3
Rated service short-circuit breaking capacity*	9.3.9.4
Verification of operational performance capability	9.3.9.5
Verification of dielectric withstand and leakage current	9.3.9.6
Verification of temperature-rise	9.3.9.7
Verification of overload releases	9.3.9.8
* For circuit-breakers falling into the case of 9.3.9.1 b) 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 15.

9.3.9.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

9.3.9.3 Test of rated short-time withstand current

Following the test according to 9.3.9.2, a test shall be made at the rated short-time withstand current according to 9.3.7.3.

This test does not need to be made on the sample of minimum I_n specified in Table 15.

9.3.9.4 Test of rated service short-circuit breaking capacity

Following the test according to 9.3.9.3, a test shall be made at the rated service short-circuit breaking capacity according to 9.3.5.2, 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 during the closing operation only.

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9.3.9.5 Verification of operational performance capability

Following the test according to 9.3.9.4, the operational performance capability shall be verified in accordance with 9.3.5.3.

9.3.9.6 Verification of dielectric withstand and leakage current

Following the test according to 9.3.9.5, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

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

9.3.9.7 Verification of temperature-rise

Following the test according to 9.3.9.6, the temperature-rise at the main terminals shall be verified in accordance with 9.3.5.5.

The temperature-rise shall not exceed the value given in Table 6.

This verification need not be made where, for a given frame size, the test of 9.3.9.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

9.3.9.8 Verification of overload releases

After cooling down following the test according to 9.3.9.7, the operation of overload releases shall be verified in accordance with 9.3.4.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature~~, on a pole singly~~.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

9.3.10 Test sequence VII: Critical DC load current ~~test~~

This test applies only to circuit-breakers with DC ratings.

NOTE A common procedure for the determination of the critical DC load current is under revision for integration in IEC 60947-1.

The circuit-breaker condition and method of installation shall be as specified in 9.3.3.1, and the test circuit in accordance with 9.3.3.5.2 of IEC 60947-1:~~2007~~2020 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 15 – test sequence I, except that for application of footnote g, construction breaks relative to the overcurrent tripping devices shall not be considered.

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

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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 16 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 7.

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 DC, 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 9.3.3.2.2.

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 and the leakage current shall be verified according to 9.3.4.6 with a DC test voltage.

9.3.11 Test sequence VIII: Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage

9.3.11.1 General

A circuit-breaker shall be able to interrupt a fault to earth. In this case, the short-circuit current shall be interrupted by only one phase pole, at the phase-to-neutral voltage.

For:

– 1-pole circuit-breakers,
– 3-pole and 4-pole circuit-breakers where all phase poles are of the same design,
– 2-pole circuit-breakers the poles of which are of the same design as those of a 3-pole or 4-pole circuit-breaker compliant with this document

the performance is covered by 9.3.6 and no additional tests are required. In these cases, I_{cu1} is considered as equal to I_{cu}.

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The tests in 9.3.11.2 to 9.3.11.5 apply to 2-pole circuit-breakers the poles of which are not of the same design as to those of a 3-pole or 4-pole circuit-breaker compliant with this document, or to 3-pole or 4-pole circuit-breakers the phase poles of which are not of the same design.

This test sequence comprises the tests of Table 24.

Table 24 – Tests of test sequence VIII

Test	Subclause
Verification of overload releases	9.3.11.2
Rated ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	9.3.11.3
Verification of dielectric withstand and leakage current	9.3.11.4
Verification of overload releases	9.3.11.5

9.3.11.2 Verification of overload releases

The operation of the overload releases shall be verified according to 9.3.6.2.

9.3.11.3 Rated ultimate short-circuit breaking capacity at phase-to-neutral AC voltage

A short-circuit test is made on each individual phase pole of the circuit-breaker under the general conditions of 9.3.3, at a value of current equal to I_{cu1}. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The test voltage(s) shall be the corresponding phase-to-neutral voltage of the test voltage(s) listed in Table 15, corresponding to the maximum rated operational voltage of the circuit-breaker, taking into account the requirements for recovery voltage of 9.3.3.2.6. The power factor appropriate to the test current shall be in accordance with Table 16. The short-time or instantaneous pick-up setting shall be adjusted to its maximum value.

The test circuit shall be in accordance with 9.3.4.1.2 of IEC 60947-1:2020 and Figure 9 of IEC 60947-1:2020.

The sequence of operations shall be: O – *t* – CO.

9.3.11.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.11.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

9.3.11.5 Verification of overload releases

The operation of the overload releases shall be verified according to 9.3.6.5.

9.4 Routine tests

9.4.1 General

For the definition of routine tests, see 3.8.2 of IEC 60947-1:~~2007~~2020 and 9.1.3 of IEC 60947-1:2020.

The following tests apply:

– mechanical operation (9.4.2);
– verification of the calibration of overcurrent releases (9.4.3);
– verification of the operation of undervoltage and shunt releases (9.4.4);
– additional tests for CBRs to Annex B (9.4.5);

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– dielectric tests (see note) (9.4.6);
– verification of clearances (9.4.7).

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] ISO 2859-1).

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 9.4.3, 9.4.4 and 9.4.5 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 9.4.2, 9.4.3, 9.4.4, 9.4.6 and 9.4.7, the term "circuit-breakers" covers CBRs, where applicable.

9.4.2 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 3.6.24 of IEC 60947-1:~~2007~~2020.

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

9.4.3 Verification of the calibration of overcurrent releases

9.4.3.1 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 5.7.3).

9.4.3.2 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 9.3.4.2.2 or 9.3.4.2.3, item a), as applicable, without measurement of break time being required.

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[1] ~~This publication was withdrawn.~~

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.

9.4.4 Verification of the operation of undervoltage and shunt releases

9.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 8.2.1.3 of IEC 60947-1:~~2007~~2020 as follows:

a) Hold-in voltage

The release shall close on to a voltage corresponding to 85 % of the minimum rated control circuit 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 circuit supply voltage, adjusted to take account of the need to operate under the conditions specified in 9.3.4.4.2.3 i). In the case of releases having a range of rated control circuit supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

9.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 8.2.1.4 of IEC 60947-1:~~2007/AMD2:2014~~2020. 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 9.3.4.4.2.4. In the case of a release having a range of rated control circuit supply voltages, the test voltage shall be related to 70 % of the minimum rated control circuit supply voltage.

9.4.5 Additional tests for CBRs

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

a) Operation of the test device

The CBR shall be subjected to two close-trip operations or, in the case of RC 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.

9.4.6 Dielectric tests

The test conditions shall be in accordance with 9.3.3.4.1, item 1), of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020, 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;

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– 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 or DC withstand voltage

The test apparatus shall be as stated in 9.3.3.4.1, item 3) b), of IEC 60947-1:~~2007/AMD1:2010~~2020, 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 RMS or 1 415 V DC, applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency or DC test in accordance with item a) 2) above ~~at a~~. For AC tests, the test voltage shall be 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.~~ U_i or 1 000 V RMS. For DC tests, the test voltage shall be equal to the highest of the values of the following: 30 % of U_{imp}, 2 U_i or 1 415 V DC.

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

For tests a) 2) and b), the following requirements apply:

– AC circuit-breakers shall be tested with power frequency voltage. Alternatively, they may be tested with a DC voltage equal to the peak value of the AC test voltage.

– DC circuit-breakers shall be tested with DC voltage. Alternatively, they may be tested with an AC voltage the RMS value of which shall be equal to the value of the DC test voltage.

If dielectric properties are tested according to a sampling plan in accordance with the note to 9.4.1, a power frequency withstand test shall be made according to 9.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 19 of IEC 60947-1:~~2007/AMD2:2010~~2020. Circuit-breakers having a rated insulation voltage greater than 1 000 V AC shall be tested at a voltage of U_i + 1 200 V AC RMS or 2 U_i whichever is the greater.

9.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:~~2007~~2020

Subclause 9.3.3.4.3 of IEC 60947-1:~~2007~~2020 applies, except that for the purposes of this document this test shall be a routine test.

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NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:~~2007~~2020 is covered by the tests of 9.4.6.

9.5 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 3.8.4 of IEC 60947-1:~~2007~~2020). 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 document.

Annex Q of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies.

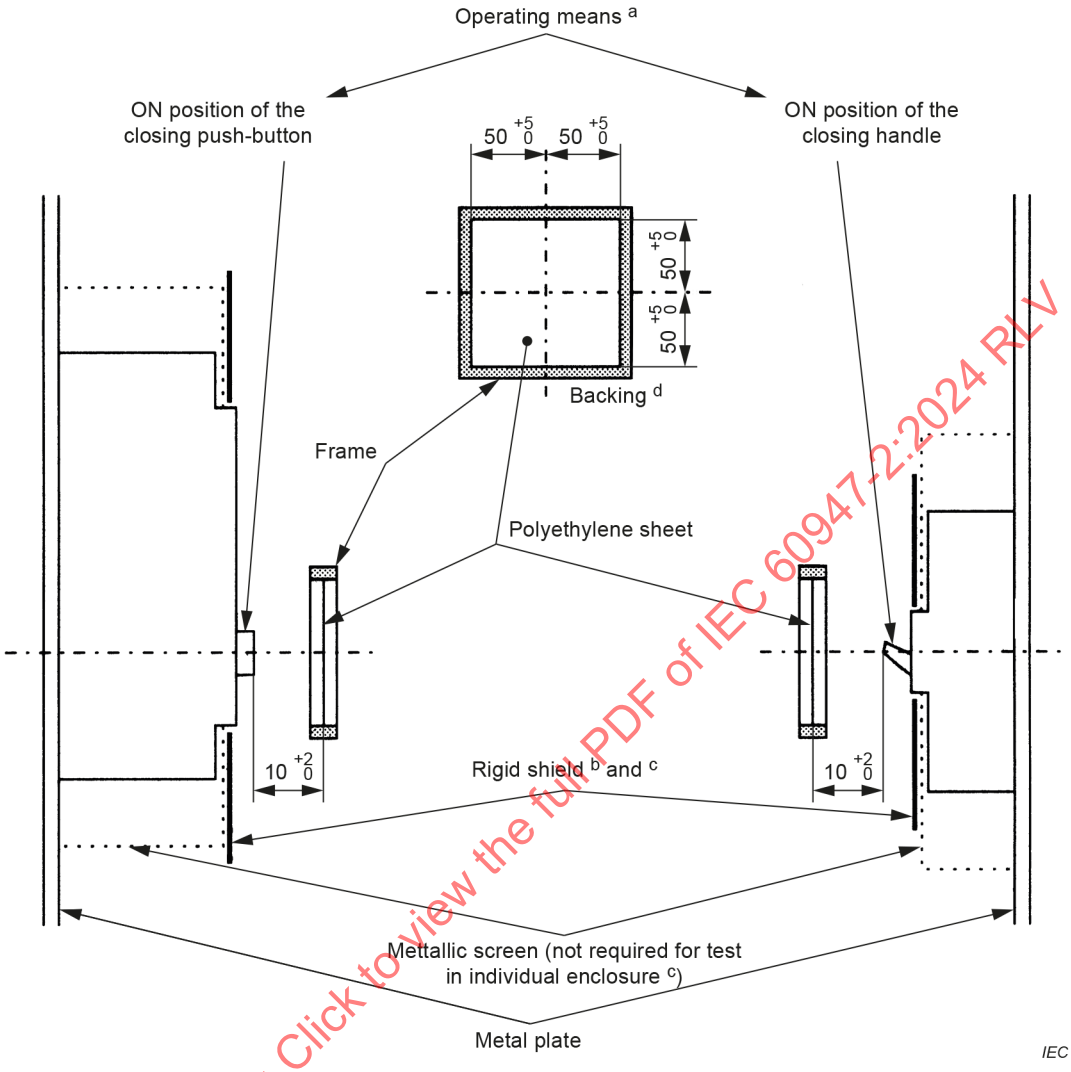
During the test sequences according to Table Q.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 9.4, except for the dielectric tests of 9.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020.

With reference to footnote e) of Table Q.1 of IEC 60947-1:~~2007~~2020, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energized with rated voltage. The circuit-breaker shall be operated according to 9.4.2 during the last hour of the test.

With reference to footnote g) of Table Q.1 of IEC 60947-1:~~2007~~2020, during damp heat test, the functional test shall consist of the mechanical operations of 9.4.2 of this document. When only manual operating means are available, this test can be done during the beginning of the following cold period.

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Dimensions in millimetres



Case of circuit-breaker with closing push-button **Case of circuit-breaker with a closing handle**

[a] The operating means includes any extension which is normally fitted for the closing operation.

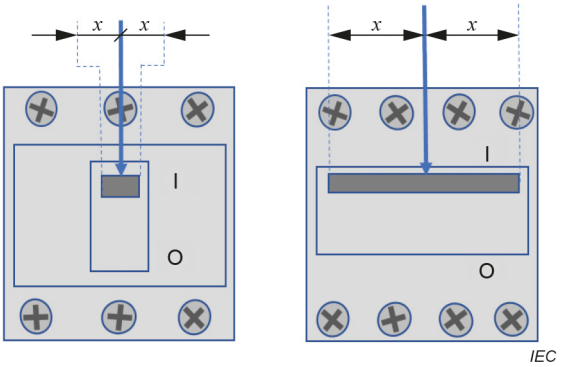
[b] The purpose of the rigid shield is to prevent emissions from areas other than those of the handle or push-button from reaching the polyethylene sheet (not required for tests in individual enclosures).

[c] The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

[d] 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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For the application of the test force, see 9.2.6.2.1 of IEC 60947-1:2020.

For the first criterion, actuator being left free, see 9.2.6.3.1 of IEC 60947-1:2020.

Figure 2 – Examples of application of the test force for the verification of the effectiveness of the indication of the main contact position (first criterion, actuator being left free)

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Annex A
(normative)

Coordination 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:

nn) 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.

oo) 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.

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If the associated SCPD is a circuit-breaker, it shall meet the requirements of this standard, or any other relevant standard.

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

pp) 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.

qq) 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.

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rr) Circuit-breakers in series (C_1 and C_2) – selectivity determination by consideration of peak let-through current

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.

ss) 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.

tt) 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.

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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.

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.

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~~**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.~~

~~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~~

~~uu) 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.~~

~~vv) 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.~~

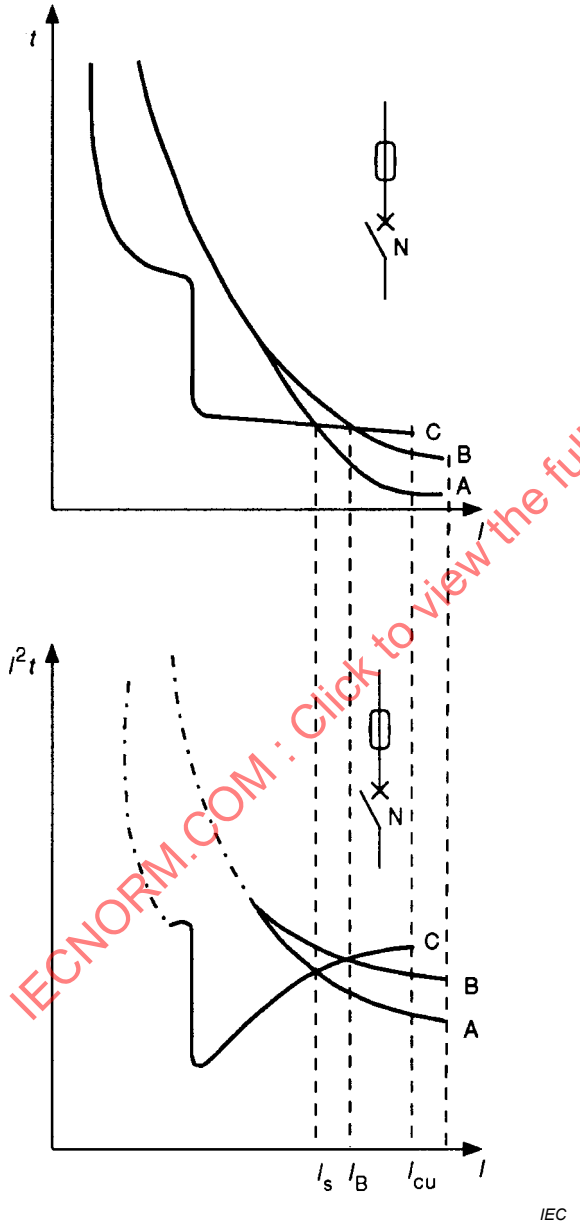
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A.6.4 Results to be obtained

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.



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

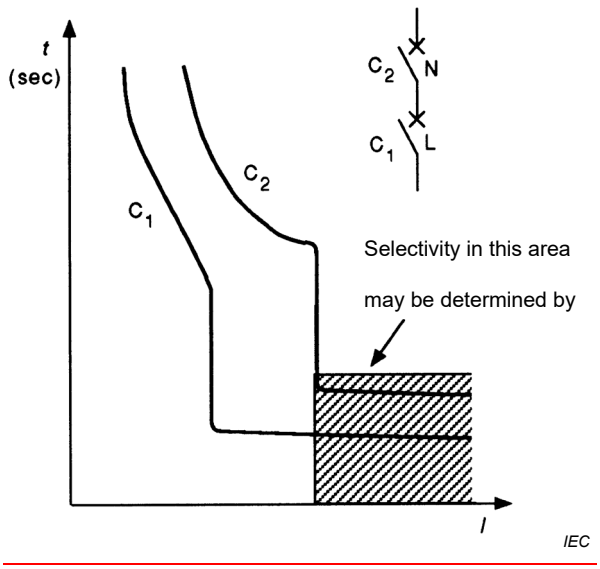
C = Operating characteristic of the circuit-breaker, non-current-limiting (N) (break-time/current and I^2t /current)

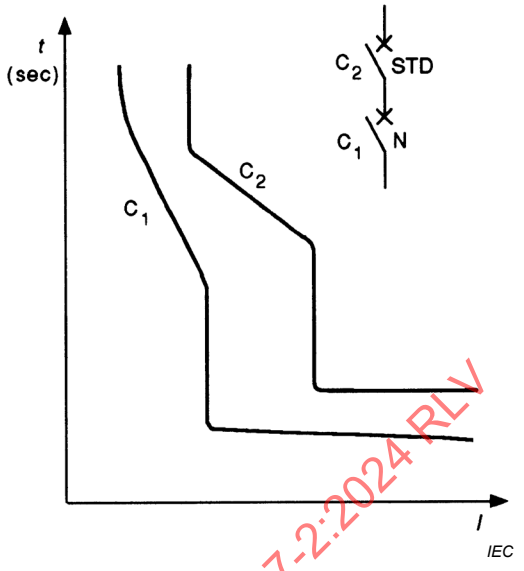
NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

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~~

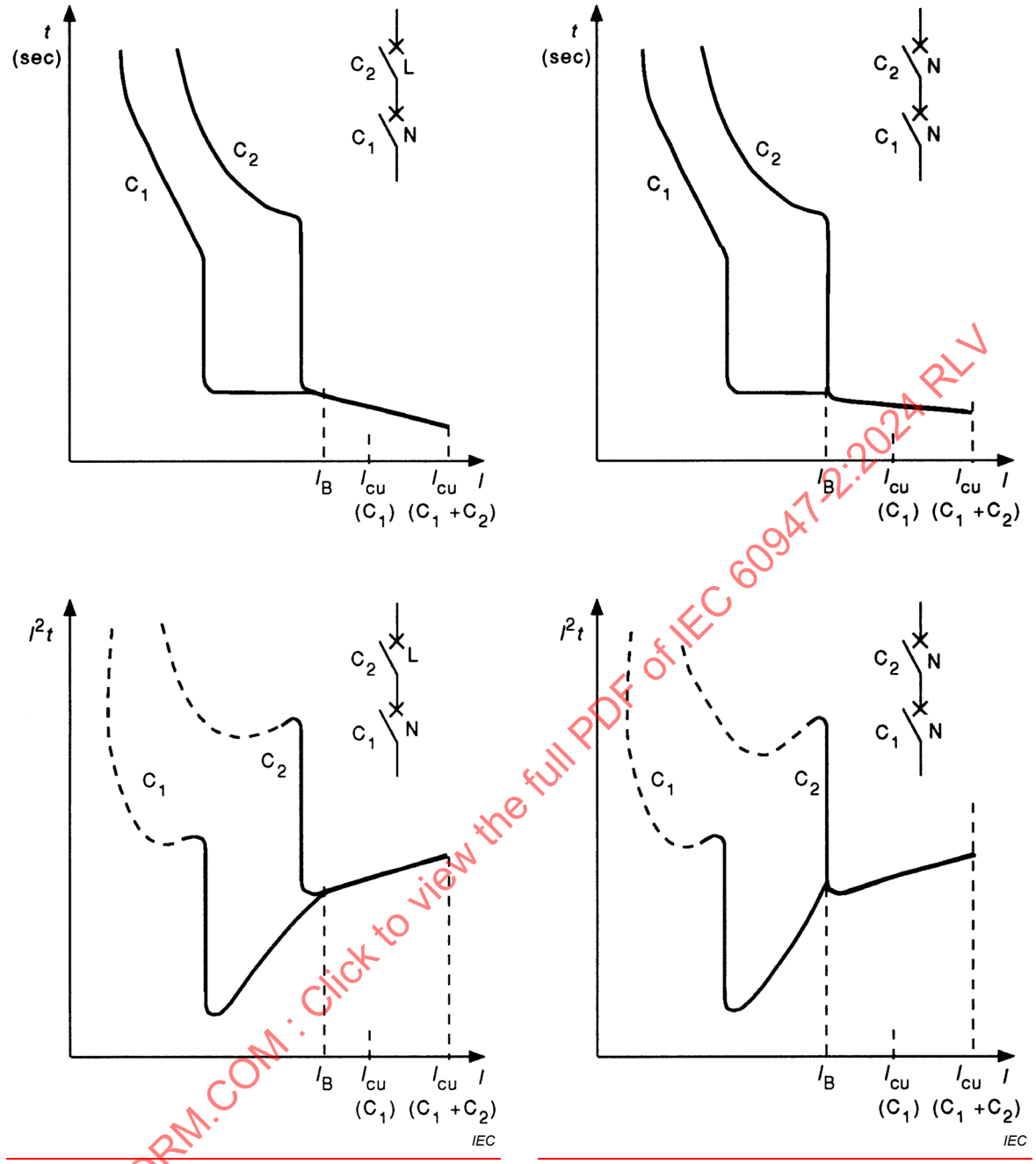
~~C_1 = Non-current-limiting circuit-breaker (N) (break-time characteristic)~~

~~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~~

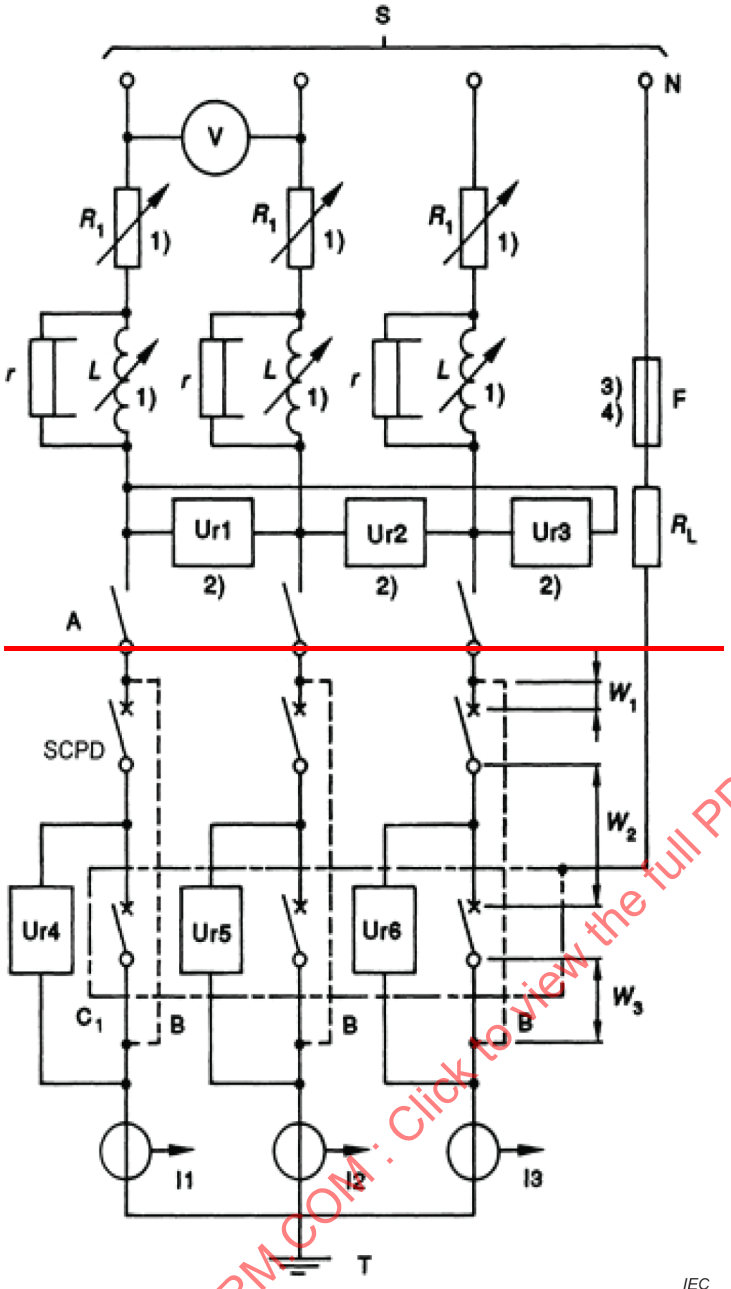
~~NOTE 1 Where applicable, restoration of supply by C_2 occurs.~~

~~NOTE 2 I_{cu} $(C_1 + C_2) \leq I_{cu}$ (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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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.

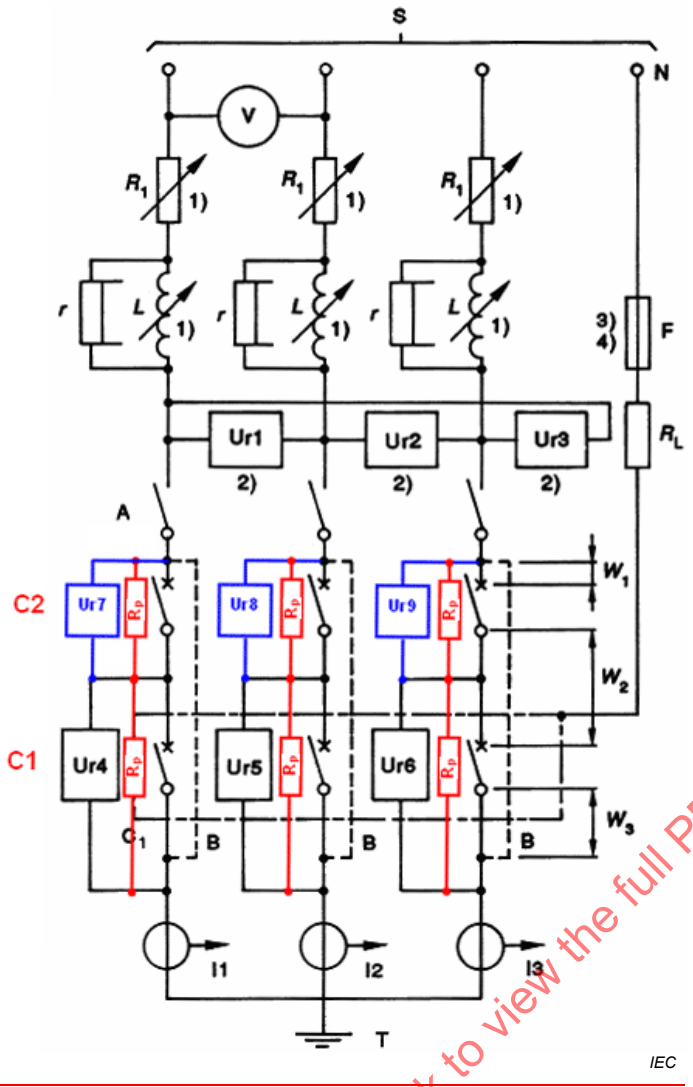
In the case of devices intended for use in a phase-earthed network, F shall be connected to one phase of the supply.

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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A.1 General

Clause X.1 of IEC 60947-1:2020 applies with the following change:

In Figure X.1 of IEC 60947-1:2020, "I_{cn}" is replaced with "I_{cu}" (see 5.3.6.2.2).

A.2 Object

Clause X.2 of IEC 60947-1:2020 applies.

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

Clause X.3 of IEC 60947-1:2020 applies, with the following addition:

The association shall also comply with the information required in the 2nd paragraph of 8.2.1.2.4 item a).

A.4 Type and characteristics of the associated SCPD

Clause X.4 of IEC 60947-1:2020 applies.

A.5 Verification of selectivity

Clause X.5 of IEC 60947-1:2020 applies with the following change:

In Figure X.1 of IEC 60947-1:2020, "I_{cn}" is replaced with "I_{cu}" (rated ultimate short-circuit breaking capacity, see 5.3.6.2.2).

A.6 Verification of back-up protection

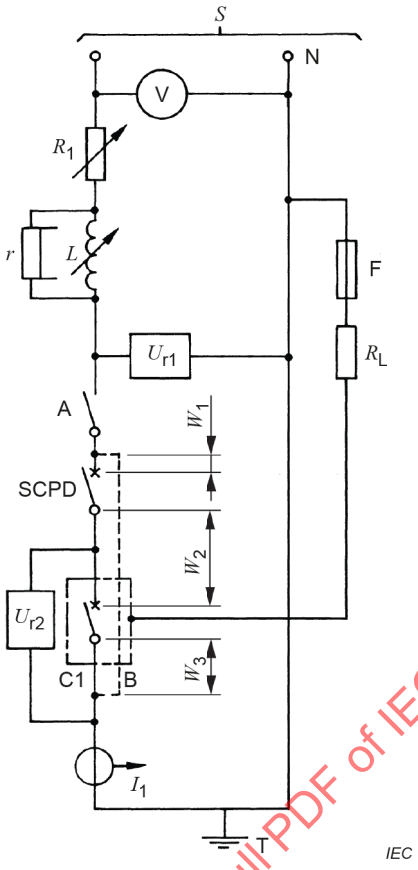
Clause X.6 of IEC 60947-1:2020 applies, with following additions:

Following the tests, if C1 is a circuit-breaker, it shall comply with 9.3.6.4 and 9.3.6.5.

For the verification of the individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}, see 9.3.11), Figure A.1 applies.

NOTE "Back-up protection" is defined in 535.5 of IEC 60364-5-53:2019 as "Combined short-circuit protection".

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Key

S	supply
U_{r1}, U_{r2}	voltage sensors
V	voltage measuring device
A	closing device
R_1	adjustable resistor
N	neutral of supply (or artificial neutral)
F	fusible element (9.3.4.1.2, item d) of IEC 60947-1:2020)
L	adjustable reactors
R_L	fault-current limiting resistor
B	temporary connections for calibration
I_1	current sensing device
T	earth: one earthing point only (load side or supply side)
r	shunting resistor (9.3.4.1.2, item b) of IEC 60947-1:2020)
W_1	75 cm of cable rated for SCPD
W_2	50 cm of cable rated for C1
W_3	25 cm of cable rated for C1
SCPD	circuit-breaker C2 or set of 3 fuses
C1	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.

Figure A.1 – Cable connections for conditional short-circuit breaking capacity tests in the case of a single pole under phase-to-neutral AC voltage (C1)

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Annex B
(normative)

Circuit-breakers incorporating residual current protection (CBRs)

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 fault 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".~~ In IEC 61140, "fault protection" was previously referred to as "protection of persons against indirect contact".

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 overcurrent protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as ~~a means for~~ additional means for basic 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".~~ In IEC 61140, "basic protection" was previously referred to as "protection of persons against direct contact".

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 RC 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.

NOTE 1 RC units do not have an adverse impact on the performance of the circuit-breaker, as verified by the performance tests per Clause 9.

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NOTE 2 The current sensing means can be external to the CBR.

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 AC circuits.

NOTE 3 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 dependent 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 3 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

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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".]

B.2.2.3
residual current
I_{Δ}
vectorial sum of the currents flowing in the main circuit of the CBR, expressed as an RMS value

[SOURCE: IEC 60050-442:~~1998~~2019, 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~~2019, 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~~2019, 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 3.1) 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~~2019, 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~~2019, 442-05-25, modified – In the term, "(of 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~~2019, 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 causing it to operate

[SOURCE: IEC 60050-442:~~1998~~2019, 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~~2019, 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 RC 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 overcurrent in the case of a single-phase load
maximum value of a single-phase overcurrent 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 AC component of a prospective residual 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 DC 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 RMS 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.

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.

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B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The RMS 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 RMS value of the AC 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~~ applicable.

$I_{\Delta n}$ 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 overcurrent in the case of a single-phase load

The limiting value of non-operating overcurrent 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 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 $I_{\Delta n}$ ≤ 30 mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.				
[b] For CBRs having $I_{\Delta n}$ ≤ 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 $I_{\Delta n}$ ≤ 30 mA shall be of the non-time-delay type.

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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}.

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 DC 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 DC 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 DC (± 6 mA), whether suddenly applied or slowly rising.

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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 6.2 and, in addition, in accordance with Table B.3.

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Table B.3 – Product information

Item	Information	Marking location	
		Integral CBR	RC 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 DC 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 [a]	Marked [a]
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 [a]	Marked [a]
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 $I_n \leq$ ...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 RC 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

[a] See 5.7.3.

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B.6 Normal service, mounting and transport conditions

Clause 7 applies.

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 RC unit device and a circuit-breaker shall be so designed and built that:

– the coupling system of the RC unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that ~~may~~ can adversely affect the installation or result in injury to the user;

– the addition of the RC unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;

– the RC 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, whatever the phase angle of the current regarding the supply voltage.

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.

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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.

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 overcurrent in the case of a single-phase load

CBRs shall withstand the smaller of the following two overcurrent 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 DC component

The behaviour of CBRs in the case of an earth fault current comprising a DC 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.

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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.

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.

For CBRs of type B with rated residual current of 0,006 A, respectively 0,01 A, the value of 3 mA, respectively 5 mA, shall be used for this test.

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~~03 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≤ 0,~~01~~03 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.

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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).

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 9.3.4.4.4 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.

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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.

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 subclause 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 RMS value.

Tests specified in this annex are supplementary to the tests of Clause 9.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 9. For the dielectric withstand verifications during these test sequences (see 9.3.4.6), 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 RC 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.

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b) Routine tests

Subclause 9.4.5 applies.

B.8.1.2 Tests to be carried out during the test sequences of Clause 9

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 (9.3.4.2) 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 9.3.4.4.4) specified in Table 7 (see 8.2.4.2), a third of the breaking operations shall be performed by actuating the test device, 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, the remaining operations being tested in accordance with 9.3.4.4.4.

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 (9.3.4.4.4).

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 9.3.5, 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 9.3.6.2 and 9.3.6.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 9.3.6.2 and 9.3.6.5 but applicable to two poles.

Following the tests of 9.3.6, 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 9.3.7.3 or 9.3.9.3, 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 9.3.7.2 and 9.3.7.7, the single pole tests specified in 9.3.6.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

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– for the combined test sequence

For the purpose of verifying the correct operation of the overload releases in accordance with 9.3.9.2, the single pole test specified in 9.3.6.2 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 9.3.9.7, the test specified in 9.3.4.8 shall be carried out using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 9.3.7 or 9.3.9, 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 CBRs (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 9.3.8.5 and 9.3.8.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 9.3.8.5 and 9.3.8.9 but applicable to two poles.

Following the tests of 9.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.5 Test sequence VI (combined)

Following the tests of 9.3.9, 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 overcurrent 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

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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~~ suitable 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~~ suitable 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~~ laboratory, 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.8.2.4.1), 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.8.2.4.6 Verification of correct operation in case of sudden appearance of residual currents higher than 5 $I_{\Delta n}$

The test circuit shall be calibrated at any two values of residual current chosen by the testing laboratory from the following list: 5 A, 10 A, 20 A, 50 A, 100 A and 200 A. The switch S1 and the CBR being in the closed position, the residual current shall be suddenly established by closing the switch S2.

The test shall be carried out once for each of the two chosen values. The CBR shall trip during each test and the break time shall not exceed the limiting value specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

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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 5.7.3) 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.

For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the CBR shall be loaded again with its rated current until the thermal steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

B.8.3 Verification of dielectric properties

CBRs shall comply with 9.3.4.3.

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.

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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 overcurrent 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~~ suitable 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.

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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.

B.8.7 Additional verifications for CBRs of types A and B

B.8.7.1 Test conditions

The test conditions of B.8.1.1 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.

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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 DC 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.

For CBRs with $I_{\Delta n} \geq$ 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 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.

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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 %.

Table B.7 – Composite test current definition and starting current value

Frequency component values of composite starting current			**Resulting composite current starting value** (RMS)
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.			

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Table B.8 – Operating current range for composite residual current

Operating current (RMS)	
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 performed 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.

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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 $I_{\Delta n}$ ≥ 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.

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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 performed 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 performed 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 performed 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.13, 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 condition. ~~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 (see B.8.2.3), shall be connected to its maximum rated voltage. For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the CBR shall be loaded again with its rated current until the steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

In the case of CBRs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

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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 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 9.3.3.6, using Figure 9 of IEC 60947-1:~~2007/AMD1:2010~~2020, 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 9.3.3.4.1 item 4) of IEC 60947-1:~~2007~~2020. 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 $I_{\Delta n}$ ≤ 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~~ a 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 test 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~~ Clause 7 of IEC 61000-4-3:2020, 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~~ a 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~~ 6 000 MHz)

Annex J applies, in particular J.3.3.

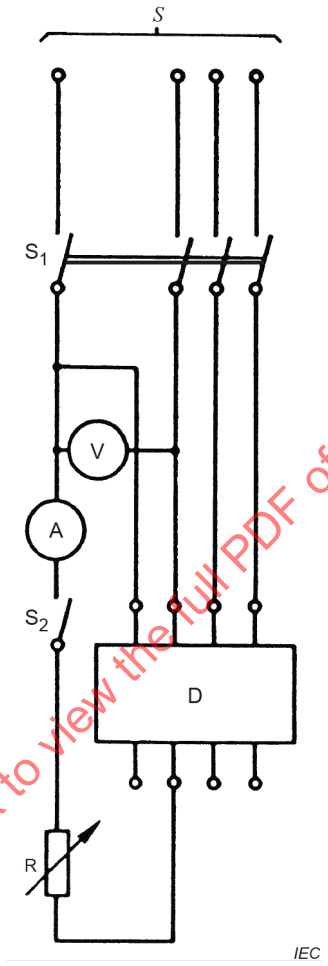
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B.8.14 Test for variations or interruptions of voltage and for voltage dips

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.

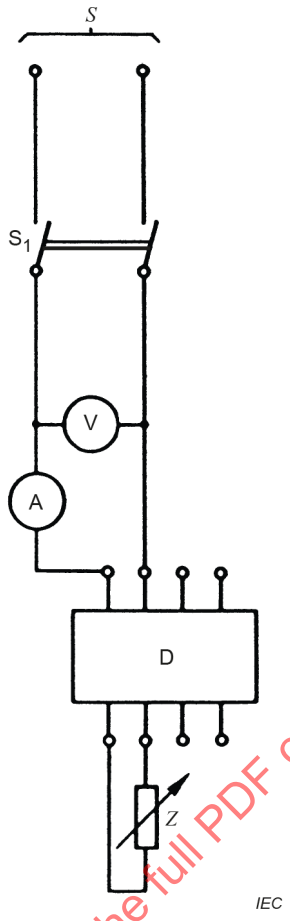


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Key

S	supply	S_2	single-pole switch
V	voltmeter	D	CBR under test
A	ammeter	R	adjustable resistor
S_1	multi-pole switch		

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)

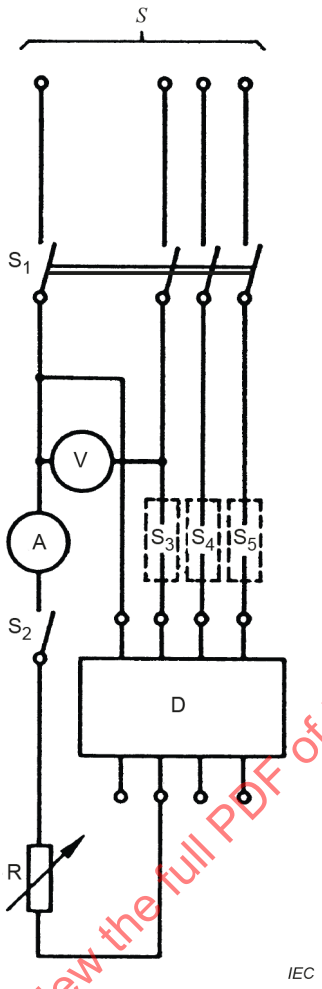


Key

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 overcurrent 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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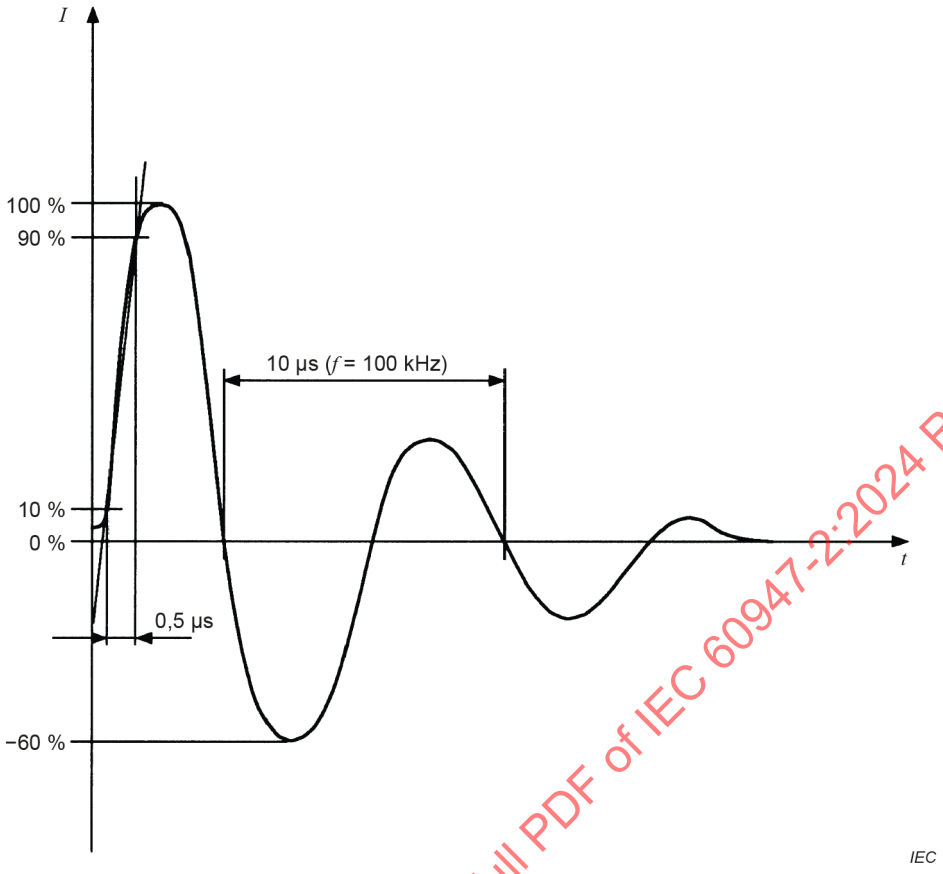
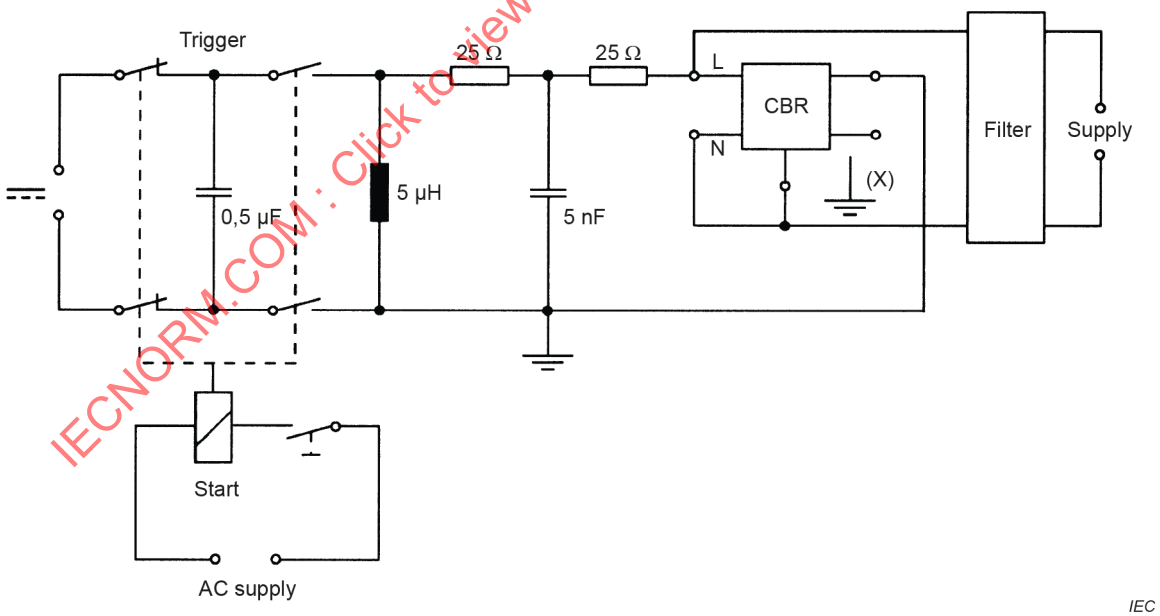


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(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~~ can 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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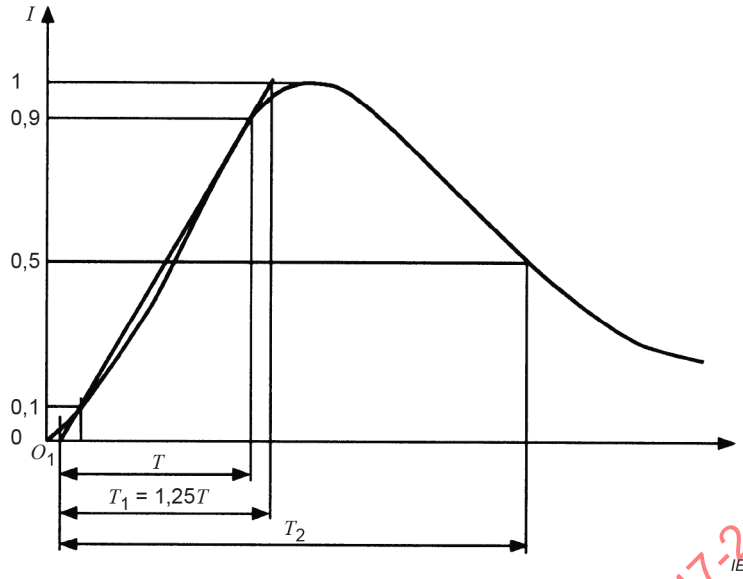
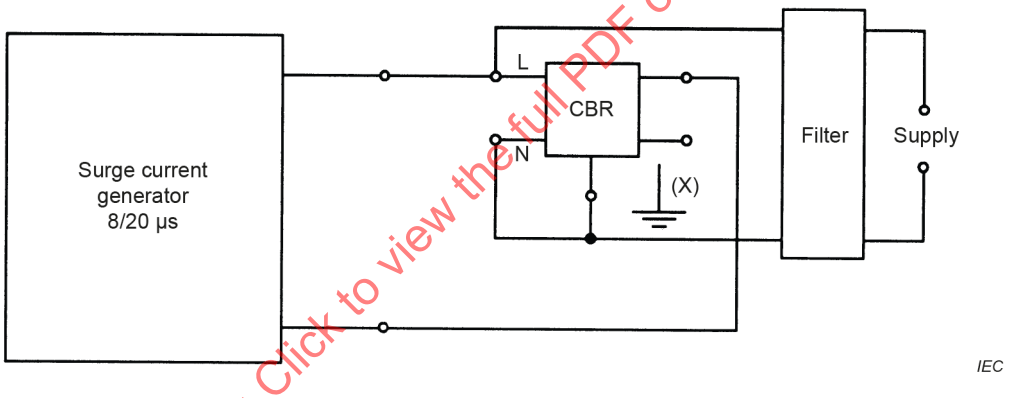


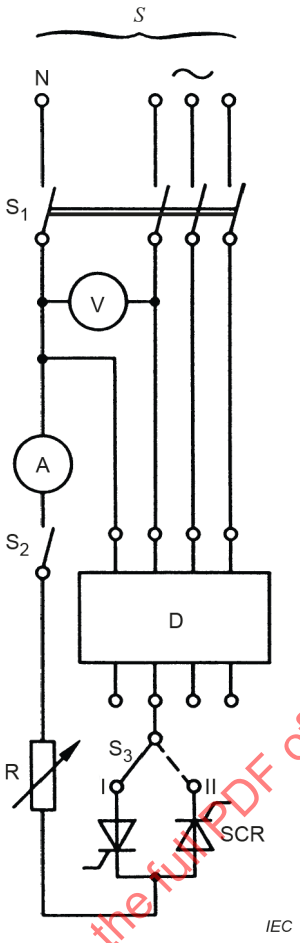
Figure B.6 – Surge current wave 8/20 µs



(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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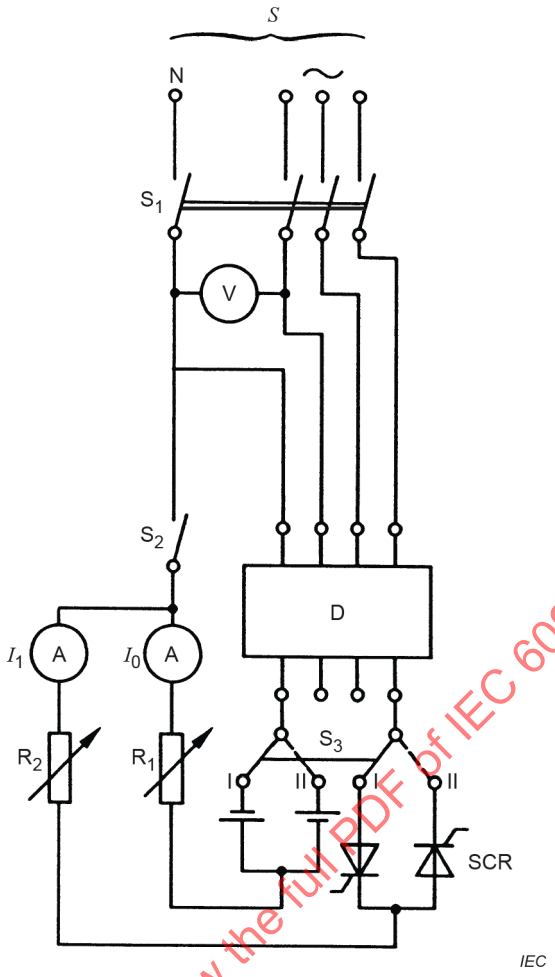


Key

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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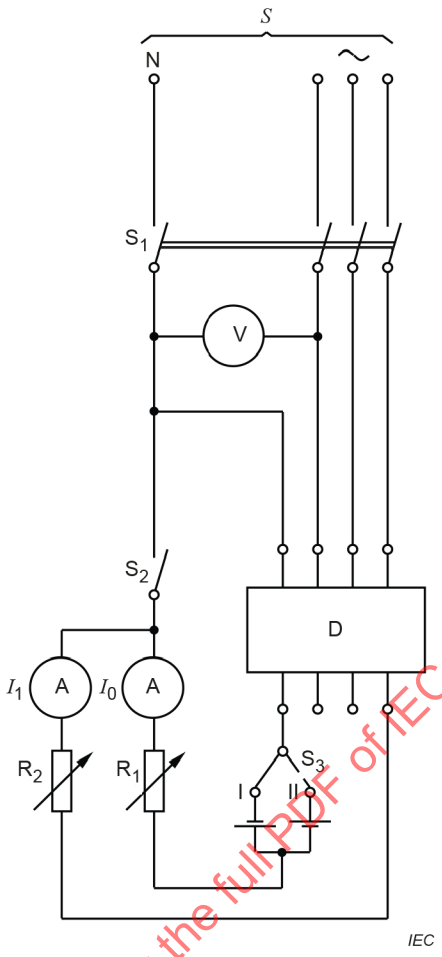


Key

S	supply	R_1, R_2	adjustable 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.9 – Test circuit for residual pulsating direct current superimposed by a smooth direct current

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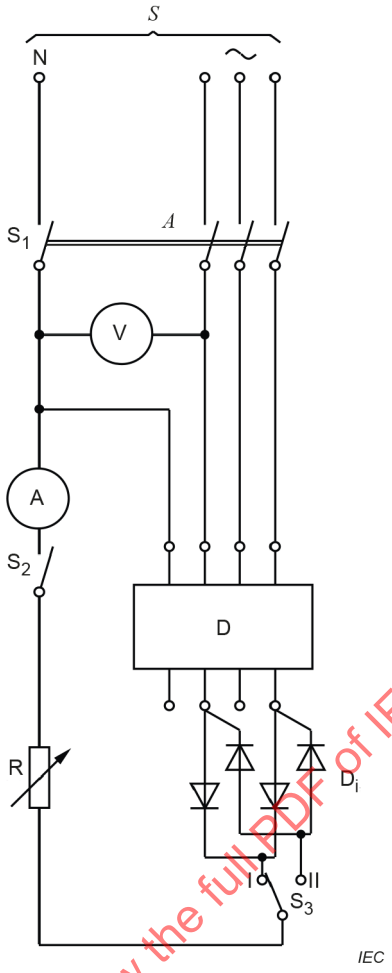


Key

S	supply	R_1, R_2	adjustable 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.10 – Test circuit for residual alternating currents superimposed by a smooth direct current

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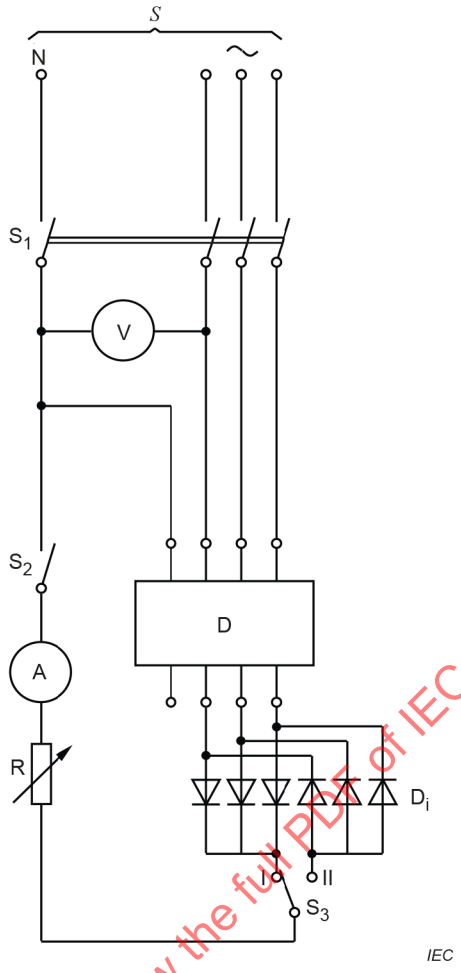


Key

Point A	supply by 2 phases chosen at random	D_i	diodes
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.11 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from two phases

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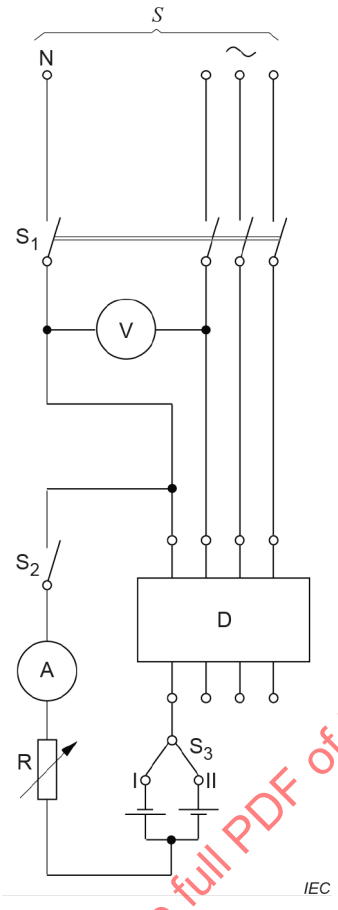


Key

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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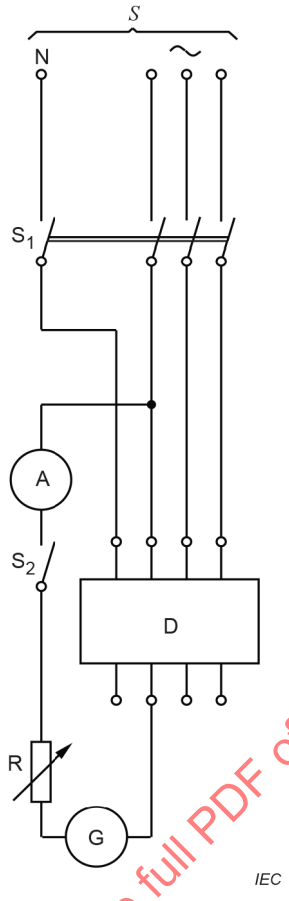


Key

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 5.3.2.1; it comprises the tests in Table C.1.

Table C.1 – Tests of Annex C

Test	Clause
Individual pole short-circuit breaking capacity (I_{su})	C.2
Verification of dielectric withstand	C.3
Verification of overload releases	C.4

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C.2 Test of individual pole short-circuit breaking capacity

A short-circuit test is made under the general conditions of 9.3.3, 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 9.3.3.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The power factor shall be according to Table 16, appropriate to the test current.

The test circuit shall be according to 9.3.4.1.2 of IEC 60947-1:~~2007/AMD1:2010~~2020 and Figure 9 of IEC 60947-1:~~2007/AMD1:2010~~2020, 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 and leakage current

Following the test according to Clause C.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

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 9.3.6.5.

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~~ bars, having a cross-section of at least 10 mm^2, for the connection of 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~~2020 for terminals as depicted in Figures D.2, D.3, D.4, D.5, D.6 (including busbars) and D.7 of IEC 60947-1:~~2007/AMD1:2010~~2020 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.2, D.3, D.4, D.5 and D.7 of IEC 60947-1:~~2007/AMD1:2010~~2020 or similar clamping units. Testing of lug terminals depicted in Figure D.6 of IEC 60947-1:~~2007/AMD1:2010~~2020 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.8 of IEC 60947-1:~~2007/AMD1:2010~~2020 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 3 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
S_f
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~~2020.

D.3 Classification

Clause 4 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 5 applies.

D.5 Product information

D.5.1 Nature of information

Subclause 6.1 applies.

D.5.2 Marking

Subclause 6.2 applies with the following addition:

The suitability of the terminal for use with aluminium conductors only (Al) or copper and aluminium conductors (Cu/Al or Al/Cu) 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 'AL/CU' or 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~~ (see Table 4, item 3.14).

Further information concerning the number of conductors, the tightening torque value of the terminal screws (if different between Al and Cu), the type of conductor (solid or stranded) and the cross-sections shall be provided in the literature.

D.5.3 Instructions for installation, operation and maintenance

Subclause 6.3 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.

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D.6 Normal service, mounting and transport conditions

Clause 7 applies.

D.7 Constructional and performance requirements

Clause 8 applies with the following addition:

Clamping units of devices and their accessories (including the terminals) which are not made of aluminium or aluminium alloy 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~~2020.

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 or 1370, as referred to in IEC 61545, shall be used for testing purposes.

NOTE 1 Grades 1350 and 1370 aluminium are 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.

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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
Climatic test		D.8.3	Terminal specimen	1 specimen
Mechanical properties of terminals	Flexion test	D.8.4.1	Circuit-breaker	As per 9.2.5.3 of IEC 60947-1: ~~2007/AMD1:2010~~2020
	Pull-out test	D.8.4.2		As per 9.2.5.4 of IEC 60947-1: ~~2007/AMD1:2010~~2020
Insertion test		D.8.5	Circuit-breaker	As per 9.2.5.5 of IEC 60947-1: ~~2007/AMD1:2010~~2020
[a] Type of connection limited to clamping unit types of Figure D.2, D.3, D.4, D.5 and D.7 as per Annex D of IEC 60947-1:~~2007/AMD1:2010~~2020.				

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.

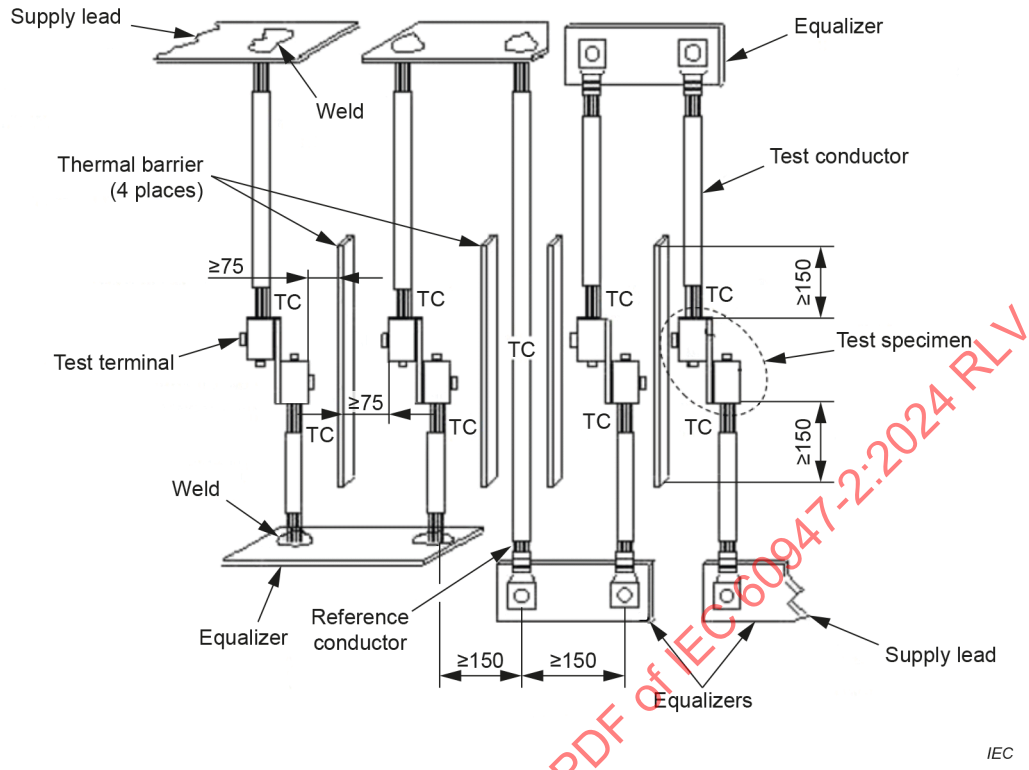
The wire shall be positioned so that 6 mm to 13 mm of the bare conductor is exposed between the wire-entry face of the terminal and the beginning of the insulation. There shall be no mechanical removal or chemical treatment of any oxide on the surface of the conductor entering the terminal, unless it 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.

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Dimensions in millimetres



Key

TC thermocouple

Figure D.1 – General test arrangement

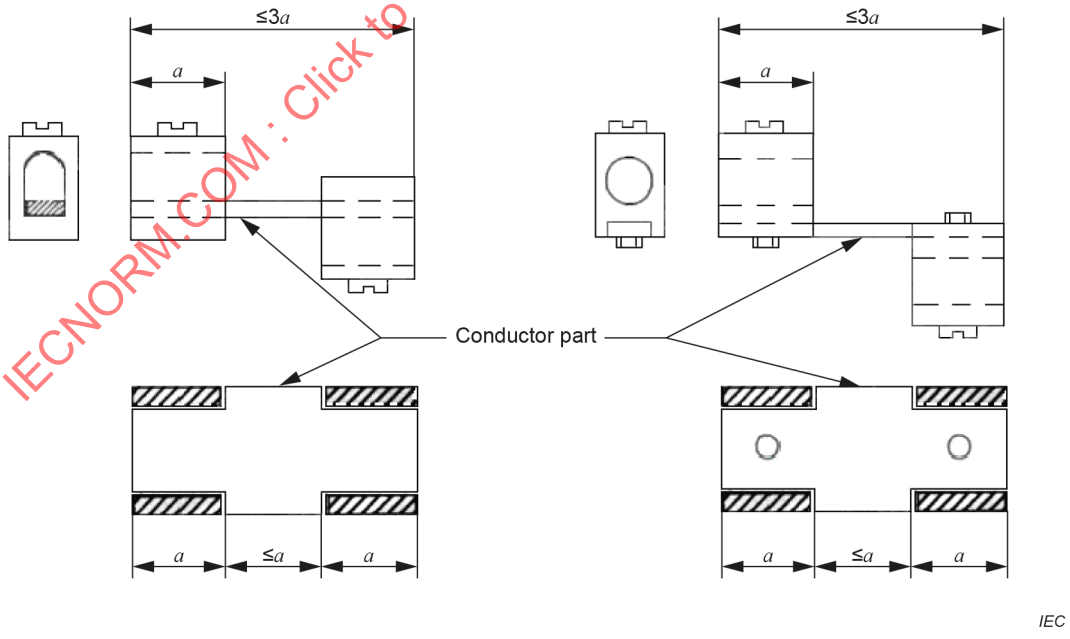


Figure D.2 – Mounting of terminals for the current cycling test

The test shall be carried out with conductors in accordance with Table D.7, specifying the equivalent cross-section of aluminium conductors.

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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.

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

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~~2020, 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.

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.

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	0,125 × 0,5	3,2 × 12,7	0,125 × 0,5
50	125	3,2 × 25	0,125 × 1	3,2 × 32	0,125 × 1,25
125	225	3,2 × 48	0,125 × 1,875	3,2 × 57	0,125 × 2,25
225	400	6,4 × 38	0,25 × 1,5	6,4 × 50	0,25 × 2
400	600	6,4 × 50	0,25 × 2	6,4 × 76	0,25 × 3
600	800	6,4 × 76	0,25 × 3	6,4 × 102	0,25 × 4
800	1 000	6,4 × 102	0,25 × 4	9,5 × 89	0,375 × 3,5
1 000	1 400	12,7 × 76	0,5 × 3	12,7 × 89	0,5 × 3,5
1 400	2 000	12,7 × 102	0,5 × 4	12,7 × 127	0,5 × 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 (2^{nd} 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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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 test current shall be DC, unless the terminals only have an AC rating, in which case the test current shall be AC.

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.

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.

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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 9.3.3.3.4 of IEC 60947-1:~~2007~~2020, 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 Climatic test

This subclause only applies to terminals with a DC rating.

A test specimen connected with its 2 cables shall be submitted to the damp heat test of Table Q.1 of IEC 60947-1:2020, category C, except that the number of cycles shall be 28. For practical reasons, the length of the cables may be adjusted. Once placed in the climatic chamber, the whole test arrangement, including the conductors, shall not be moved until all the following voltage drop measurements have been completed.

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The voltage drop of the test specimen shall be measured, using the same test current and the same measurement points:

– before the damp heat test
– and after a recovery duration of 24 hours following the damp heat test

The difference of the two voltage drops shall not exceed 10 % of the voltage drop before the damp heat test.

The measurement points of the voltage drop and the value of the test current shall be stated in the test report.

D.8.4 Mechanical properties of terminals

D.8.4.1 Flexion test

Subclause 9.2.5.3 of IEC 60947-1:~~2007/AMD1:2010~~2020 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.4.2 Pull-out test

Subclause 9.2.5.4 of IEC 60947-1:~~2007/AMD1:2010~~2020 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.5 Test for insertability of unprepared round aluminium conductors having the maximum cross-section

Subclause 9.2.5.5 of IEC 60947-1:~~2007/AMD1:2010~~2020 applies. Table 7 of IEC 60947-1:~~2007~~2020 applies, except the column relating to flexible conductors.

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	-

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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.

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 This table is based on UL 486E.

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[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.

Table D.7 – Test aluminium cables for test currents up to 800 A[a, b]

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 9.3.3.3.4 of IEC 60947-1:~~2007~~2020.

~~[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.~~

[b] 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 9.3.3.3.4 of IEC 60947-1:~~2007~~2020.

[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~~ laboratories.

Annex J of IEC 60947-1:~~2007~~2020 applies with regard to clauses and subclauses of this document, with the additions of Table E.1.

~~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~~

Table E.1 – List of items subject to agreement between manufacturer and user

Clause or subclause number of this document	Item
5.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 1
8.2.3.2	Impulse withstand voltage for circuit-breakers rated above 1 000 V AC
9.3.3.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
9.3.4.2.3, item b)	Test current value for the verification of inverse time/current characteristics
9.3.4.5	Test method if the testing means do not withstand the let-through energy occurring during the automatic operation
9.3.4.5, Note 2	To increase the severity of the conditions for testing overload performance
9.3.4.8 9.3.5.6	Permissible delay between the verification of temperature-rise and that of overload release in test sequences I and II
9.5	Special tests – Damp heat, salt mist, vibration and shock
B.8.1.1	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.3	Details of the modification for the use of a low-power source for the loading with current
B.8.2.5	Extension of the test ambient temperature limits
Table D.8, footnote e	Sizes of aluminium bars if different from Table D.8
Table D.8, footnote f	All relevant items of the test for rated currents greater than 3 150 A

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Annex F
(normative)

Additional tests for circuit-breakers with electronic overcurrent protection

F.1 General

This annex applies to circuit-breakers intended to be installed on AC circuits and providing overcurrent 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 overcurrent 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 overcurrent 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 9.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this document, 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 Table 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 time current characteristic provided by the manufacturer, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker. The disturbance shall be applied until the circuit-breaker trips.

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 time current characteristic provided by the manufacturer 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 9.

The figures in this annex, showing 3-pole circuit-breakers, apply also to 1-pole, 2-pole and 4-pole circuit-breakers.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

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. For devices having different numbers of poles, only the design with the highest number of poles shall be tested.

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.

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NOTE This enables comparisons to be made between test results obtained on different phase pole combinations ~~as required by~~ in the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M) or a ground-fault release (5.7.1 item 2 d):

– 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 or by ground-fault 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 or by ground-fault current is avoided.

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 declared by the manufacturer to be RMS responsive (see Table 4, item 3.9).

~~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;

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– 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~~ shall have at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;
– fifth harmonic > 14 %;
– seventh harmonic > 7 %;
– twenty-first harmonic > 1 %.

Other harmonics can also be present.

NOTE 1 The peak factor is the peak value of the current divided by the RMS value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 The test current waveform for option b) can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 3 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the RMS 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 8.2.1.2.4 carrying the test current at any ~~convenient~~ suitable 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.

NOTE The suitable voltage is that chosen by the testing laboratory, not exceeding the rated voltage of the circuit-breaker

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.

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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.

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 AC 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 AC 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.

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On the AC 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.

The tests shall be performed with a sinusoidal current at any ~~convenient~~ suitable 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

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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 have been shown not to create ~~negligible~~ disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to ~~1 GHz~~ 6 000 MHz)

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.

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~~ suitable 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.

Undervoltage 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 5) 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 5) is applied.

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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 5);
– 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.

F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 8.2.2 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 4, 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, or during a temperature-rise test with a new sample. The method of determining the temperature-rise of the air surrounding the electronic components shall be stated in the test report;
– install the electronic controls in the test chamber;
– supply the electronic controls with their ~~input~~ energizing ~~value~~ input quantity;
– adjust the temperature of the test chamber to a value of 40 ~~K above~~ °C plus the temperature-rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

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 8.2.1.2.4, item b).

F.8 Damp heat test

F.8.1 Test procedure

The test shall be performed according to IEC 60068-2-30.

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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.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

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 8.2.1.2.4, 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.

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.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

F.9.3 Test results

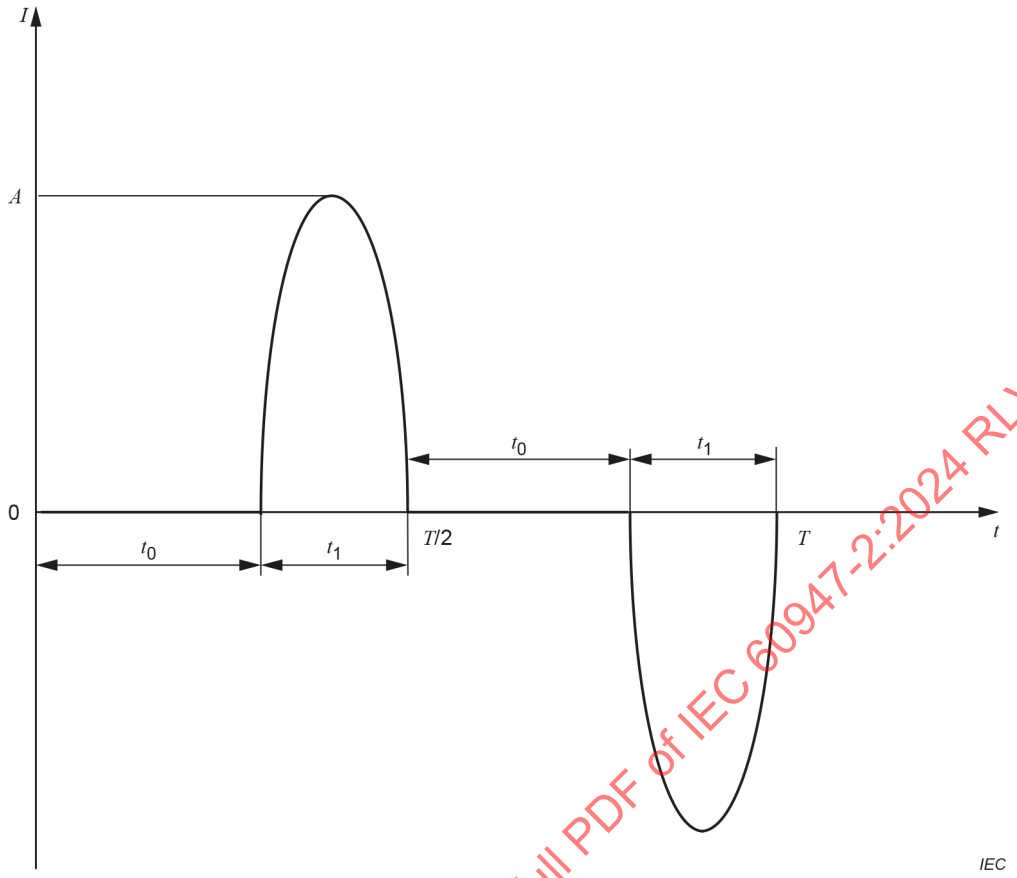
The electronic controls shall meet the following requirement.

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 8.2.1.2.4, 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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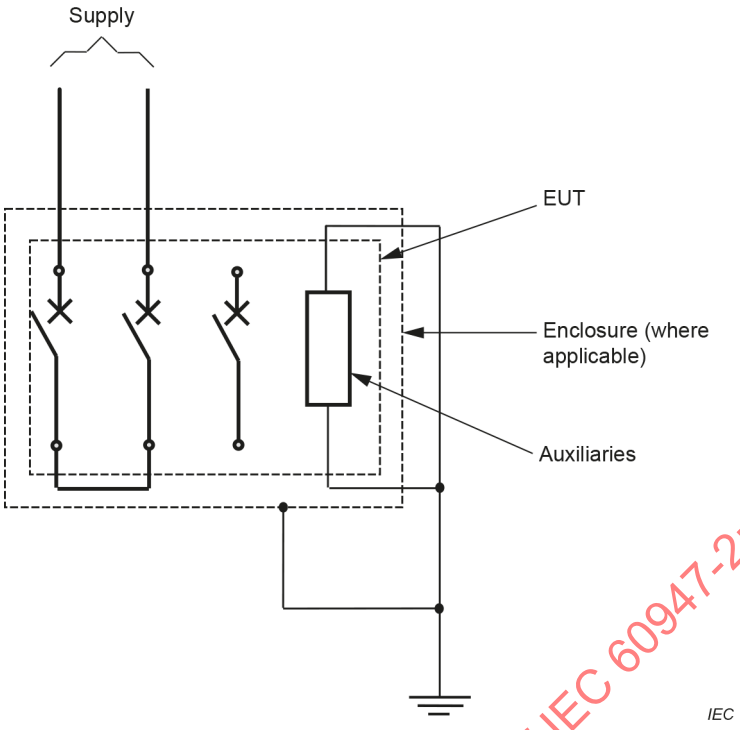


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

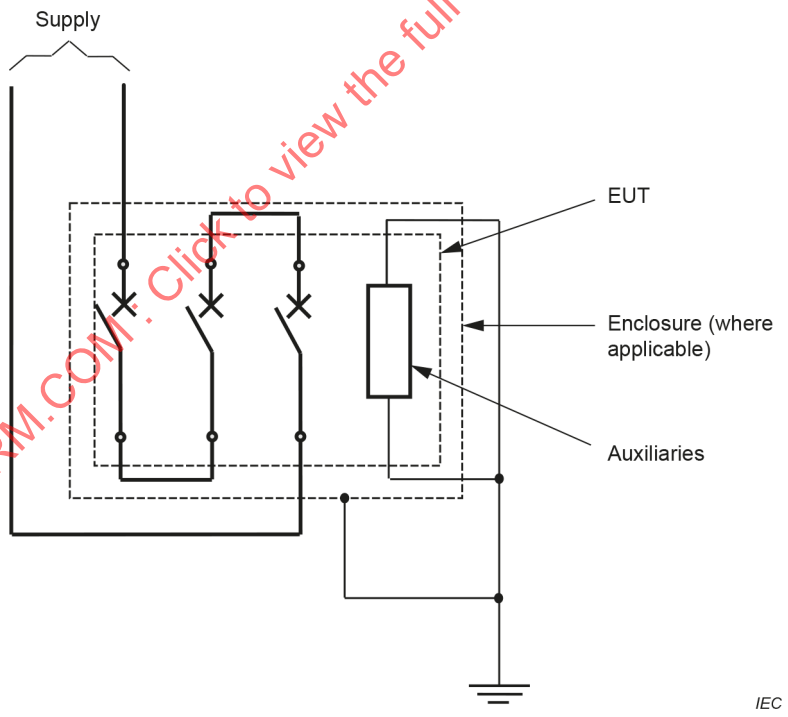
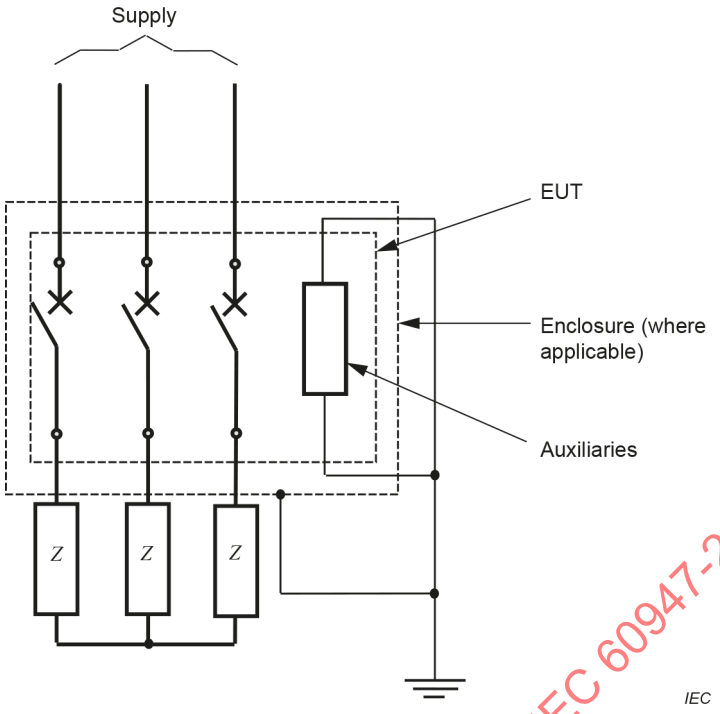


Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series

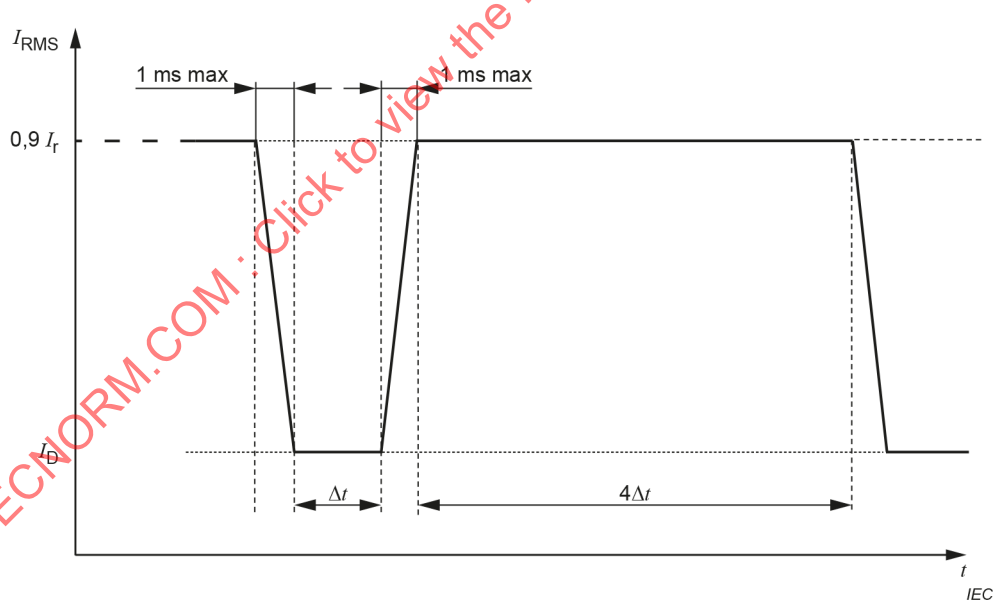
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Key

Z impedance for adjusting the current (where ~~required~~ applicable)

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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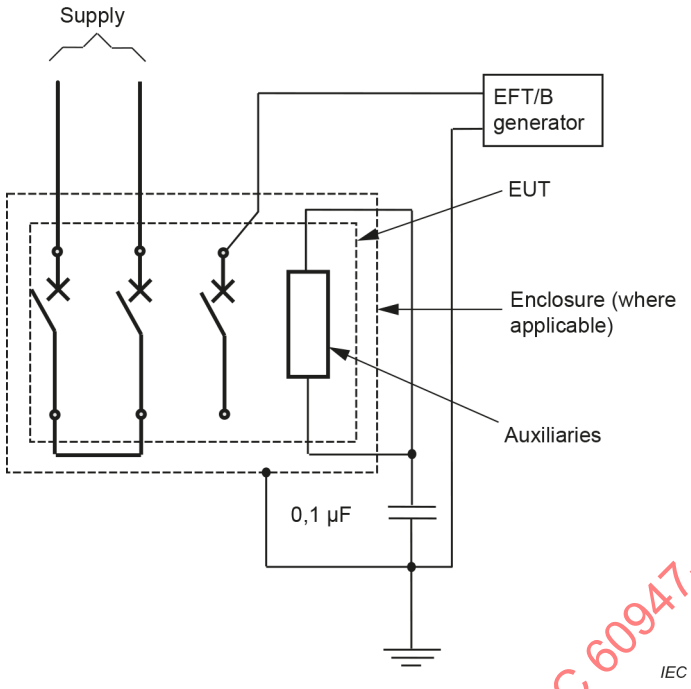


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

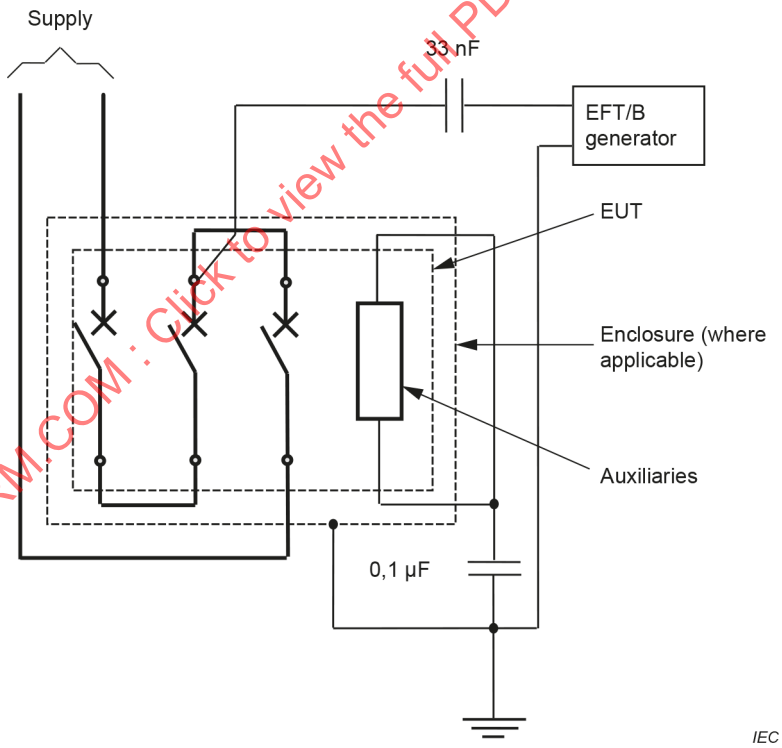
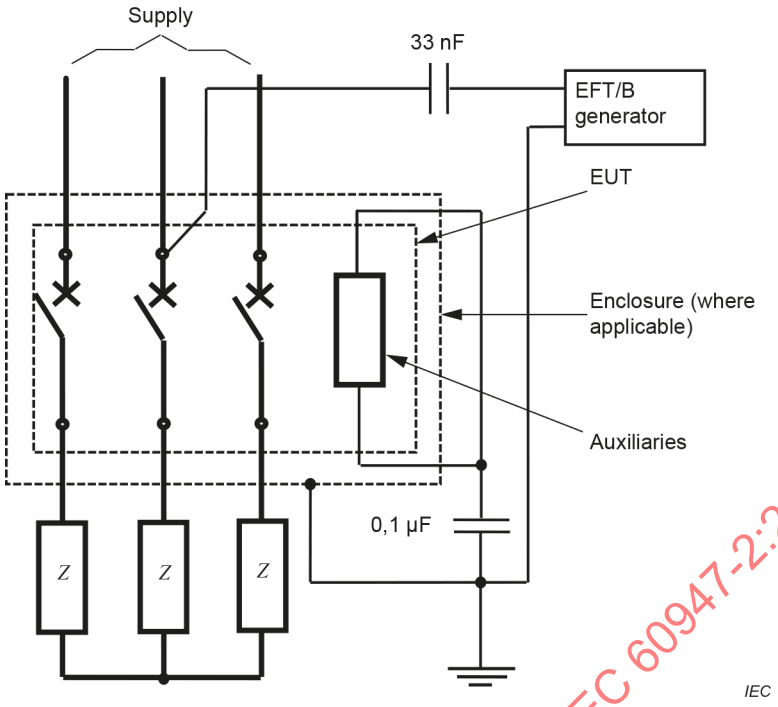


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series

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Key

Z impedance for adjusting the current (where ~~required~~ applicable)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

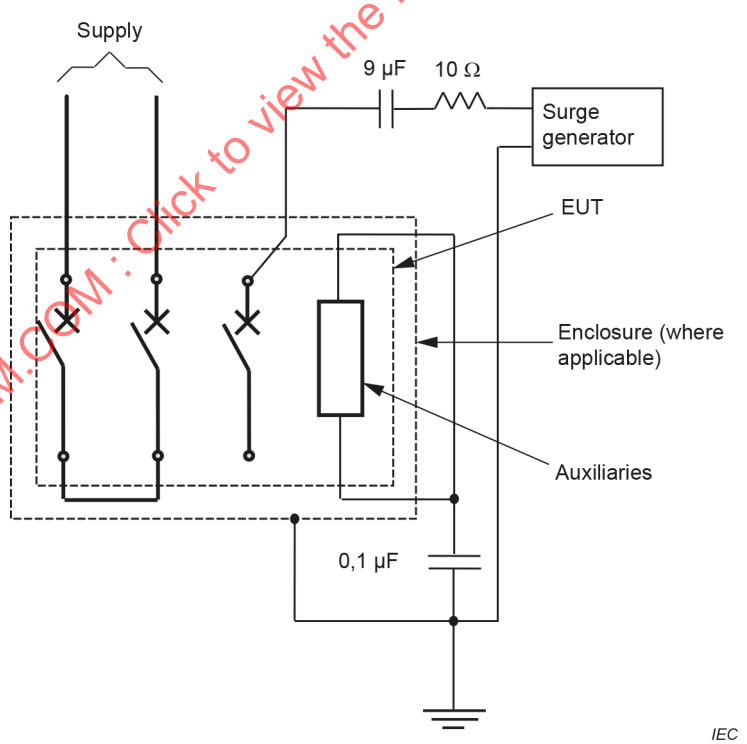


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

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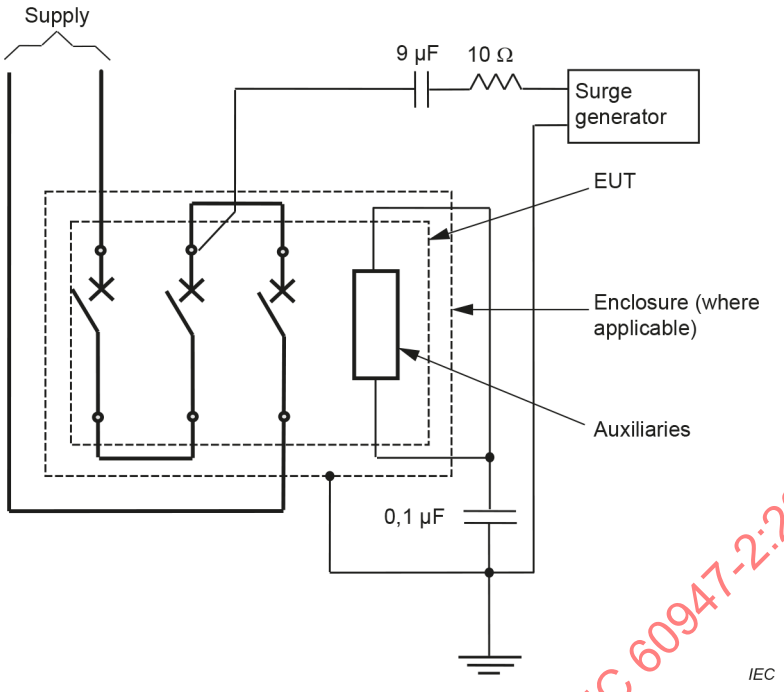
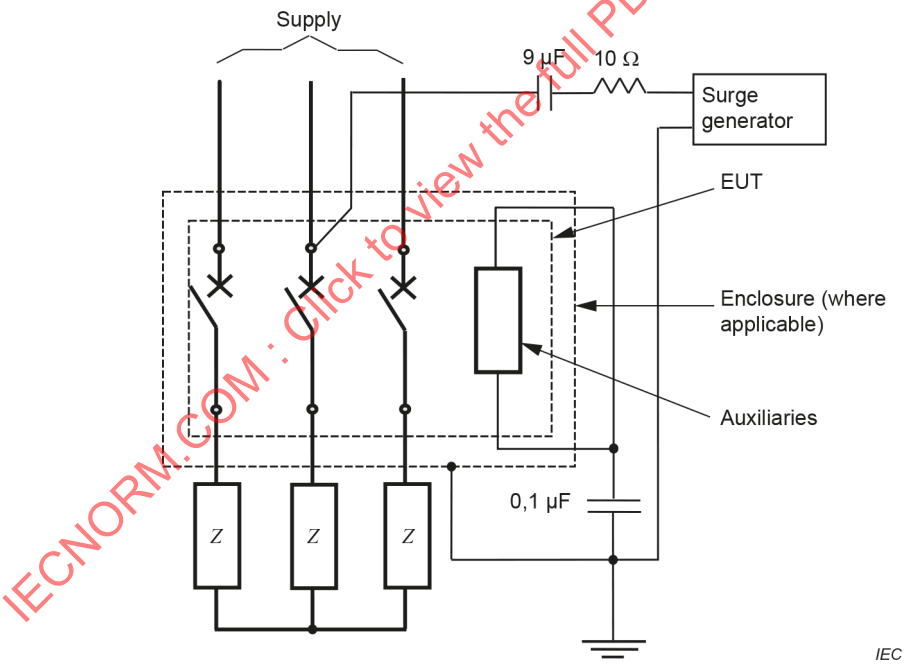


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where ~~required~~ applicable)

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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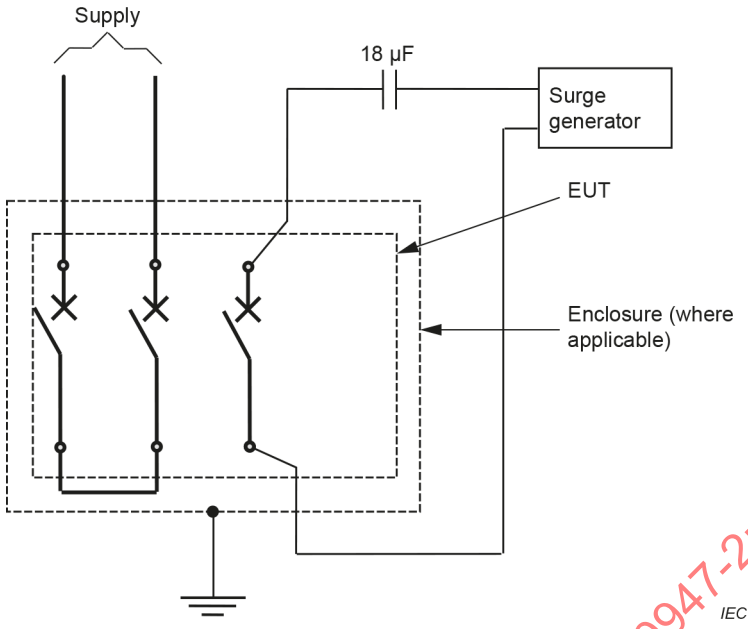


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

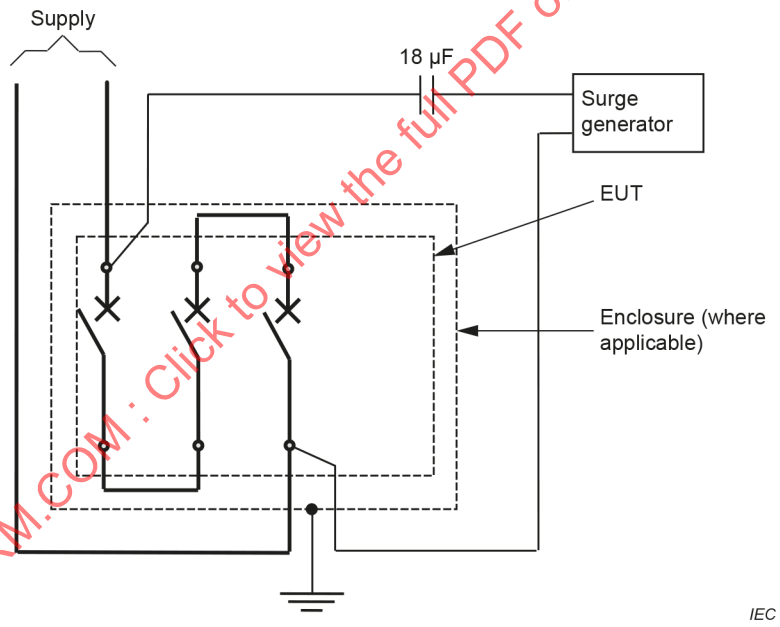
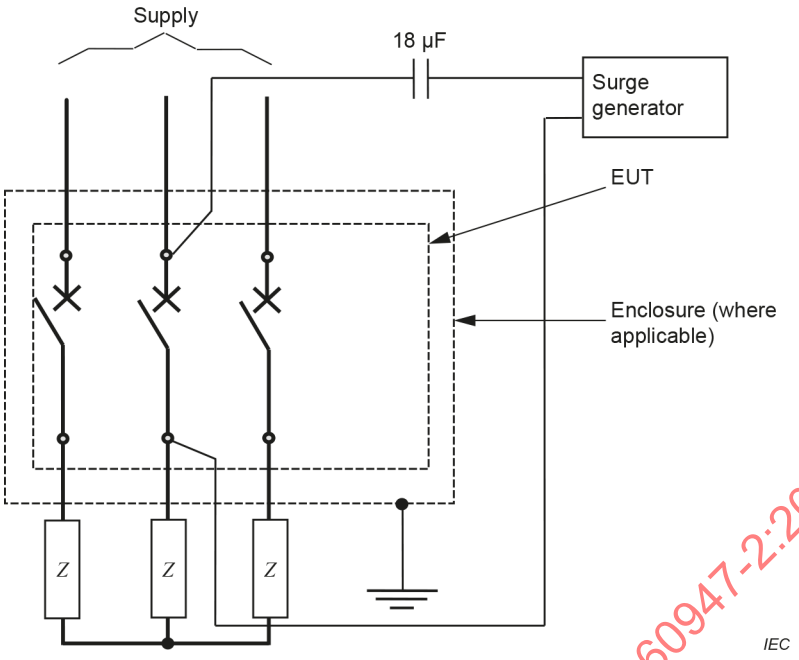


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series

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Key

Z impedance for adjusting the current (where ~~required~~ applicable)

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

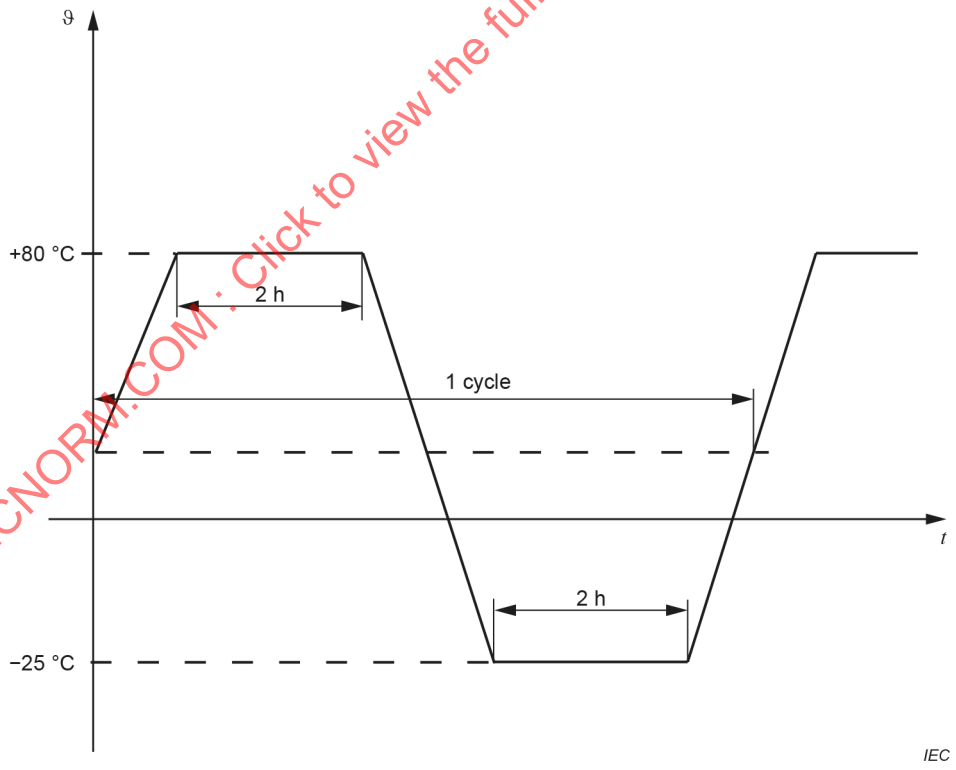
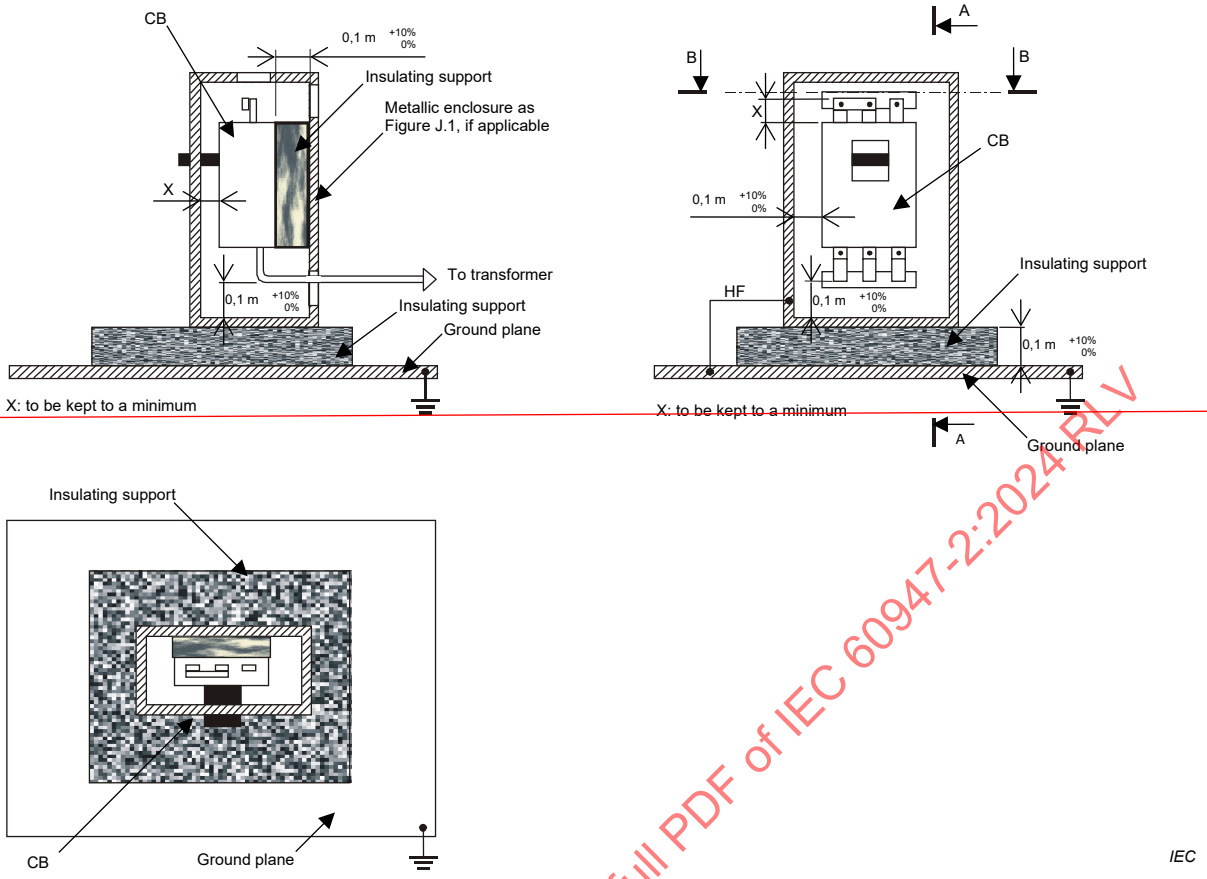


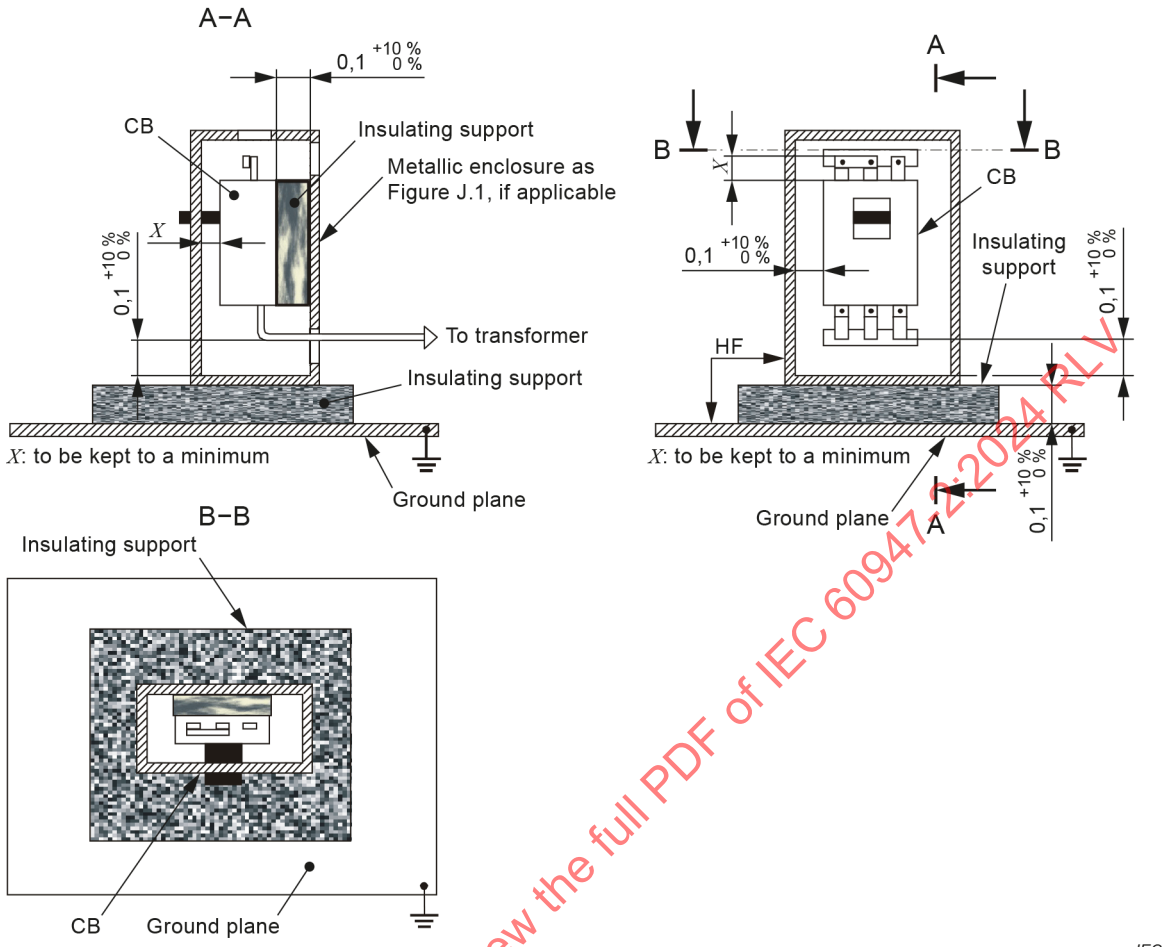
Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1

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Dimensions in metres



Key

CB circuit-breaker

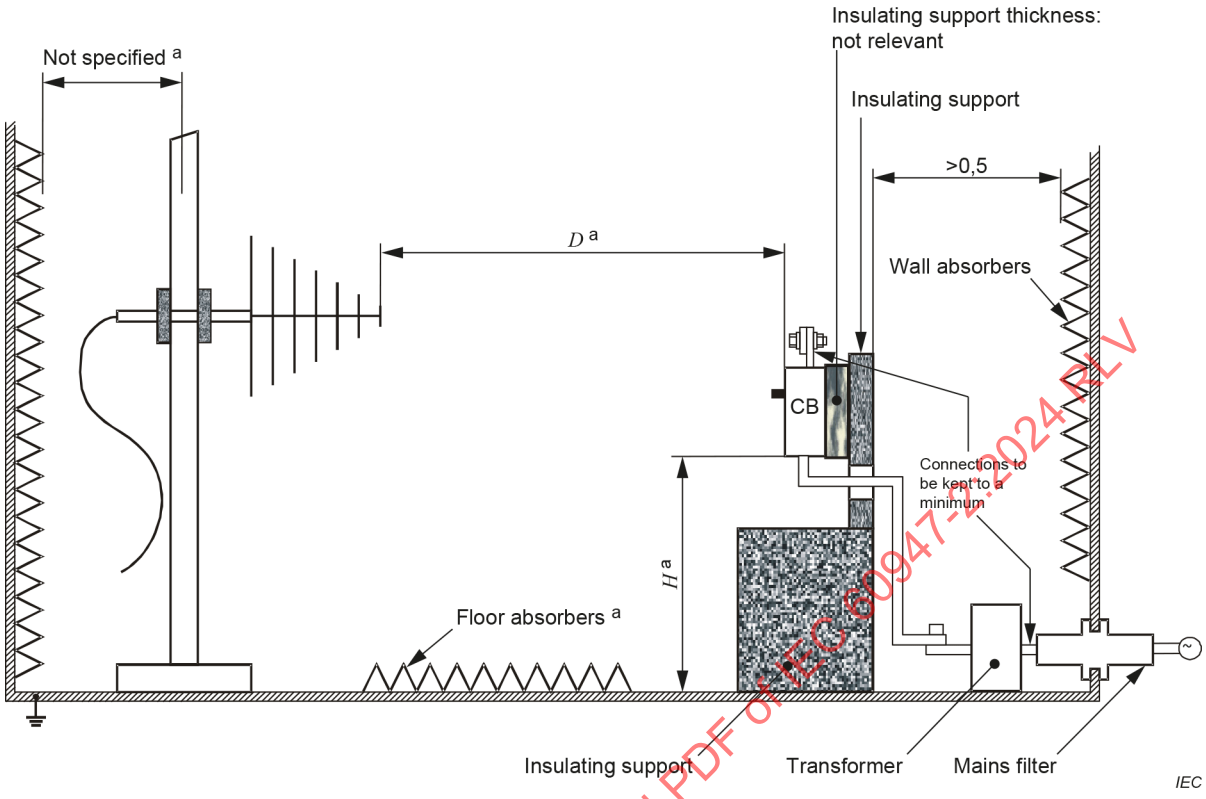
HF high frequency connection

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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Dimensions in metres



Key

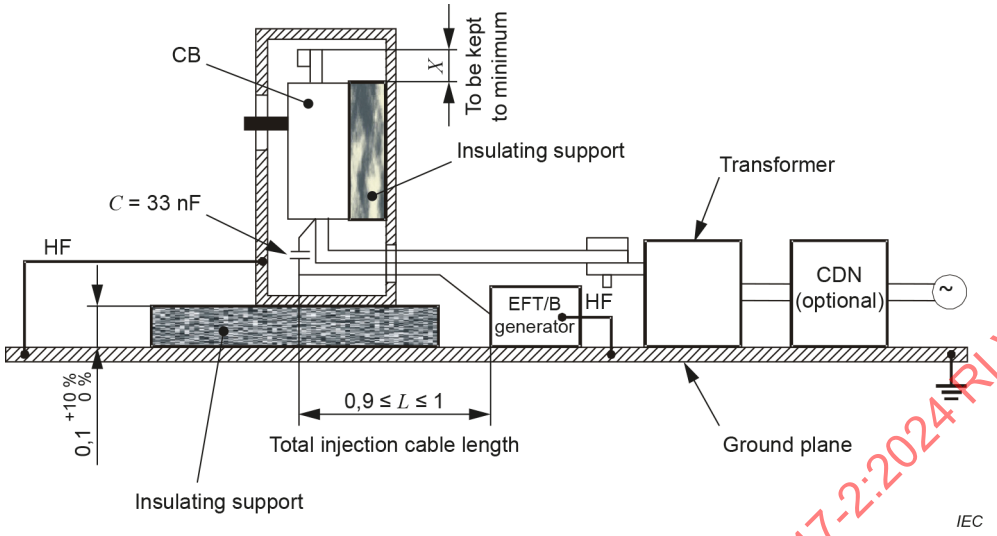
CB circuit-breaker

a See IEC 61000-4-3.

Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields

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Dimensions in metres

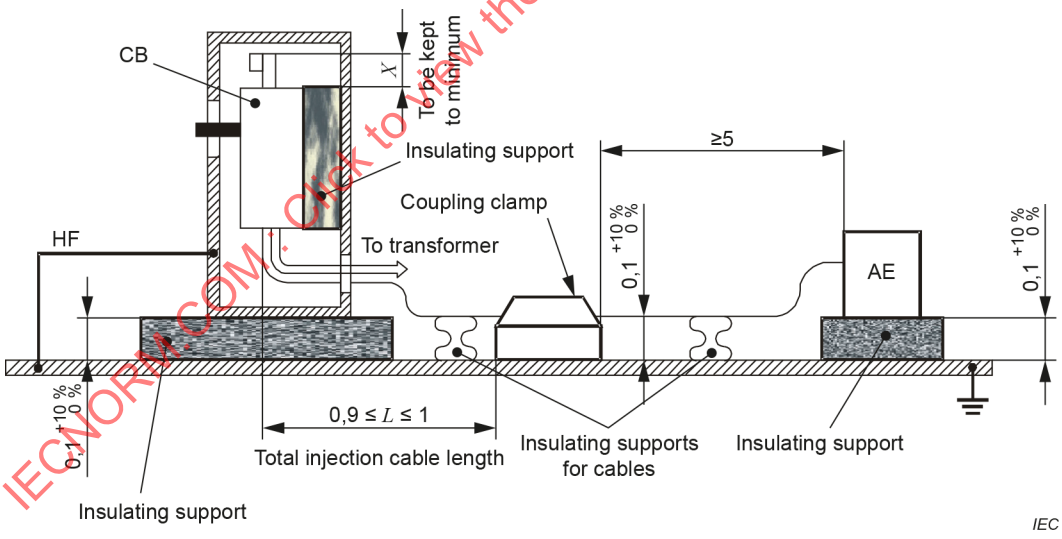


Key

CB	circuit-breaker	HF	high frequency connection
CDN	coupling-decoupling network		

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines

Dimensions in metres



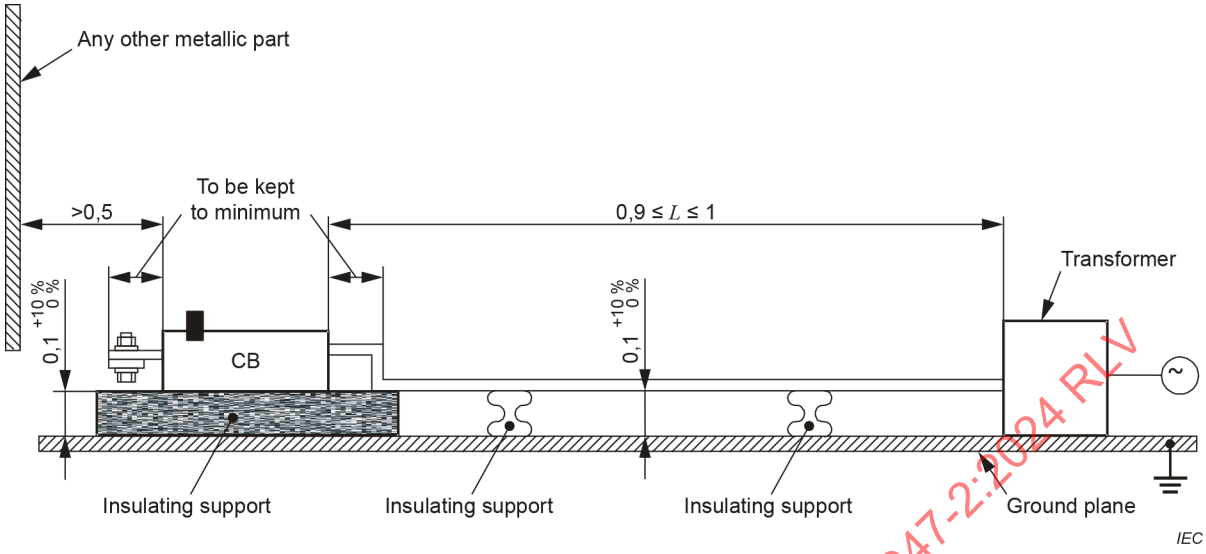
Key

AE	auxiliary equipment	HF	high frequency connection
CB	circuit-breaker		

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

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Dimensions in metres

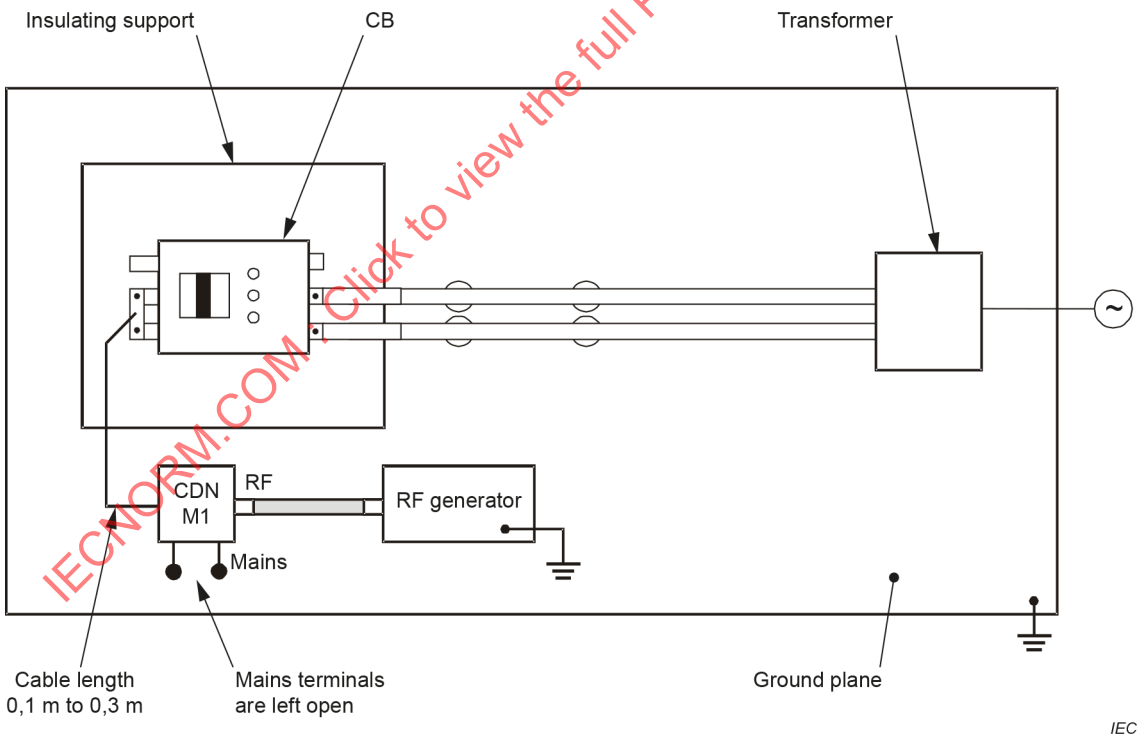


Key

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)



Key

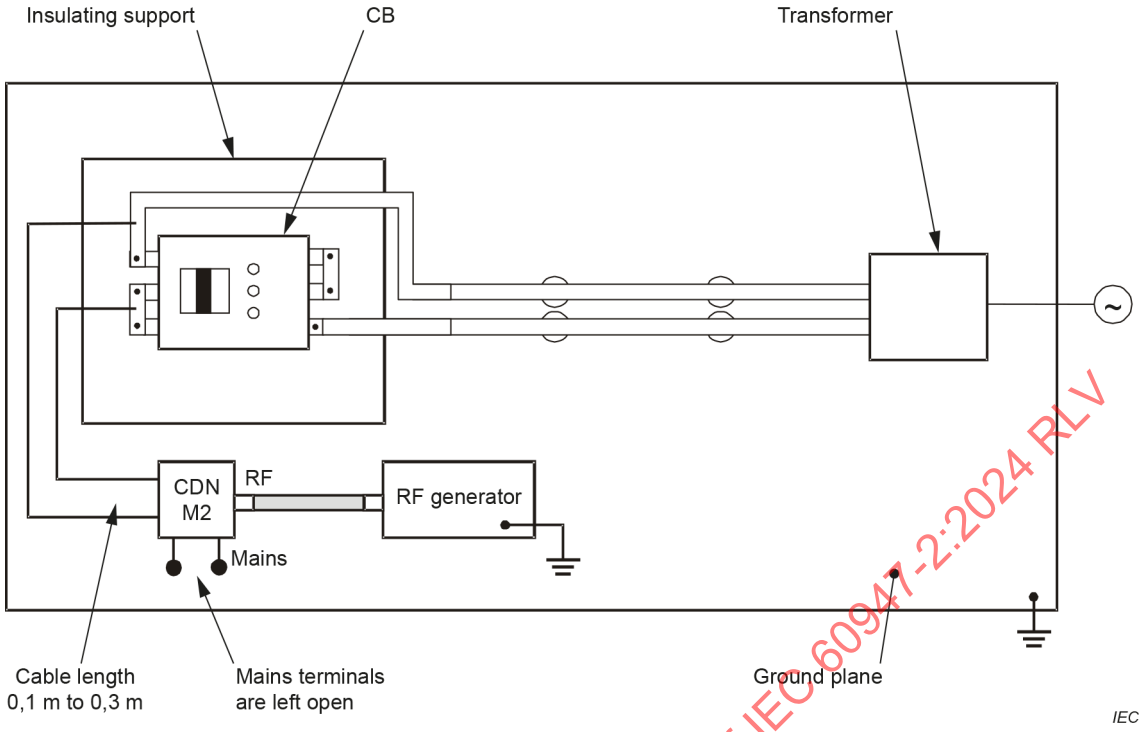
CB circuit-breaker

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

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Key

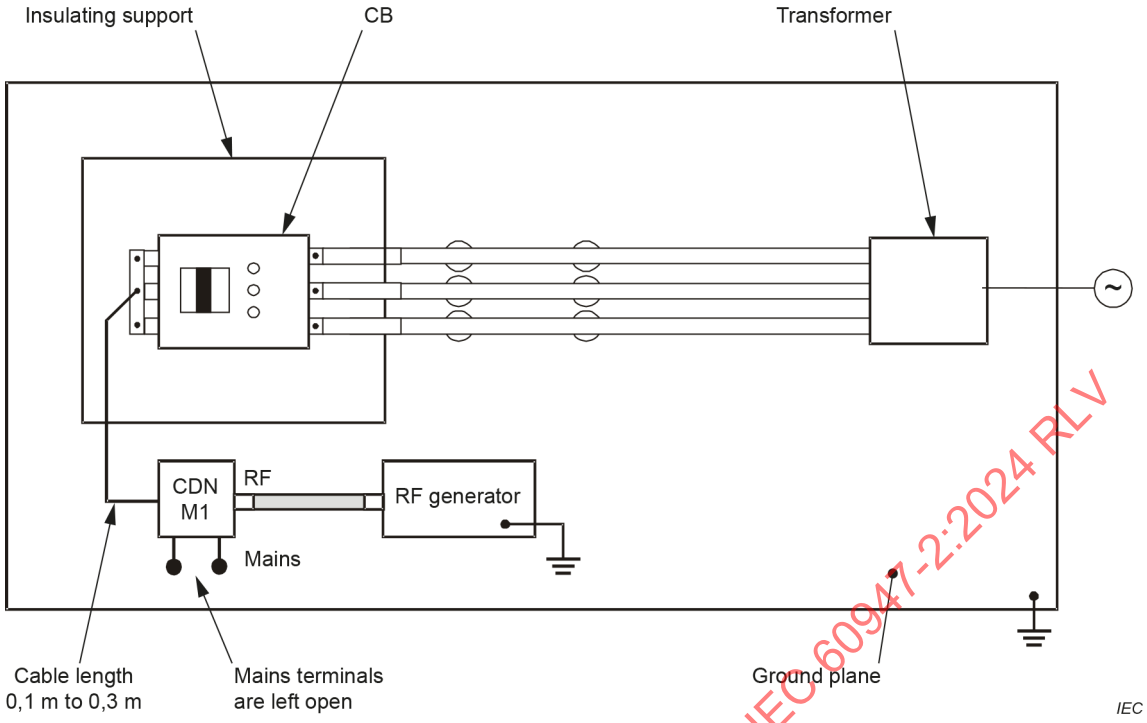
CB circuit-breaker

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.

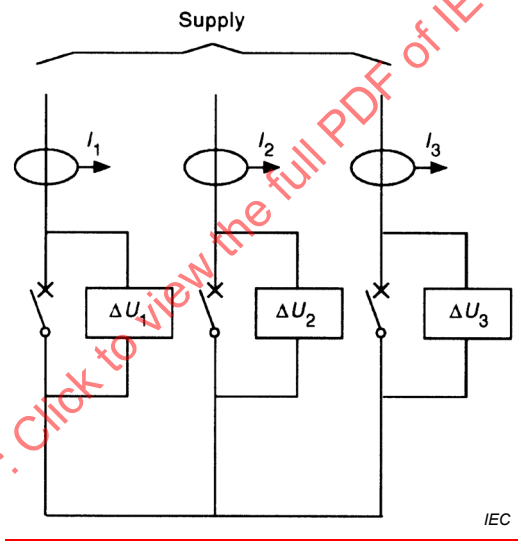
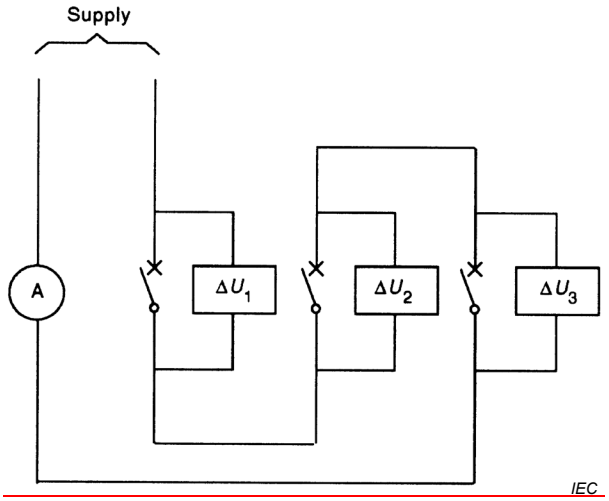


Figure G.1 – Example of power loss measurement according to G.2.1

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~~Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3~~

G.1 General

The power loss value gives 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 Determination method

G.2.1 AC circuit-breakers of rated current exceeding 400 A

For AC circuit-breakers of rated current exceeding 400 A, power loss shall be determined with one of the following methods:

a) Power factor method

The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \Delta U_k I_k cos\varphi_k$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop, see G.4.2;

I is the test current, see G.3 and G.4.3;

$cos\varphi$ is the power factor.

A wattmeter may be used instead of measuring independently on each pole.

For a circuit breaker with multiple poles per phase, the power loss of each phase is the sum of the power losses of each pole.

b) Integral method

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The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \left(\frac{1}{T} \int_{0}^{T} \Delta u i dt \right)$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

T is the duration of the measurement;

Δu is the instantaneous value of voltage drop, see G.4.2;

i is the instantaneous value of the test current, see G.3 and G.4.3.

The duration of the measurement shall be at least 10 cycles for AC. For a circuit breaker with multiple poles per phase, the power loss of each phase is the sum of the power losses of each pole.

NOTE For circuit-breakers with a rated current more than 1 000 A and with current transformers with iron cores, the integral method is preferred.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

All methods described in G.2.1 may be applied. It is also acceptable to use single-phase AC measurement without power factor measurement, as described below.

The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \Delta U_k I$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop, see G.4.2;

I is the test current, see G.3 and G.4.3.

G.2.3 DC circuit-breakers

For DC circuit-breakers, the power loss shall be measured with DC current.

It is evaluated as in G.2.2.

G.3 Test conditions

The circuit-breaker under test shall be installed according to 9.3.3.1.

The conductor size for the power loss measurement shall be suitable for the test current and comply with 9.3.3.3.4 of IEC 60947-1:2020.

The power loss shall be evaluated at the rated current at steady-state temperature, under the conditions of 9.3.3.2.2

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Tests can be made at any suitable voltage.

The power loss test shall be conducted at the rated frequency of the circuit-breaker. For circuit-breakers rated 50/60 Hz, 50 Hz covers 60 Hz and vice-versa.

The waveforms of AC current and AC voltage shall be practically sinusoidal, meaning that the ratio between the peak value and the RMS value is $\sqrt{2} \pm 3$ %.

G.4 Test method

G.4.1 General

The power loss measurement circuit for AC circuit-breakers of rated current exceeding 400 A shall be according to Figure G.1. For other circuit-breakers, Figure G.1 or Figure G.2 may be used.

For evaluating the power loss of four-pole AC circuit-breakers, the test shall be performed without current in the neutral pole.

G.4.2 Voltage drop measurements

The voltage drop measurement depends on the design of the circuit-breaker.

a) Circuit-breakers with a single pole per phase

   The voltage drop shall be measured between incoming and outgoing terminals on each pole as in Figure G.3.

b) Circuit-breakers with multiple poles per phase

   The voltage drop shall be measured between incoming and outgoing terminals on each of the multiple poles as in Figure G.4.

G.4.3 Current measurement

The current measurement depends on the design of the circuit-breaker.

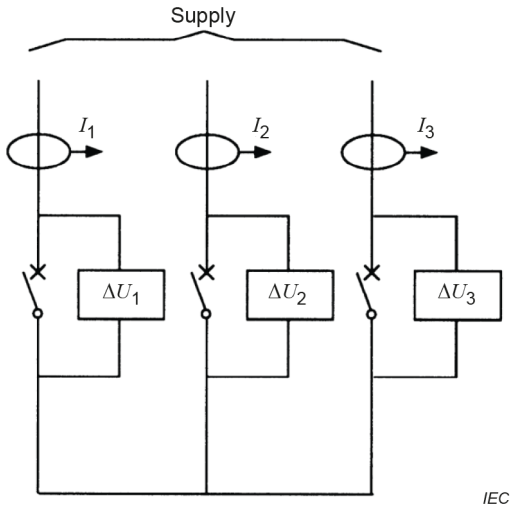
a) Circuit-breakers with single pole each phase

   The current shall be measured on each pole as in Figure G.3.

b) Circuit-breakers with multiple poles per phase

   The current shall be measured on each of the multiple poles as in Figure G.4.

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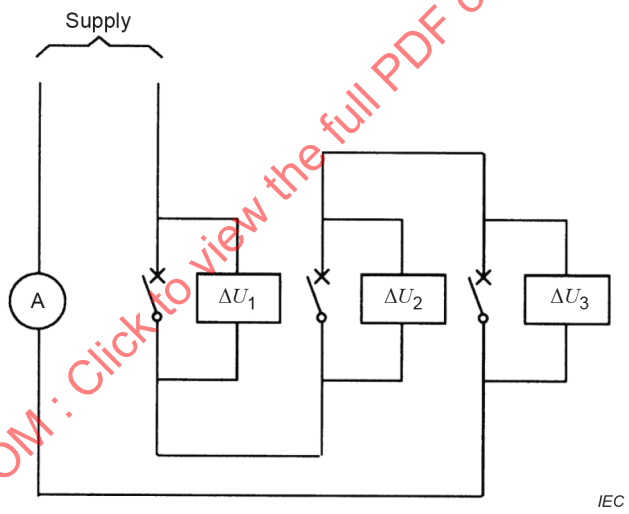


Key

I_1, I_2, I_3 current sensing devices

ΔU_1, ΔU_2, ΔU_3 voltage sensing devices

Figure G.1 – Power loss measurement circuit for AC circuit-breakers

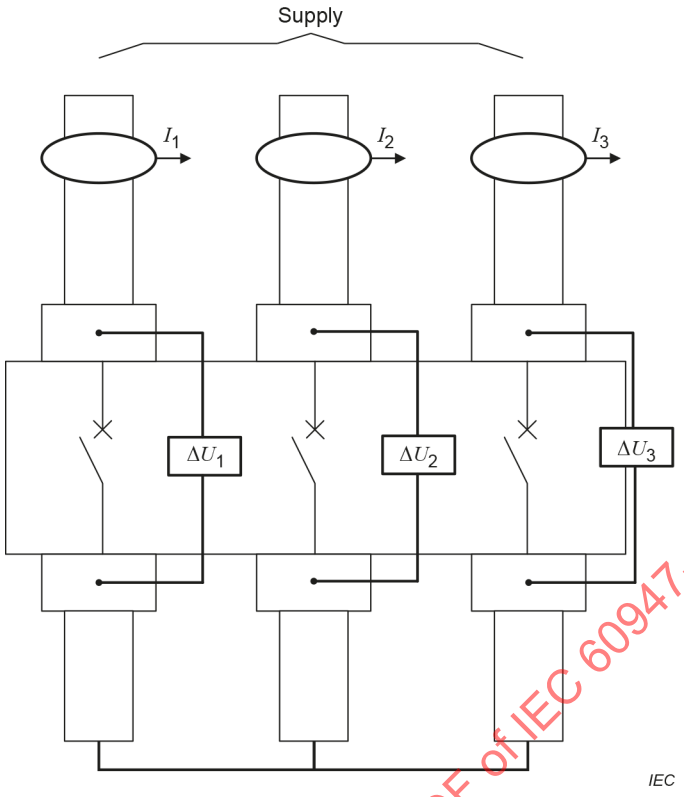


Key

ΔU_1, ΔU_2, ΔU_3 voltage sensing devices

Figure G.2 – Power loss measurement circuit for AC circuit-breakers with rated current not exceeding 400 A and DC circuit-breakers

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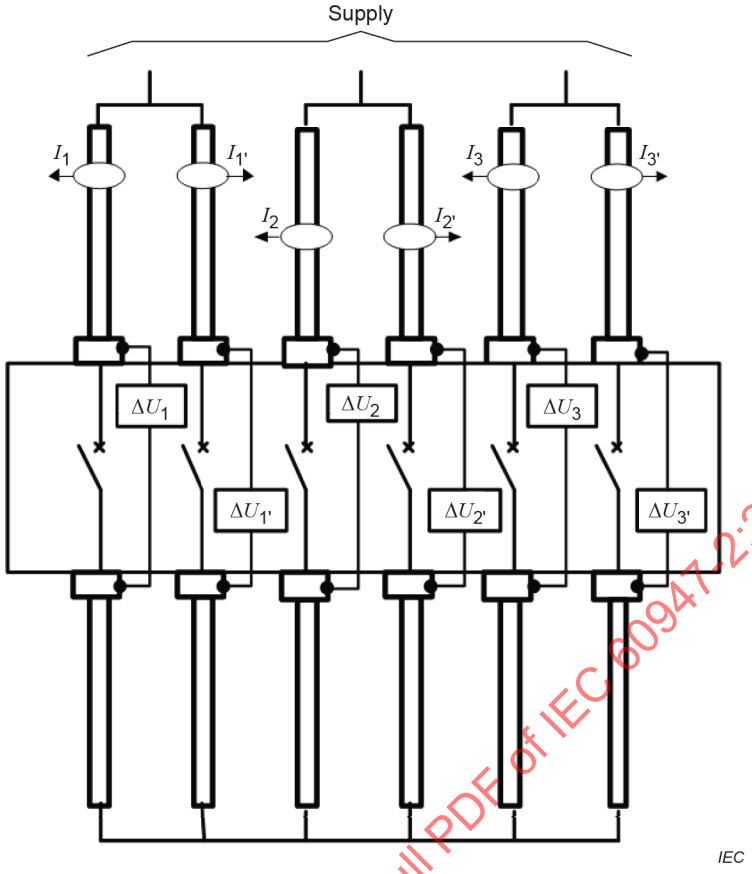


Key

I_1, I_2, I_3	current sensing devices
ΔU_1, ΔU_2, ΔU_3	voltage sensing devices

Figure G.3 – Measurement points for circuit-breakers with a single pole per phase

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Key

I_1, $I_{1'}$, I_2, $I_{2'}$, I_3, $I_{3'}$	current sensing devices
ΔU_1, $\Delta U_{1'}$, ΔU_2, $\Delta U_{2'}$, ΔU_3, $\Delta U_{3'}$	voltage sensing devices

Figure G.4 – Measurement points for circuit-breakers with multiple poles per phase

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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 5.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 5.3.2.1; it comprises the tests of Table H.1.

Table H.1 – Tests of Annex H

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 9.3.3, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay short-circuit 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~~ may 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 9.3.3.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The power factor shall be according to Table 16, 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 $\sqrt{3}$. 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 9.3.4.1.2 of IEC 60947-1:~~2007/AMD1:2010~~2020 and Figure 9 of IEC 60947-1:~~2007/AMD1:2010~~2020, the supply S being derived from two phases of a three-

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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.

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 and leakage current

Following the test according to H.2, the dielectric withstand and the leakage current shall be verified according to to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 9.3.6.5.

H.5 Marking

Subclause 6.2 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.2.

Table H.2 – Product information

Item	Information	Marking location
H.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 690 V  (IEC 60417-6363:2016-07)	Marked
Key Marked: marked on the product		

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Annex I

Vacant

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~~Annex I~~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 document.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this document to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this document, 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 8.3.2 of IEC 60947-1:~~2007/AMD1:2010~~2020 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~~2020, 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 performance criteria ~~shall be defined~~ are as follows:

– performance criterion A: during the test, the ~~resistance against~~ immunity to 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).

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 [b]
Electrical fast transients/bursts [k]	IEC 61000-4-4	Power port: U_e ≥ 100 V, AC / DC: 4 kV 5 kHz ~~or~~ and 100 kHz [j] U_e < 100 V, AC / DC [f]: 2 kV 5 kHz ~~or~~ and 100 kHz [j] Signal port [f]: 2 kV 5 kHz ~~or~~ and 100 kHz	B (unless otherwise stated)	Enclosure Figure J.1

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Description	Reference standard	Test level	Performance criterion	Mounting
Surges	IEC 61000-4-5	Power port, U_e ≥ 100 V AC: 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)[d] Power port, U_e < 100 V AC: 2 kV line-to-earth 1 kV line-to-line Power port, DC [e]: 1 kV line-to-earth 0,5 kV line-to-line Signal port [g, i]: 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 AC / DC: 10 V (150 kHz to 80 MHz) Signal port [f]: 10 V (150 kHz to 80 MHz)	A	Free air [b]
Power frequency magnetic fields	Not applicable [h]	Not applicable [h]	Not applicable[h]	Not applicable[h]
Voltage dips and interruptions	IEC 61000-4-11 [c]	[c]	[c]	Free air
Harmonics	IEC 61000-4-13 [a]	[a]	[a]	Free air
Current dips	[a]	[a]	[a]	Free air

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Description	Reference standard	Test level	Performance criterion	Mounting
~~a~~ ~~Vacant.~~				
~~b~~a 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~~b 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~~c 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, as specified in F.4.7.				
~~e~~d The immunity level is higher for residual current devices because they perform safety functions.				
~~f~~e Not applicable to input ports intended for connection to a battery or a rechargeable battery, which shall be removed or disconnected from the ~~apparatus~~ circuit-breaker for recharging. ~~Apparatus~~ Circuit-breakers with a DC power input port intended for use with an AC – DC power adapter shall be tested on the AC power input of the AC – DC 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~~; where no adapter is specified, the test shall be done on the DC power port using the specified test level.				
~~g~~f Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.				
h Power frequency magnetic fields tests are covered by short-circuit tests of Clause 9.				
~~h~~g 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 specified, this test is applied only to the shield.				
~~j~~i Signal lines with direct connection to AC power ports shall be treated as AC 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.~~				
j In Japan, tests are done only at 100 kHz for electrical fast transients/bursts (IEC 61000-4-4), based on IEC TR 63216:2019. For retesting of already evaluated circuit-breakers, the repetition frequency of 5 kHz can be used.				

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's immunity to unwanted operation is tested 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~~ 6 000 MHz, in accordance with Clause 8 of IEC 61000-4-3:~~2006~~2020. 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 and 5 800 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 EM 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 8.3.3 of IEC 60947-1:~~2007/AMD2:2014~~2020 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~~ 6 000 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 11 and 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.8.13.2.2	[a]	[a]
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.13.2.2	[a]	[a]
	Other devices	J.3.2, N.3.2	[a]	[a]
Radiated RF disturbances	CBR	J.3.3, B.8.13.2.3	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.8.13.2.3	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)

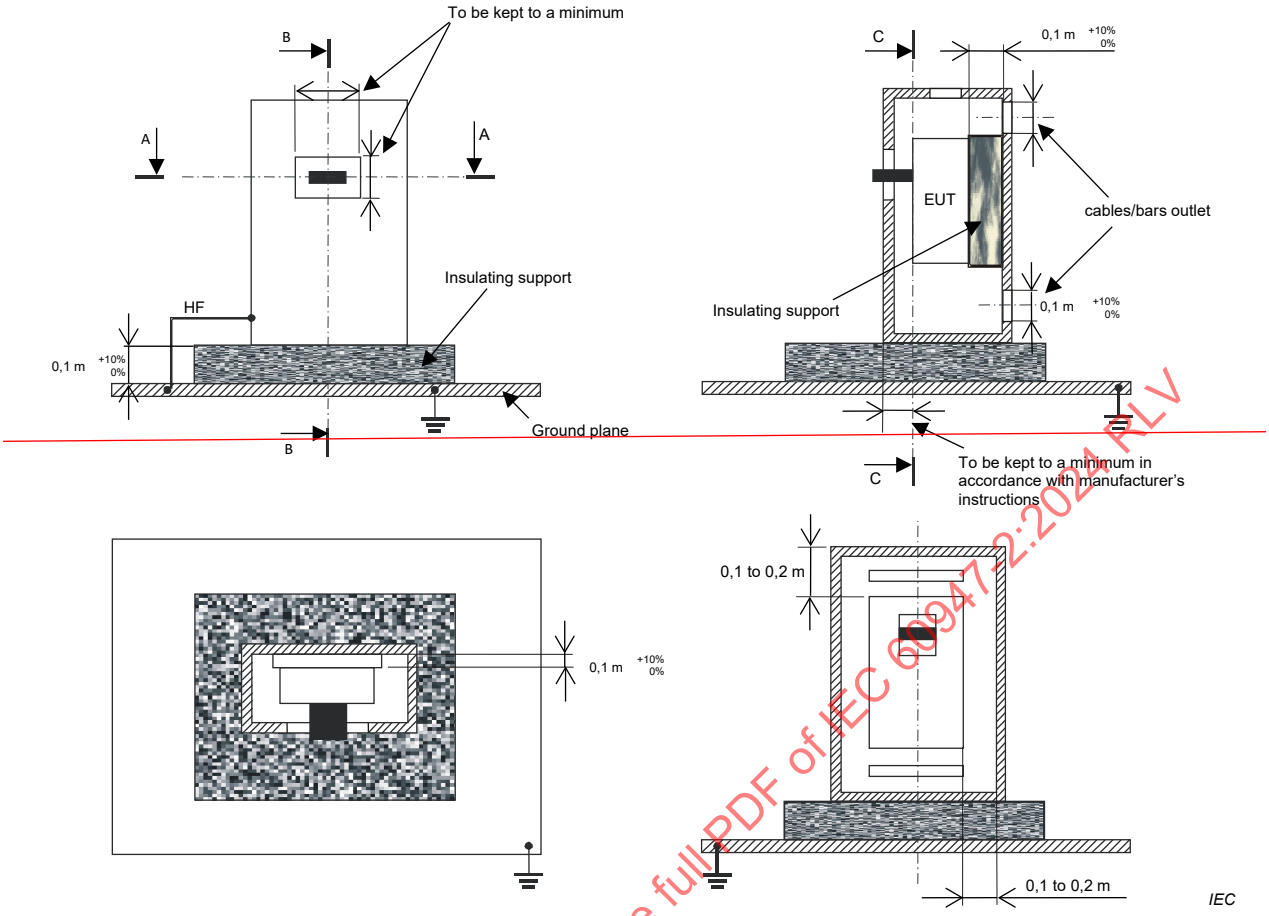
The test method and test arrangement shall be as in CISPR 11 or CISPR 32, as relevant.

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~~ 6 000 MHz)

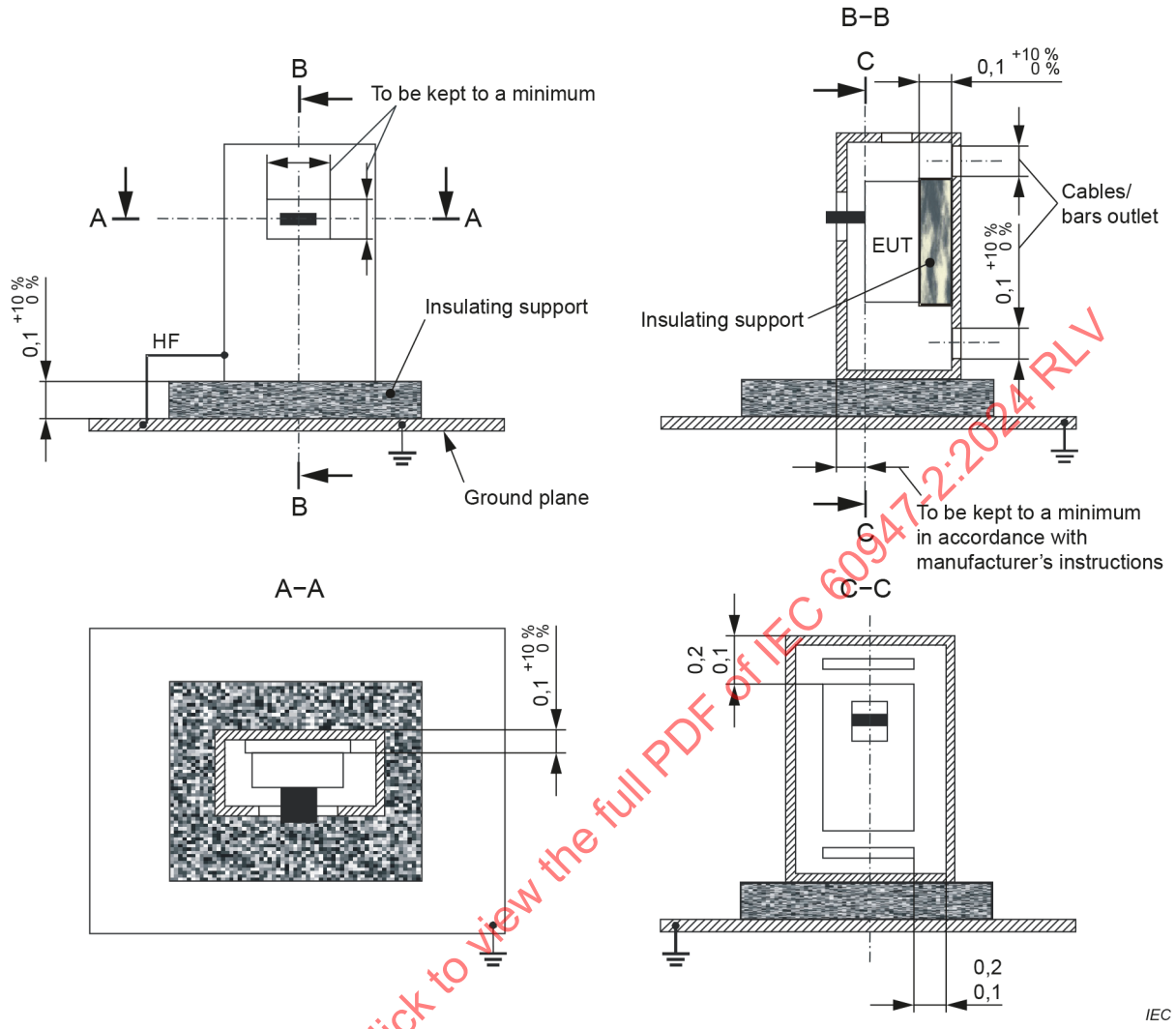
The test set-up is shown in Figure J.2.

The particular test set-up including supply bars, transformer, etc. shall be detailed in the test report.



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Dimensions in metres

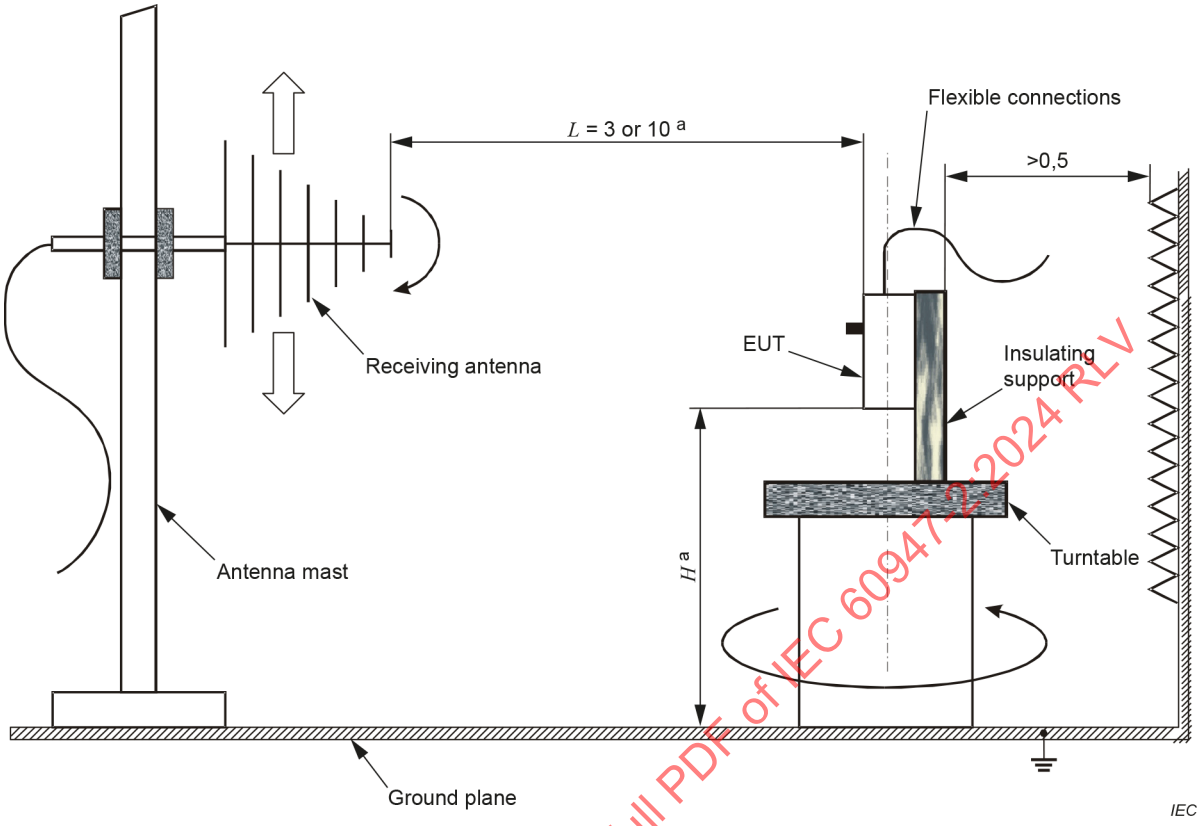


NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure

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Dimensions in metres



[a] See CISPR 11 and CISPR 32.

Figure J.2 – Test set up for the measurement of radiated RF emissions

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Dimensions in metres

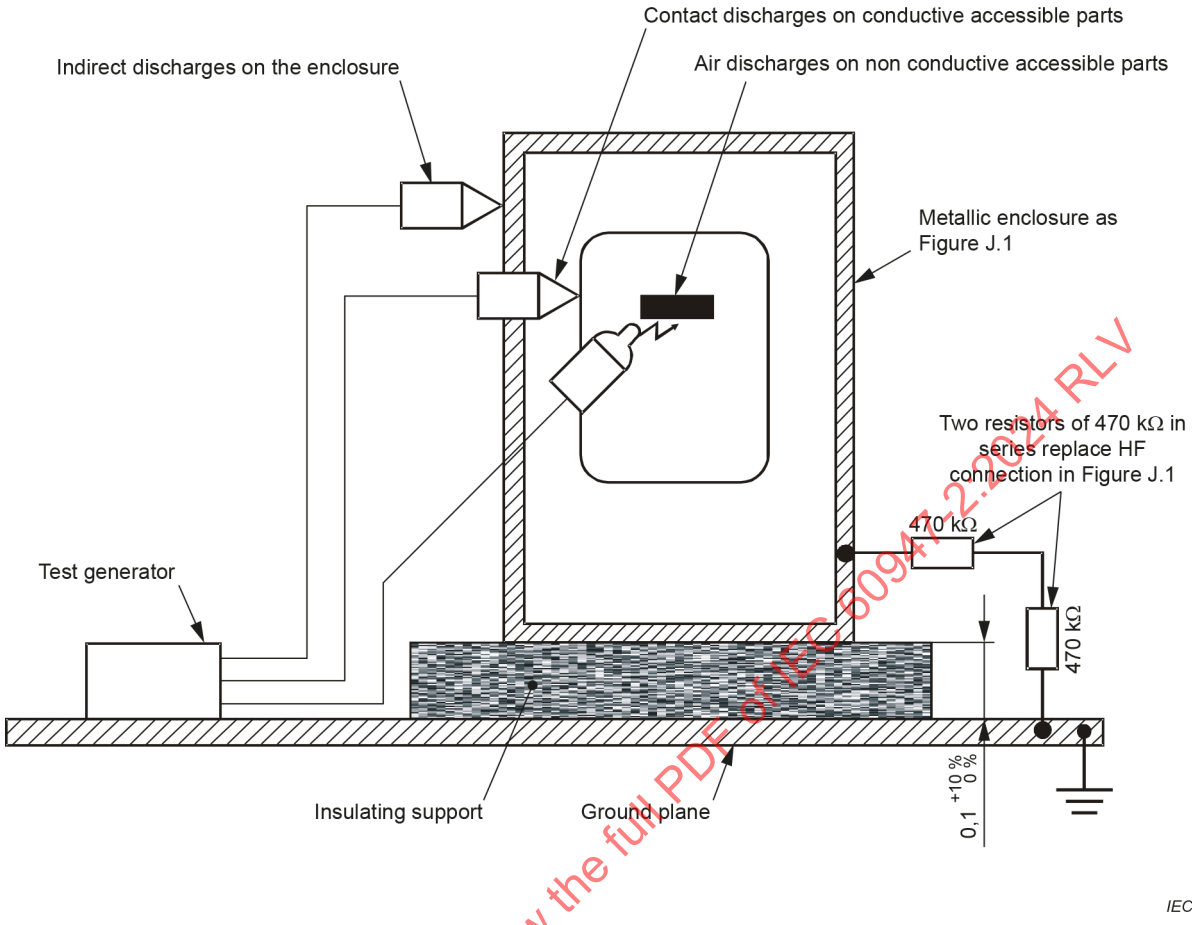
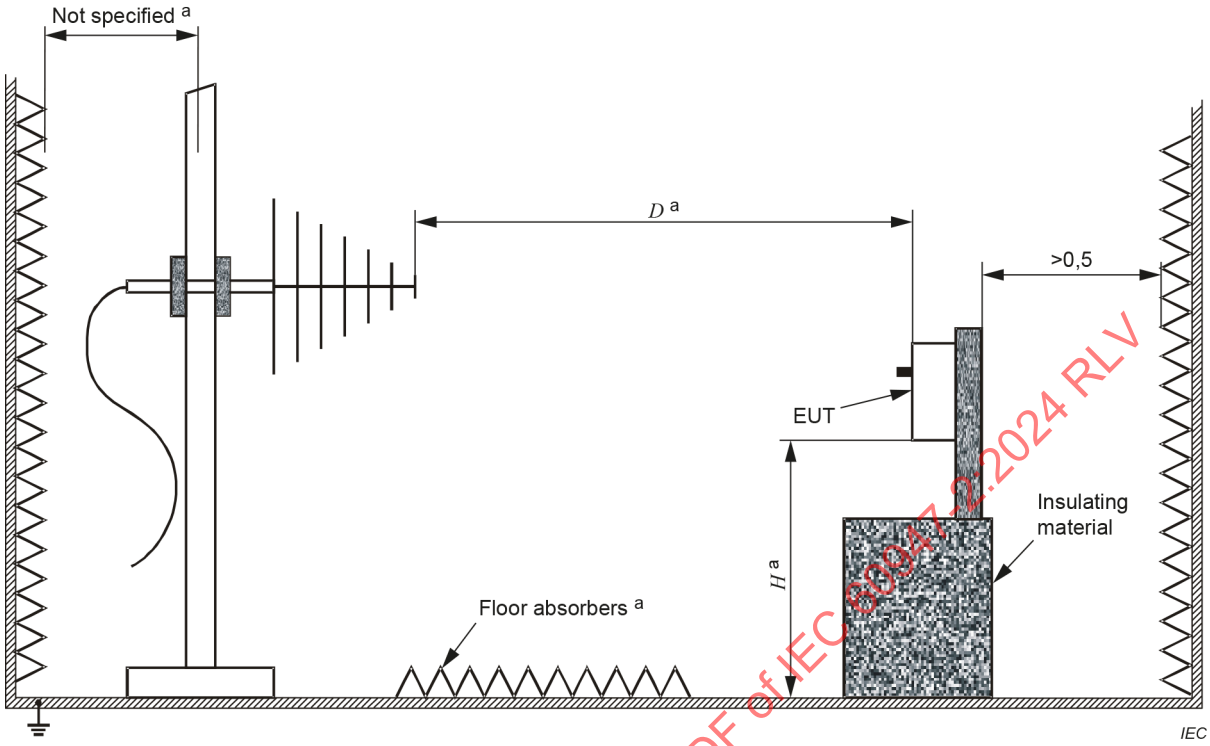


Figure J.3 – Test set up for the verification of immunity to electrostatic discharges

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Dimensions in metres

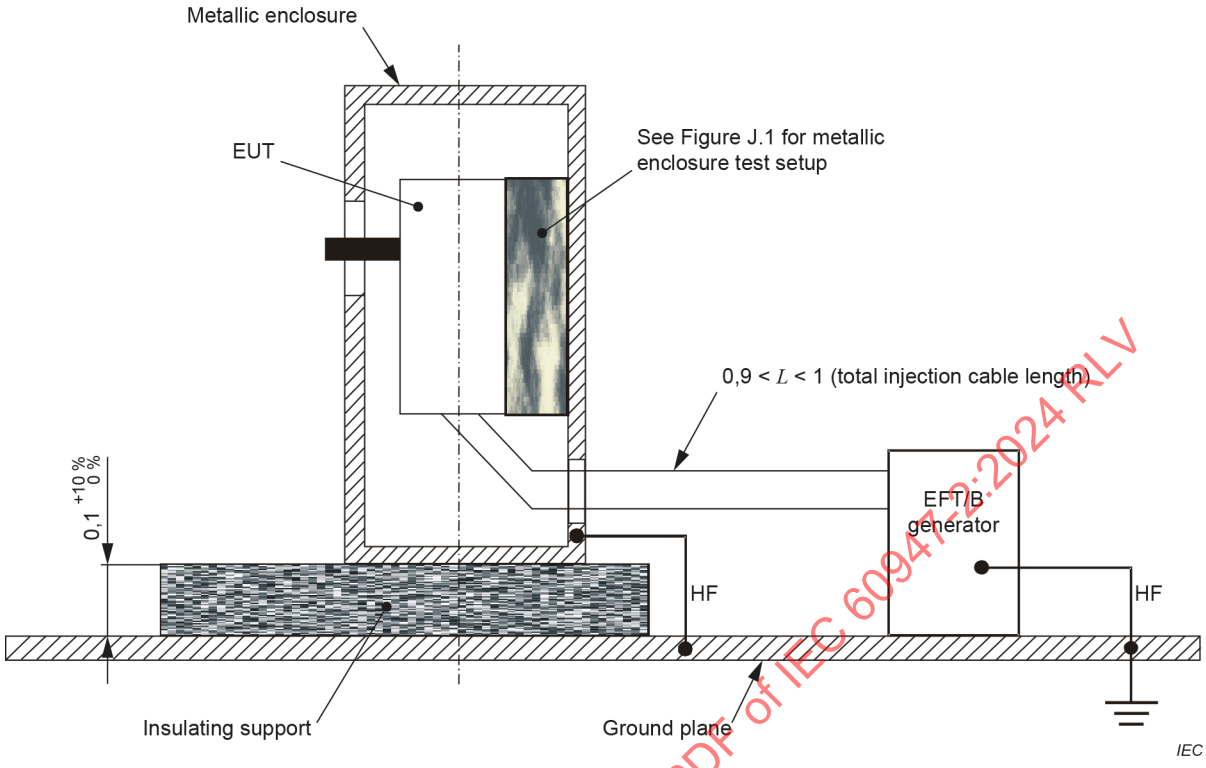


a See IEC 61000-4-3.

Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields

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Dimensions in metres

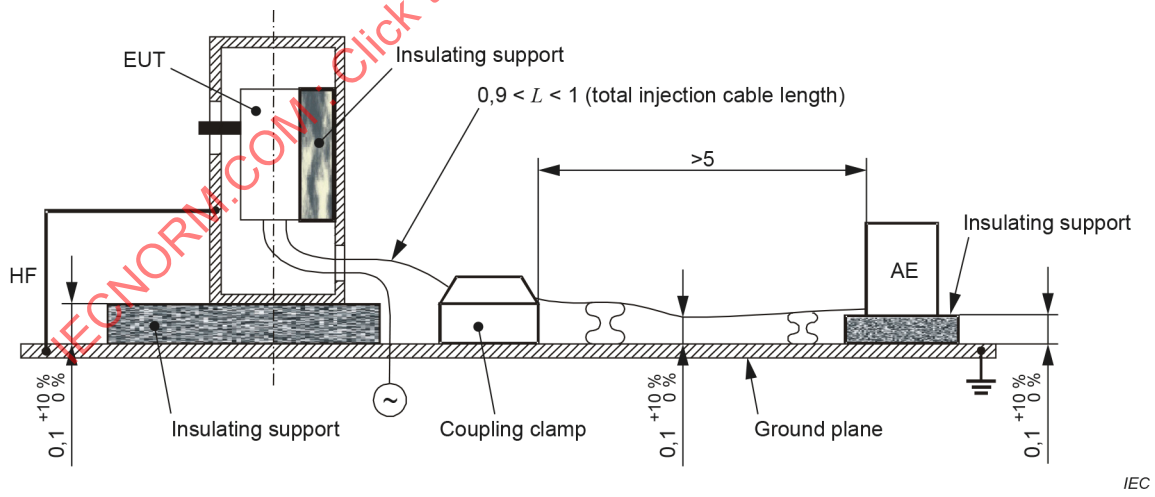


Key

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

Dimensions in metres



Key

AE auxiliary equipment

HF high frequency connection

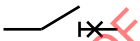
Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

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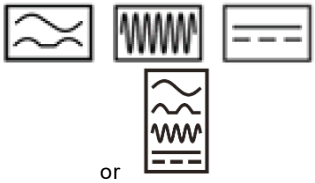
~~Annex J~~Annex K
(informative)

Glossary of symbols and graphical representation of characteristics

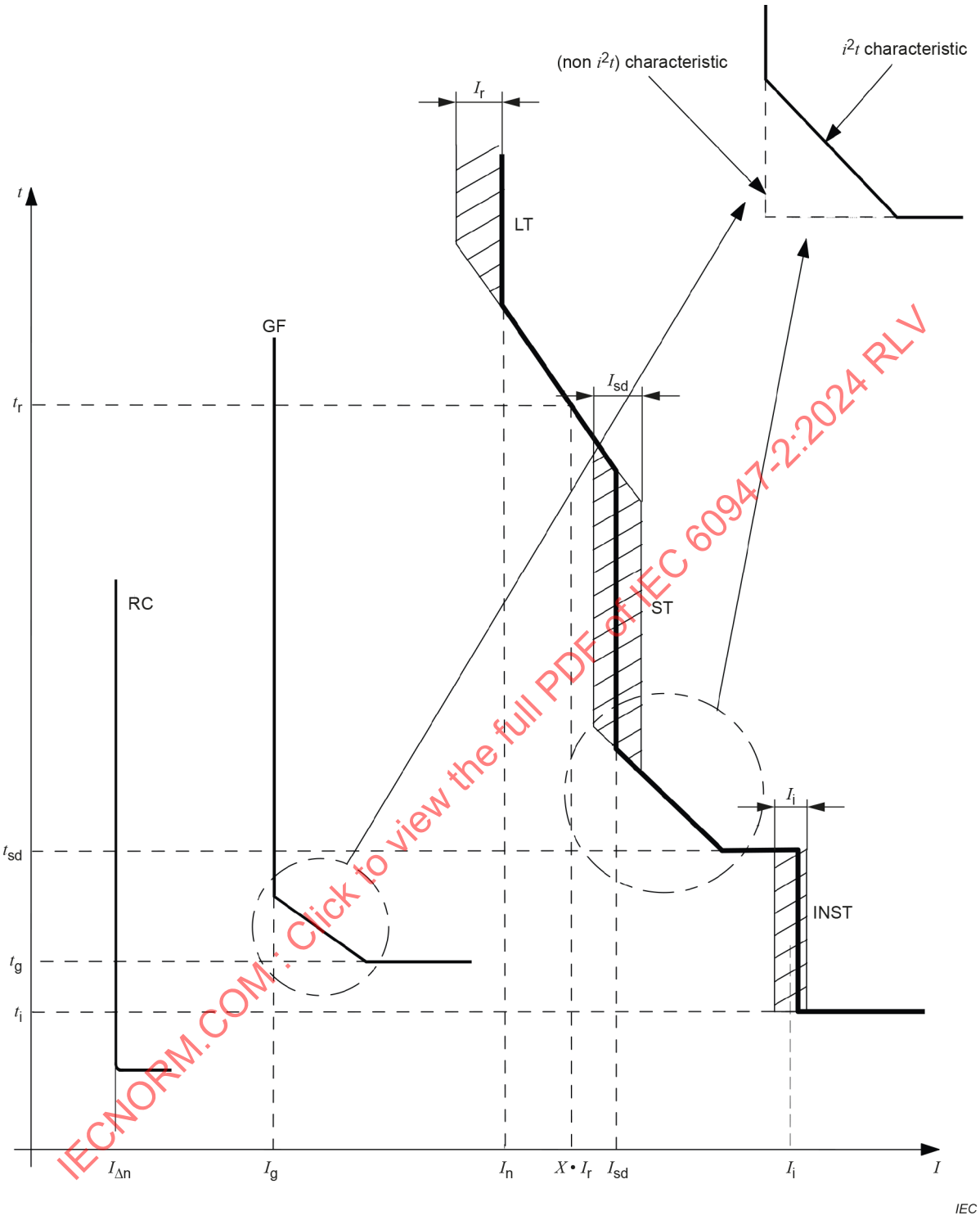
Table K.1 – Glossary of symbols and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Reference in this document
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	6.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	6.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 (2001-07) combined with IEC 60617-S00220 (2001-07)	6.2 O.4
Isolation suitability – CBI class W		IEC 60617-S00287:2001-07 combined with IEC 60617-S00220:2001-07	L.5
Isolation suitability – CBI classes X and Y		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		6.2
Protective earth terminal		IEC 60417-5019 (2006-08)	6.2
Rated control circuit voltage	U_c		5.7.2
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		5.3.3.3
Rated impulse withstand voltage	U_{imp}		5.3.2.3
Rated insulation voltage	U_i		5.3.2.2
Rated operational voltage	U_e		5.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		5.3.6.2.4
Rated short-circuit making capacity	I_{cm}		5.3.6.1
Rated short time withstand current	I_{cw}		5.3.6.4
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}		5.3.6.2.2
Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	I_{cu1}		5.3.6.2.3
Selectivity limit current	I_s		~~2.17.4~~
Take-over current	I_B		~~2.17.5~~

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Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Reference in this document
Conventional enclosed thermal current	I_{the}		5.3.3.2
Conventional free air thermal current	I_{th}		5.3.3.1
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
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		3.16, 5.7.3, Figure K.1
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		3.15, 5.7.3 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}		3.17 Figure K.1
Corresponding ~~tripping~~ intentional time-delay	t_{sd}		Figure K.1
Suitability for phase-earthed systems	C		5.3.2.1
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)	Table B.3, item B2.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2

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Key

RC	residual current
GF	ground-fault
LT	long time
ST	short time
INST	instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

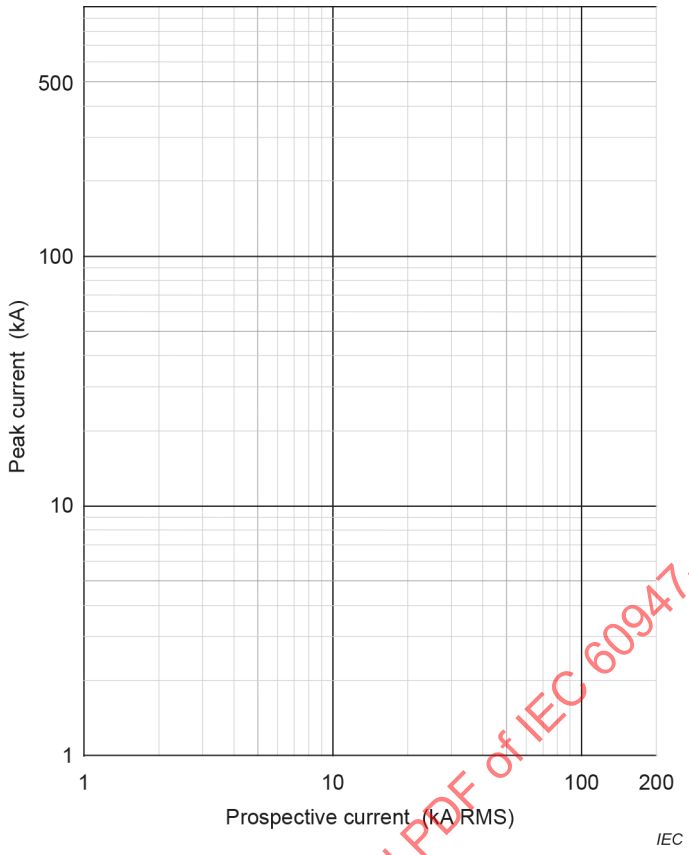


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

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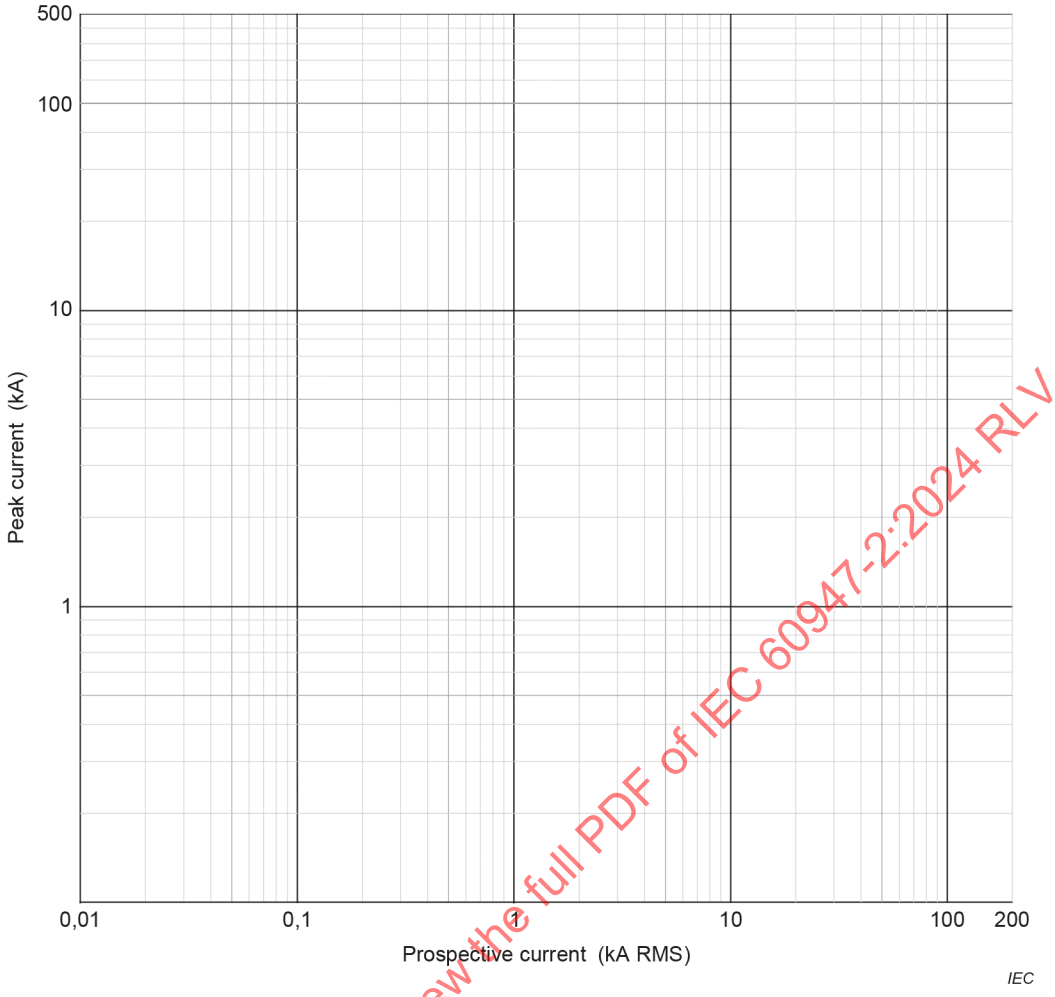


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

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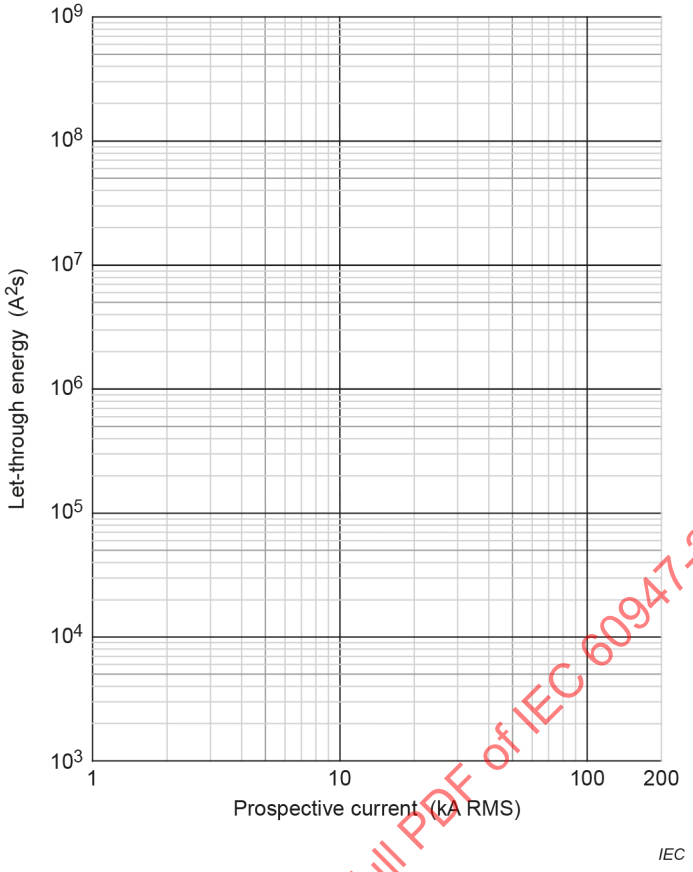


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

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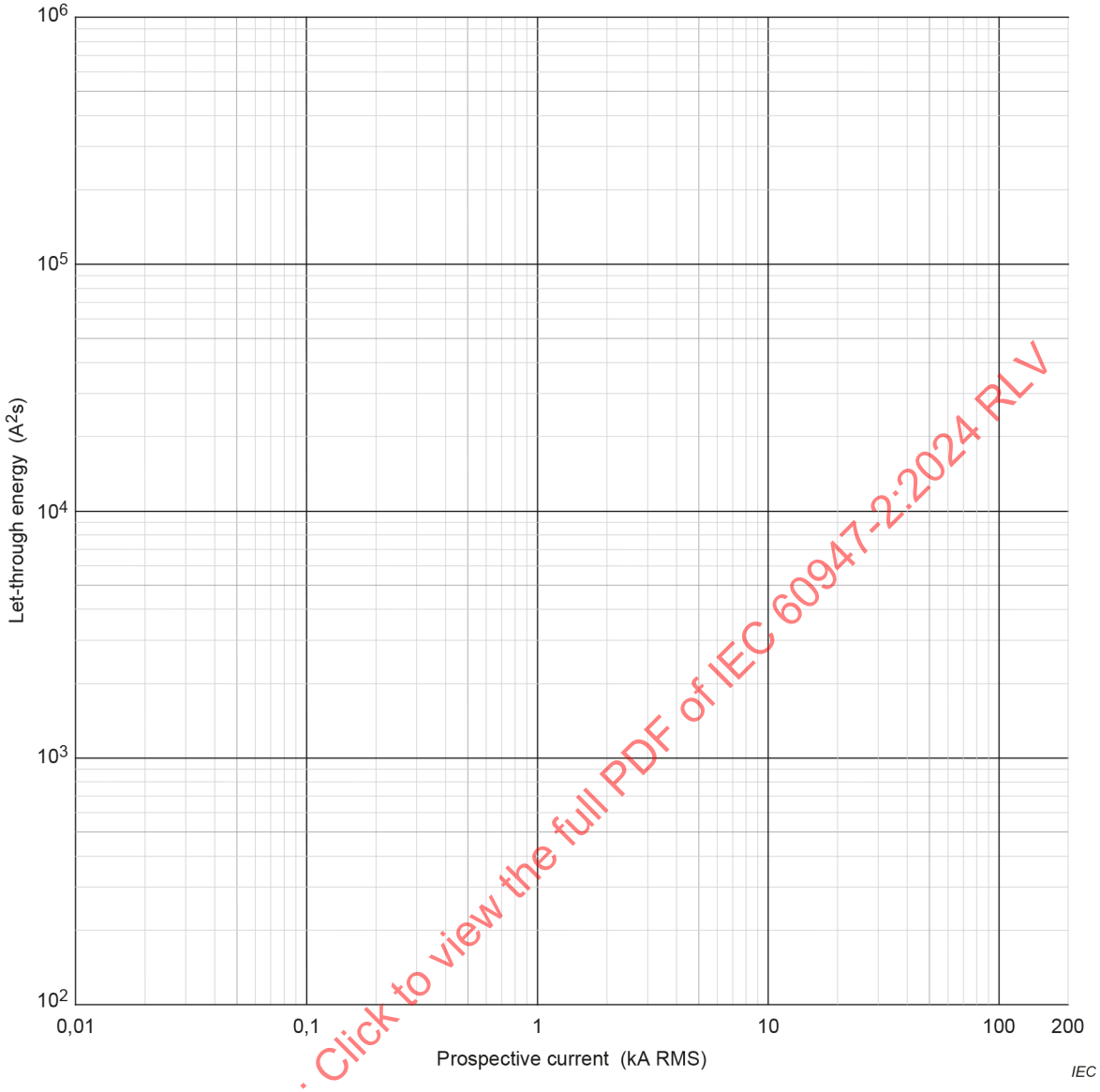
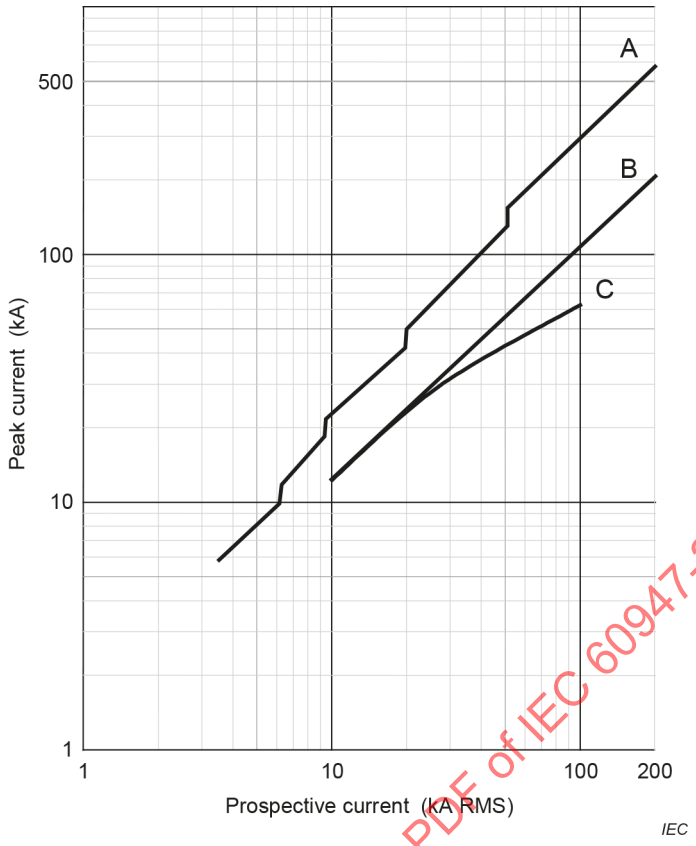


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA

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Key

A Prospective asymmetric peak current under the test conditions of this document

B Prospective symmetrical peak current

C Typical cut-off current characteristic

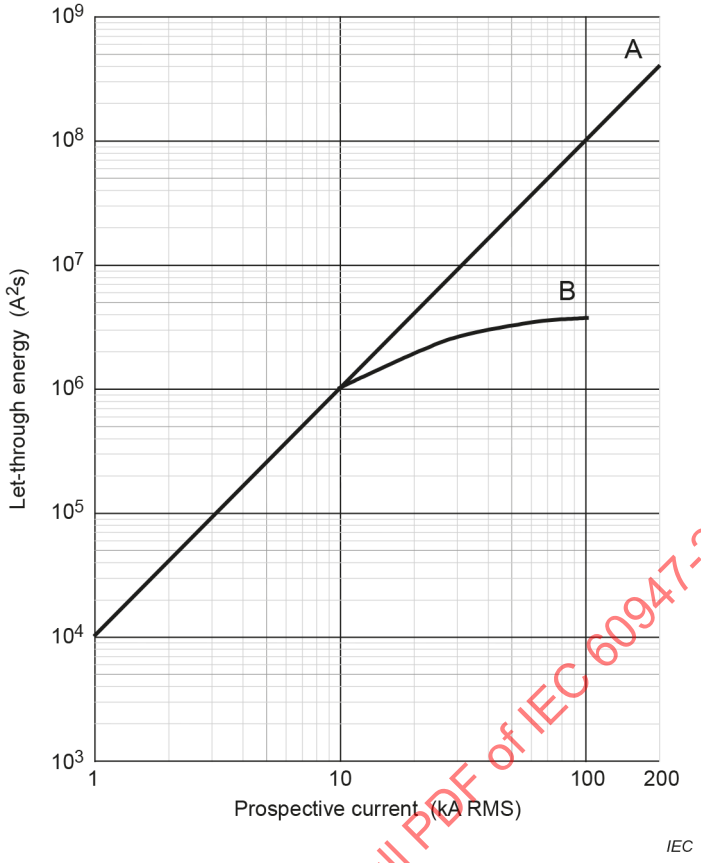
The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

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 3.3 for the definition of current-limiting circuit-breakers).

The typical curve does not imply any requirement of this document 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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Key

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 3.3 for the definition of current-limiting circuit-breakers).

The typical curve for the 250 A MCCB does not imply any requirement of this document 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 K~~Annex L
(normative)

Circuit-breakers not fulfilling the requirements for overcurrent protection (CBIs)

L.1 General

This annex covers circuit-breakers which do not fulfil all requirements for overcurrent protection specified in the main part of this document, hereinafter referred to 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~~ by themselves. They ~~have a conditional short-circuit rating and~~ may be used for isolation. CBIs 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), or intended to be used with external protection relays to provide circuit protection (class W), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 3, 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 document 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.~~

In addition to the classifications given in Clause 4, CBIs are classified as follows:

– Class W: intended to be used with external protection relays to provide circuit protection.

They are derived from an equivalent selectivity category B circuit-breaker (L.2.1). To ensure circuit protection, they shall be used with external protection relays. Such external protection relays generally use separate current sensors and trip the CBI via an auxiliary release.

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NOTE This solution is generally used when the embedded releases do not provide all the protection characteristics for a particular application, or when the user prefers to use a specific model of protection relay for standardisation purpose.

– Class X: with integral non-adjustable instantaneous short-circuit releases for self-protection. They are derived from an equivalent circuit-breaker (L.2.1) by omitting the overload release only. They have a rated conditional short-circuit current.
– Class Y: without integral overcurrent releases. They are derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases. They have a conditional short-circuit current rating.

L.4 ~~Rated values~~ Characteristics

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~~2020).

L.4.2 Rated conditional short-circuit current (I_{cc})

Subclause 5.3.6.4 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies to CBIs class X and Y.

~~A CBI may have a value of I_{cc} equal to or higher than that of the I_{cu} of the equivalent circuit-breaker.~~

Both CBIs class X and Y do not have I_{cu} or I_{cs} ratings, but shall have at least one I_{cc} rating.

L.4.3 Other characteristics

Clause 5 applies, except:

– 5.7.1 item 2), 5.7.2 item 2), 5.7.3 and 5.7.4 for all CBIs.
– 5.3.6.2 and 5.3.6.3 for CBIs class X and Y.

The rated values of a CBI shall not exceed those of the equivalent circuit-breaker.

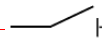
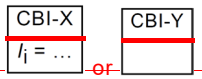
For a CBI class W, the marked I_{cu} value (see 5.3.6.2.2) shall be equal to I_{cw} (see 5.3.6.4).

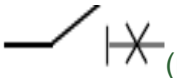
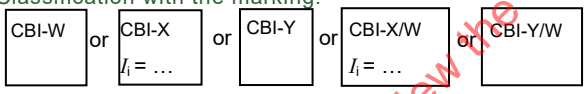
L.5 Product information

Subclause 6.2 applies, as relevant, with modifications and additions as per Table L.1.

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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  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~~		

Item	Information	Marking location
L1.1	Suitability for isolation: For CBIs class X and Y with the symbol  (IEC 60617-S00288:2001-07) For CBIs class W with the symbol  (IEC 60617-S00287:2001-07 combined with IEC 60617-S00220:2001-07)	Visible [a]
L1.2	Classification with the marking:  as applicable, where I_i is the instantaneous short-circuit current setting (see 3.15)	Visible [b]
L3.1	For CBIs class X or Y only, rated conditional short-circuit current (I_{cc}) and, if specified, overcurrent protective device (OCPD)	Literature
L3.2	Statement that CBIs class X or Y do not provide overcurrent protection (coordination with the upstream SCPD shall be ensured)	Literature
L3.3	Statement that CBIs class W need an external relay to provide overcurrent protection, within the tripping limits and ratings of the equivalent circuit-breakers (in particular, the CBIs class W shall be used within their I_{cw} rating and their maximum short time delay)	Literature
L3.4	For CBIs class W, requirements to operate the auxiliary releases	Literature
L3.5	Presence of a making-current release for CBIs class W, when applicable	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		
[a] As applicable, these symbols replace the symbol used in Table 4, item 1.2 [b] CBIs may be classified as : class W and class X : class W and class Y		

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L.6 Constructional and performance requirements

CBIs, being derived from the equivalent circuit-breaker (see L.2.1), comply with all the applicable construction and performance requirements of Clause 8, except 8.2.1.2.4.

NOTE CBIs can additionally comply with IEC 60947-3 and be marked accordingly.

L.7 Tests

L.7.1 General

L.7.1.1 CBI class W

As the CBI class W is derived from an equivalent circuit-breaker having higher or equal short-circuit characteristics (see 5.3.6) and which has been subjected to the type tests of 9.3, the compliance of the CBI-W with the test requirements of 9.3 is met by carrying out the test of 9.3.6.3, on one sample of maximum current rating, tested at max kVA rating (I_{cu} × corresponding U_e), under the following conditions.

If a CBI class W does not utilize a making-current release, the sequence of operations in 9.3.6.3 is replaced with CO-*t*-CO, otherwise the sequence of operations shall be O-*t*-CO.

The CBI class W shall be opened by the activation of an auxiliary release, supplied with a voltage equal to the operational limit as given in 9.3.4.4.2.3 item ii) and 9.3.4.4.2.4, as appropriate.

For the first operation, the voltage, or the interruption of voltage in case of an undervoltage release, shall be applied to the auxiliary release after a time equal to the maximum time setting of the short-time delay short-circuit release of the equivalent circuit-breaker, according to the manufacturer's instructions.

For the second operation, the voltage, or the interruption of voltage in case of an undervoltage release, shall be applied to the auxiliary release between 0 and 10 ms after the initiation of the short-circuit.

NOTE The purpose of these tests is to verify the ability of the auxiliary release to trip the circuit-breaker under short-circuit conditions.

Following these tests, the dielectric withstand and the leakage current of the sample shall be verified in accordance with 9.3.6.4, and the auxiliary release shall be verified in accordance with 9.3.4.9.

For a CBI class W with both 3-pole and 4-pole variants, the tests shall be performed on the 4-pole variant, covering the 3-pole variant.

When the equivalent circuit-breaker, which the CBI class W is derived from, has been subjected to the type tests of Annex C, Annex H or Annex P, compliance of the CBI class W with the corresponding annexes is covered.

L.7.1.2 CBI 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} ≥ 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.

In both cases, the relationship between short-circuit making capacity and I_{cc} is given in Table 1.

L.7.1.3 CBI class Y

No tests are required, provided that one of the following two conditions are fulfilled:

– condition 1: I_{cc} ≤ 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.

In both cases, the relationship between short-circuit making capacity and I_{cc} is given in Table 1.

L.7.2 Rated conditional short-circuit current tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.2 (CBI-X) case 2, or by L.7.1.3 (CBI-Y) case 1 or case 2, as applicable.

For CBIs having variants with different number of poles, tests shall be carried out on each variant.

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L.7.2.1.2 Test conditions

Subclause 9.3.3.6 applies.

The test circuit shall be in accordance with Figure ~~A.4~~ X.4 of IEC 60947-1:2020, SCPD being replaced with 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 9.3.3.6.4 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~~ X.4 of IEC 60947-1:2020).

L.7.2.1.3 Behaviour during tests

Subclause 9.3.3.6.5 applies.

L.7.2.2 OCPD specified

L.7.2.2.1 Test sequence

The test sequence comprises the tests in Table L.2.

Table L.2 – Rated conditional short-circuit tests when the OCPD is specified

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 9.3.6.3, 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 and leakage current

Following the test of L.7.2.2.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

L.7.2.3 OCPD not specified

L.7.2.3.1 Test sequence

The test sequence comprises the tests in Table L.3.

Table L.3 – Rated conditional short-circuit tests when the OCPD is not specified

Test	Subclause
Verification of I_{cc}	L.7.2.3.2
Verification of dielectric withstand	L.7.2.3.3

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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 9.3.6.3, 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 and leakage current

Following the test of L.7.2.3.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA..

L.7.3 Routine tests

Subclause 9.4 applies, except the verification of the calibration of overcurrent releases (9.4.3).

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~~Annex L~~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 is 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 is 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.

MRCDs may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements that the MRCD shall ~~be complied~~ comply 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~~ SCPD, can satisfactorily withstand for the total operating time of the SCPD, 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 M.2.1.1)

M.3.2.2 MRCD with voltage source

M.3.2.2.1 Operating automatically in the case of failure of the voltage source

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M.3.2.2.2 Not operating automatically ~~after~~ in the case of failure of the voltage source but able to operate as intended in M.8.13 in the 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 DC 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 5.3.3.3 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.

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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 5.3.1.2 of IEC 60947-1:~~2007~~2020 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:~~2007~~2020 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 5.6 of IEC 60947-1:~~2007~~2020 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 $I_{\Delta n}$ ≤ 30 mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n}$ ≤ 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 $I_{\Delta n}$ ≤ 30 mA shall be of the non-time-delay type.

M.4.2.2 Operating characteristic in the case of residual current with DC 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

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M.4.3 Behaviour under short-circuit conditions

M.4.3.1 Rated conditional short-circuit current (I_{cc})

Subclause 5.3.6.4 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 5.3.6.4 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 5.3.6.1 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

M.4.3.4 Peak withstand current

Subclause 3.7.28 of IEC 60947-1:~~2007~~2020 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.4.2.2 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.4.2.3 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

Subclause 5.5.1 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 DC 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~~ which an MRCD with separate sensing means will not trip at an overcurrent of 6 I_n, with a single-phase load (see M.8.6)	-	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~~2020)	Literature	Literature	Literature
M3.9	position of use and mounting precautions	Literature	Literature	Literature

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Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M3.10	wiring diagram	Literature	Literature	Literature
M3.11	connection of the sensing means to the processing device (cable type, length, etc.)	-	Literature	-
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 7 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.

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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 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 8.2.3 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020.

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~~2020 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.

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M.7.2.9 Behaviour of MRCDs of types A and B in the case of an earth fault current comprising a DC component

MRCDs of type A and type B shall meet the requirements of 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 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~~ in the case of 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 8.2.2 of IEC 60947-1:~~2007/AMD2:2014~~2020.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:~~2007~~2020 and in Table 3 of IEC 60947-1:~~2007/AMD2:2014~~2020 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~~2020 and in Table 3 of IEC 60947-1:~~2007/AMD2:2014~~2020.

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.

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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.

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.

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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 DC 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.

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 9.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 9.2 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 applies, except in so far as 8.1 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.

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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:

– 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.

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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.

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 9.3.3.4 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020 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 9.3.3.4.1 item 2), of IEC 60947-1:~~2007/AMD1:2010~~2020.

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~~,~~ is installed according to the manufacturer's instructions.

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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.

If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:~~2007~~2020 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 DC 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.

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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.

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 DC 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

Subclause 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.

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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.

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.

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

Subclause 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.

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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.

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.

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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.

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 condition. ~~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 dependent on the line voltage. For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the MRCD shall be loaded again with its rated current until the steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

In the case of MRCDs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

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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.

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~~2020, 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 9.3.3.3.1 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 9.3.3.3.4 of IEC 60947-1:~~2007~~2020, 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~~2020 and Table 3 of IEC 60947-1:~~2007/AMD2:2014~~2020.

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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~~ applicable.

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.

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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~~ voltage source 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.

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 9.3.4.1.2 of IEC 60947-1:~~2007/AMD1:2010~~2020 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 18 of IEC 60947-1:~~2007~~2020 applies.

M.8.14.2.3 Power factor of test circuit

Table 16 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 9.3.2.2.3, item a), of IEC 60947-1:~~2007/AMD2:2014~~2020 applies.

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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 9.3.4.6.

The MRCD shall perform satisfactorily the tests specified in B.8.11.4 b) 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.

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M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 9.3.4.3 of IEC 60947-1:~~2007~~2020 applies to the primary circuit.

The test may be carried out at any ~~convenient~~ suitable 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:

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).

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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.8.13.1 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.

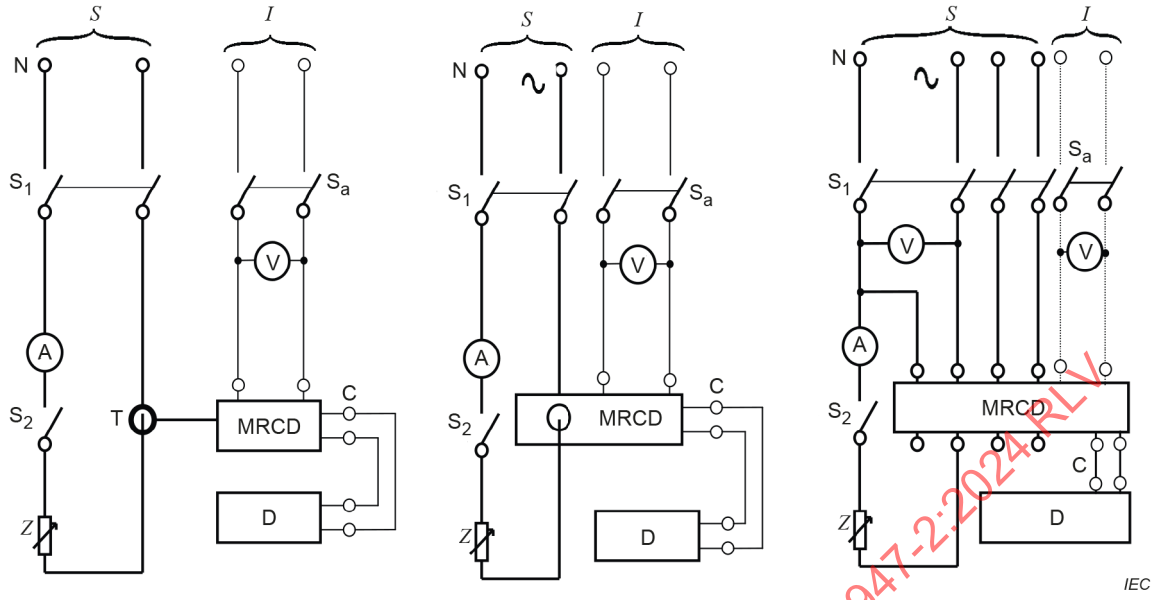
The test set-up shall be in accordance with Figure M.24 for MRCDs with separate sensing means.

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.

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

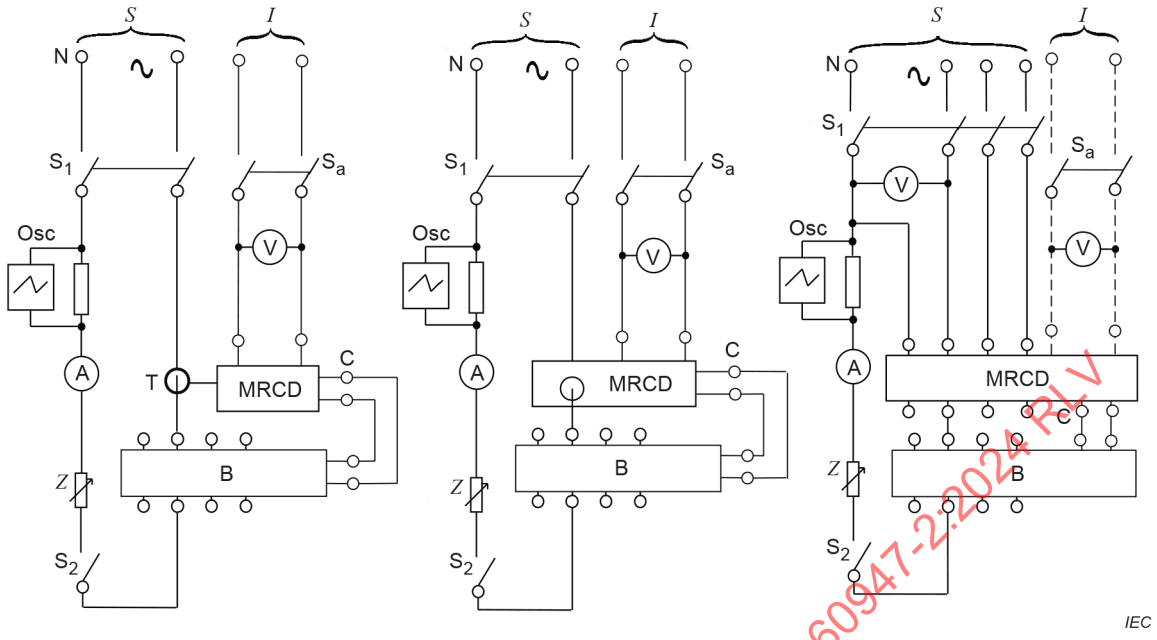
c) **Terminal-type MRCD**

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		

Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current

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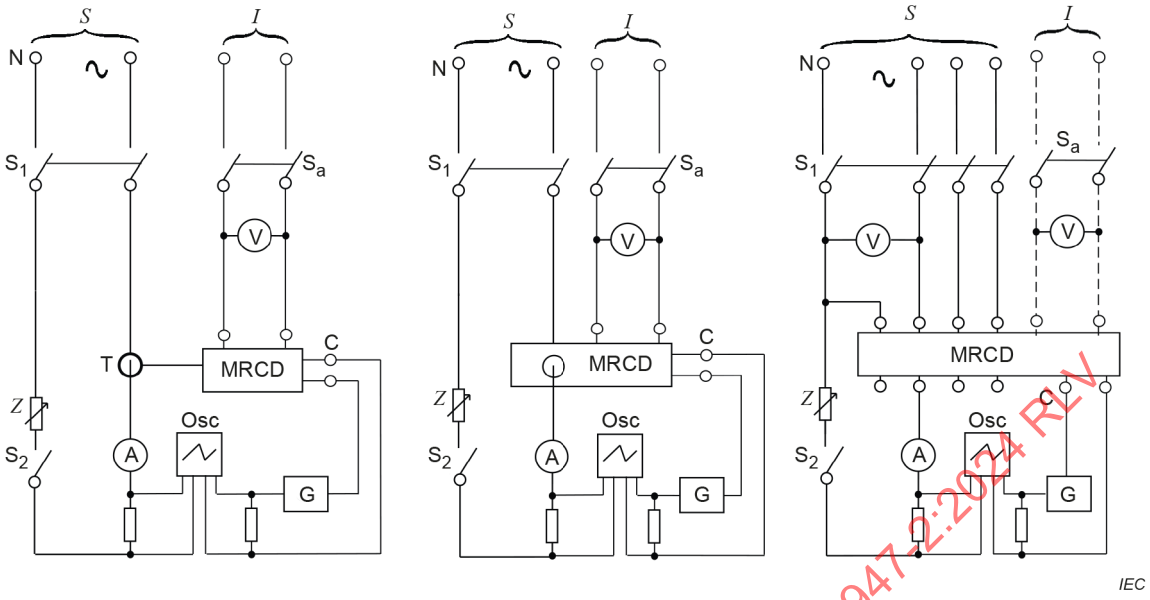
a) MRCD with separate sensing means **b) MRCD with integral sensing means** **c) Terminal-type MRCD**

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**

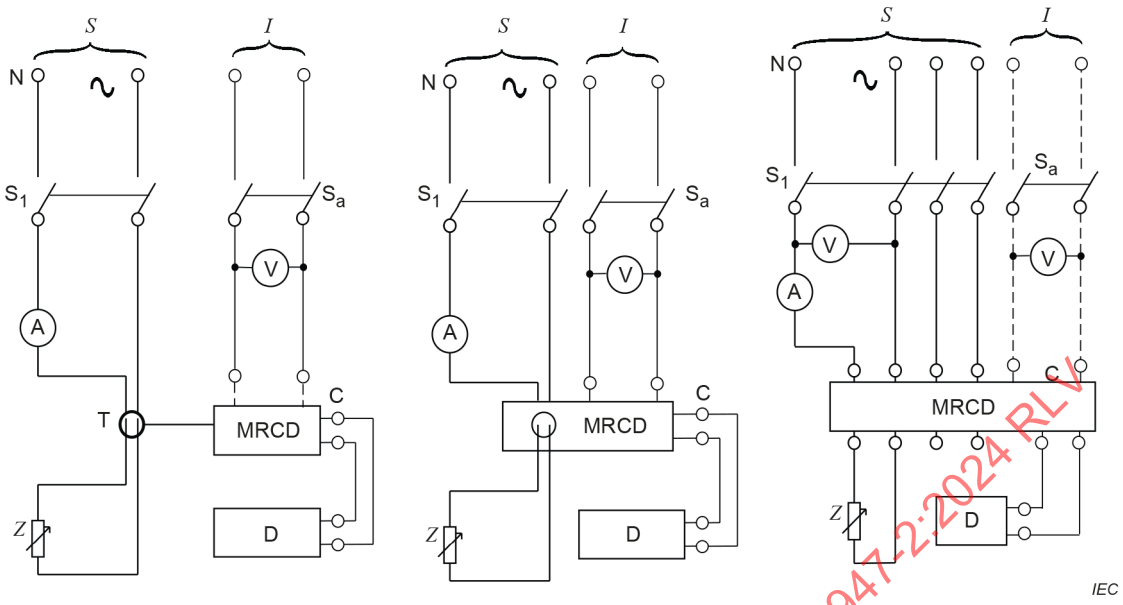
c) **Terminal-type MRCD**

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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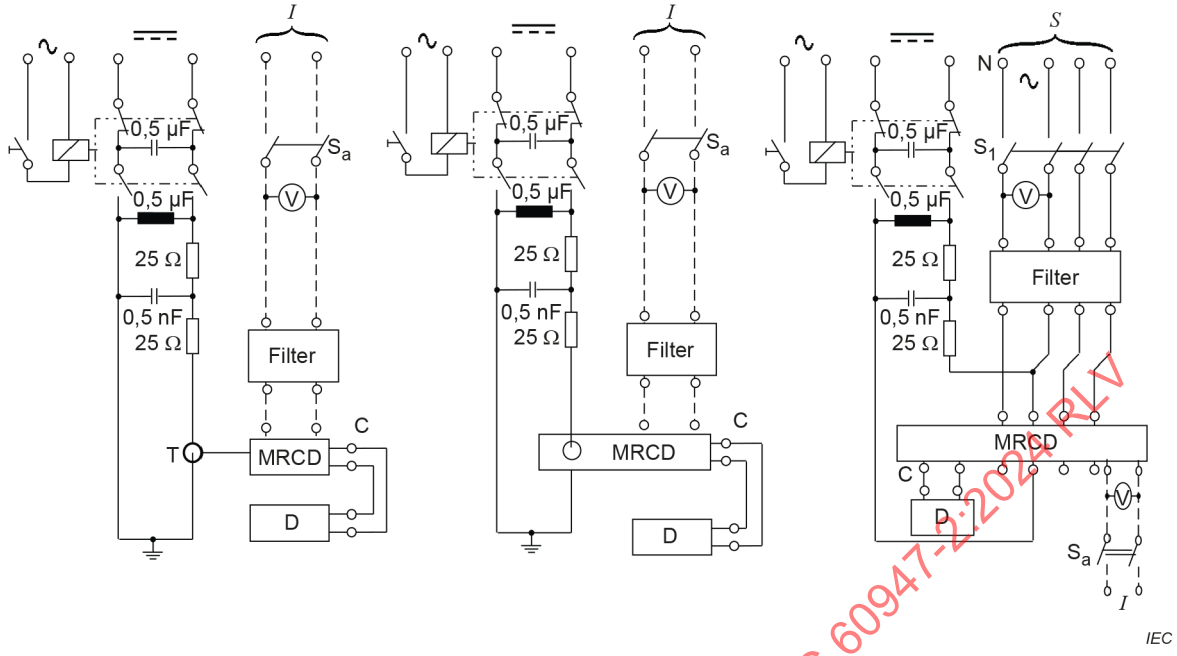
a) MRCD with separate sensing means **b) MRCD with integral sensing means** **c) Terminal-type MRCD**

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

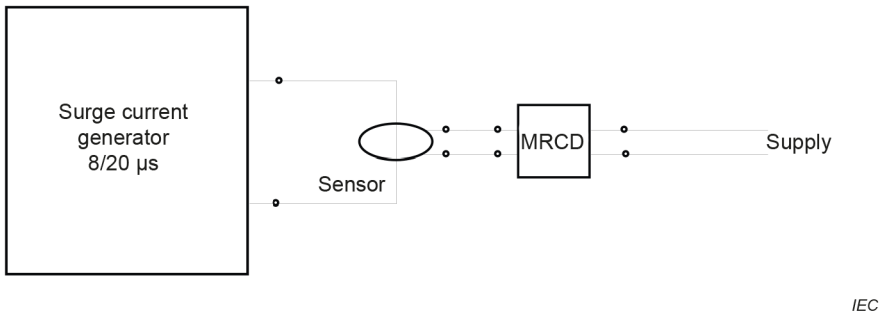
c) Terminal-type MRCD

Key

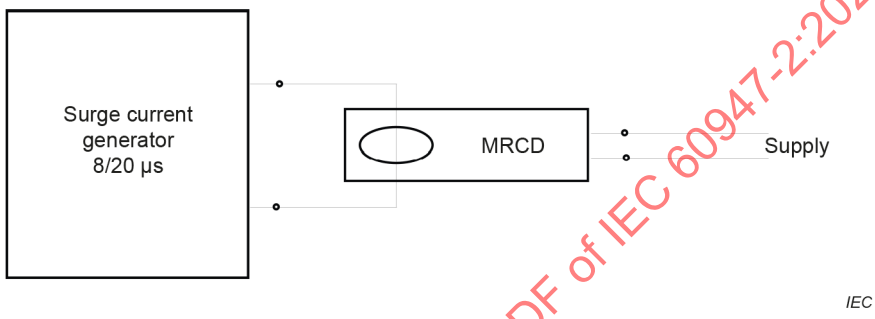
S	power supply	T	sensing means
V	voltmeter	C	output circuit
I	separate voltage source, if applicable	D	instrument indicating the change of status
S_1	multi-pole switch	S_a	auxiliary switch

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

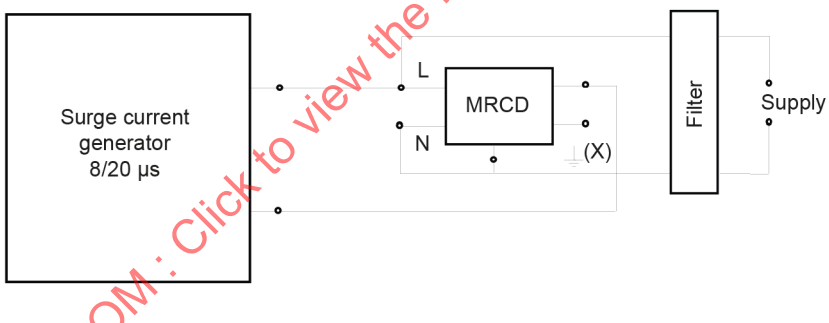
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(a) MRCD with separate sensing means



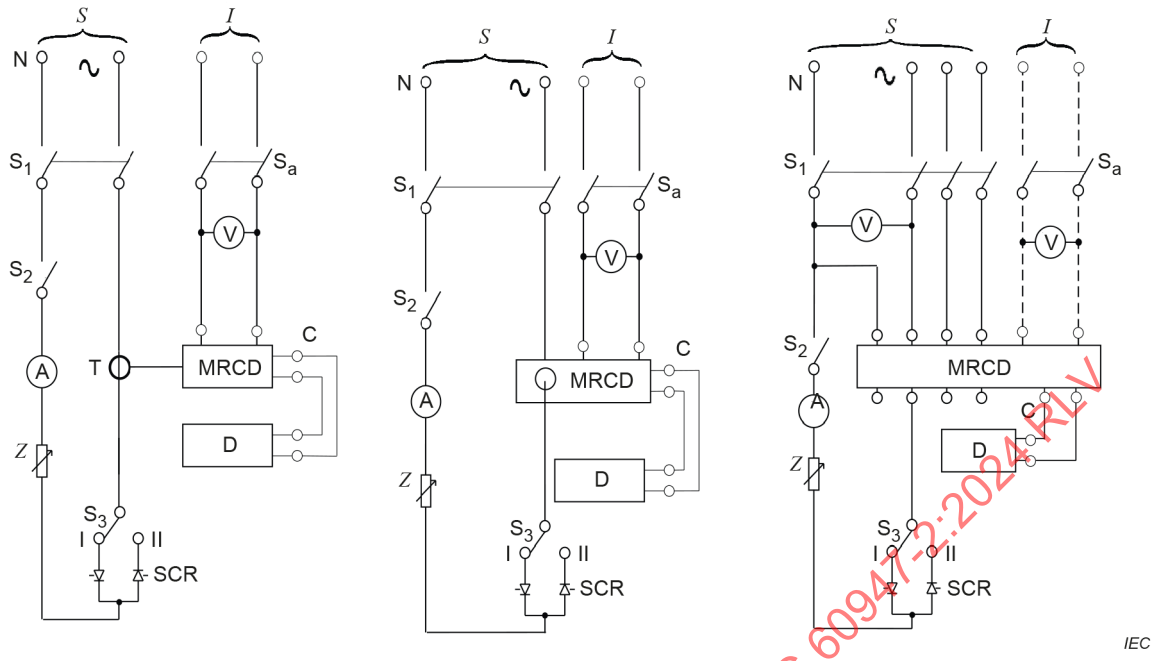
(b) MRCD with integral sensing means



(c) Terminals type MRCD

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

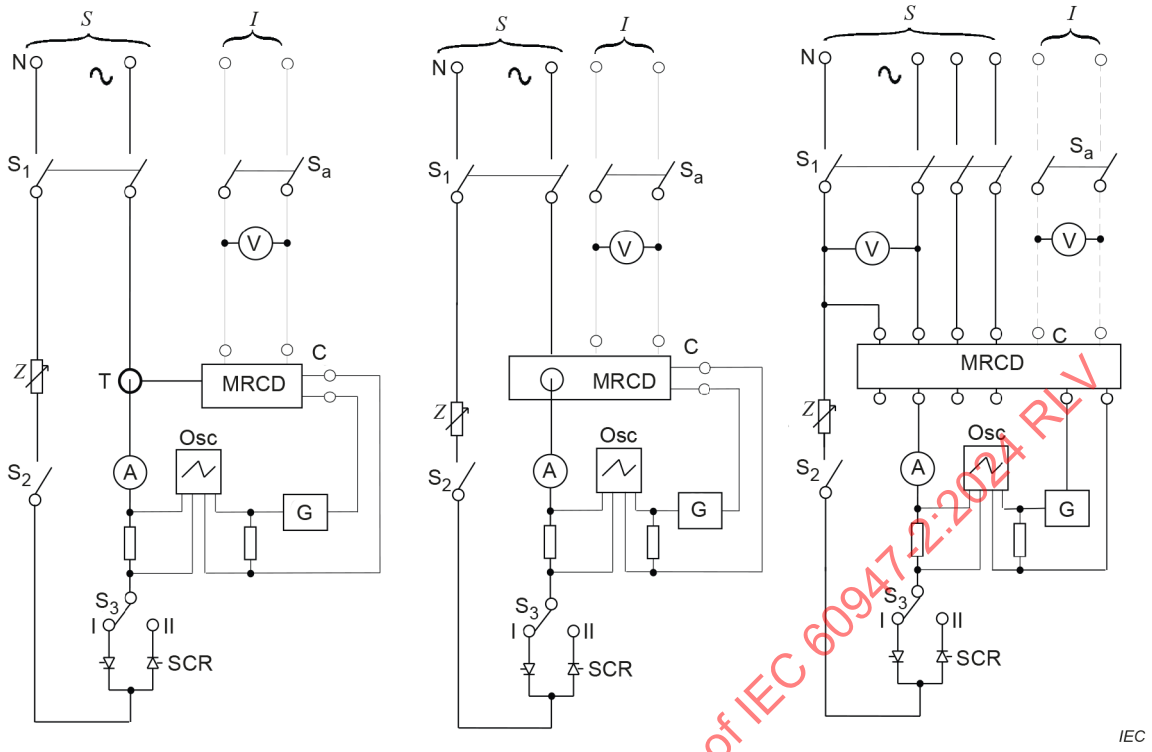
c) Terminal-type MRCD

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**

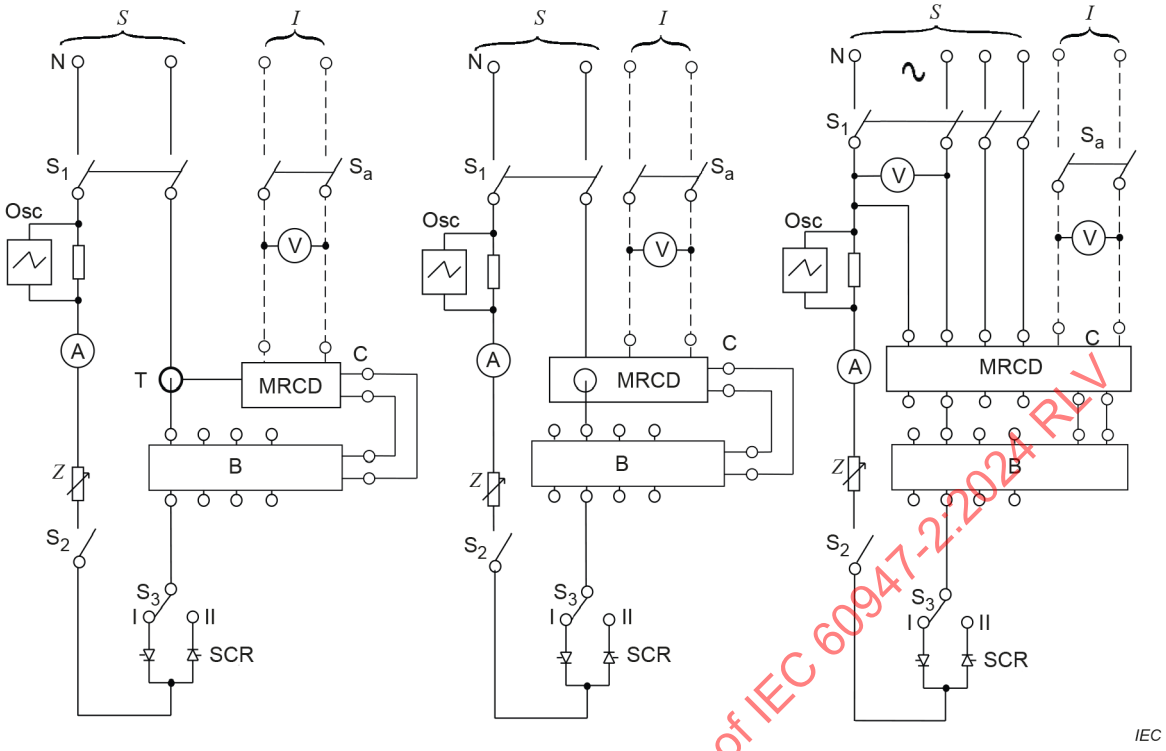
c) **Terminal-type MRCD**

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**

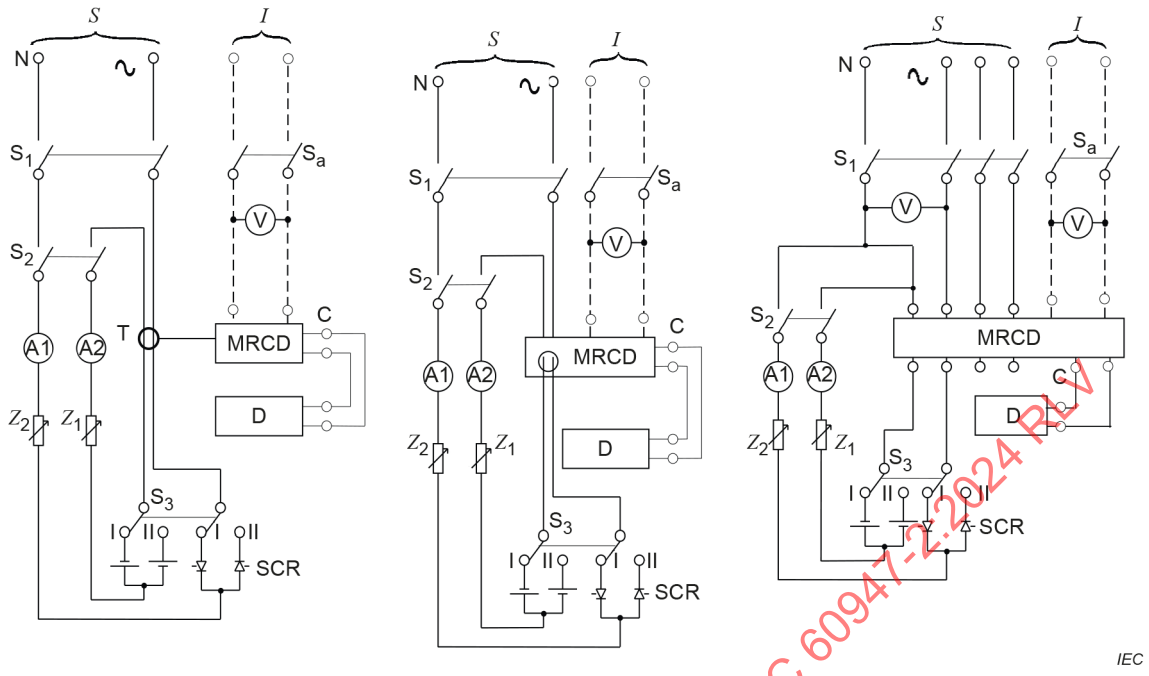
c) **Terminal-type MRCD**

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

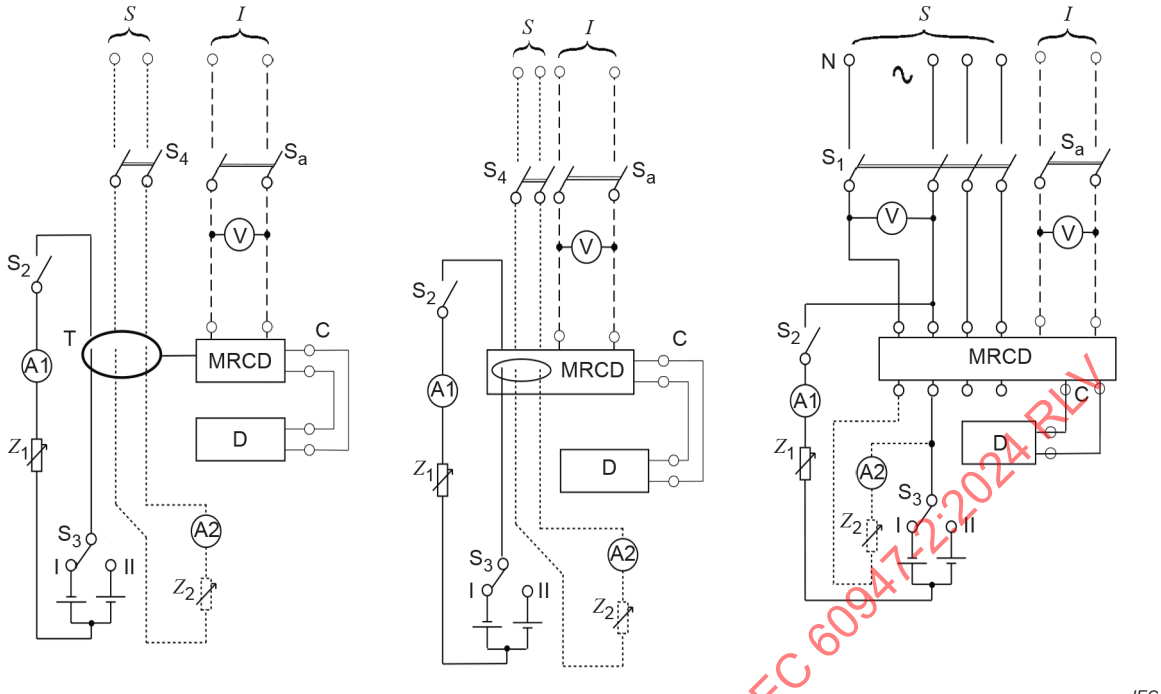
c) Terminal-type MRCD

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 DC current	T	sensing means
A2	ammeter measuring AC 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**

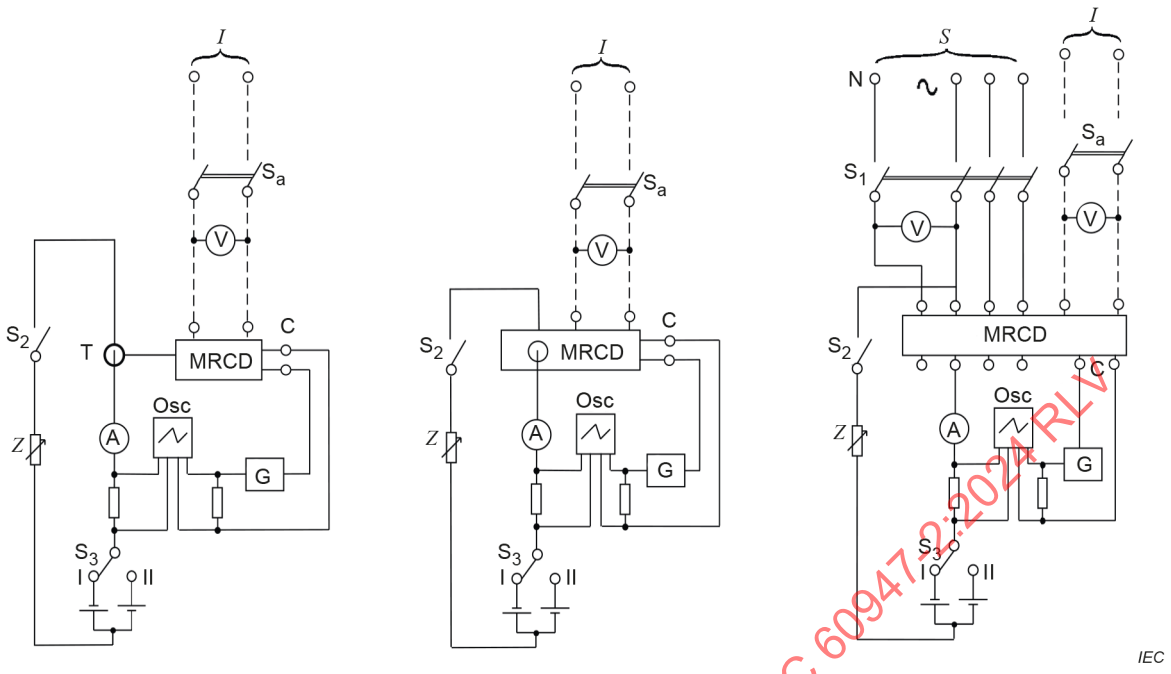
c) **Terminal-type MRCD**

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 DC current	Z_1, Z_2	adjustable impedances
A2	ammeter measuring AC 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**

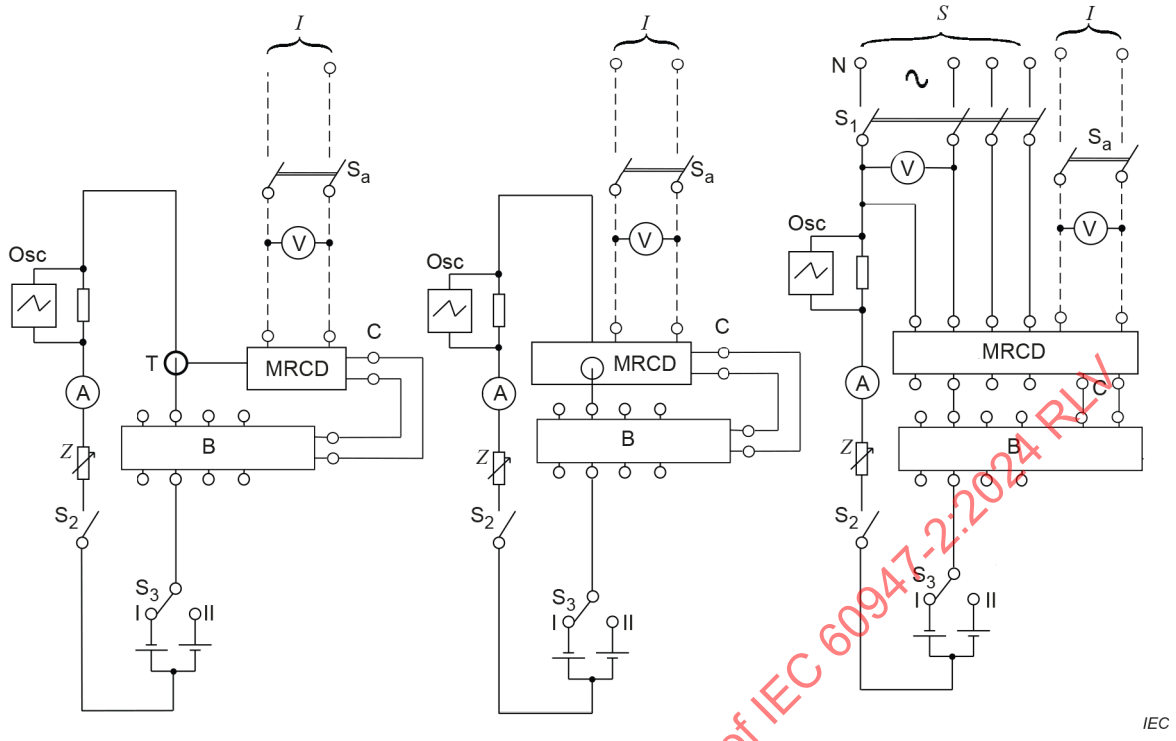
c) **Terminal-type MRCD**

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 DC 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**

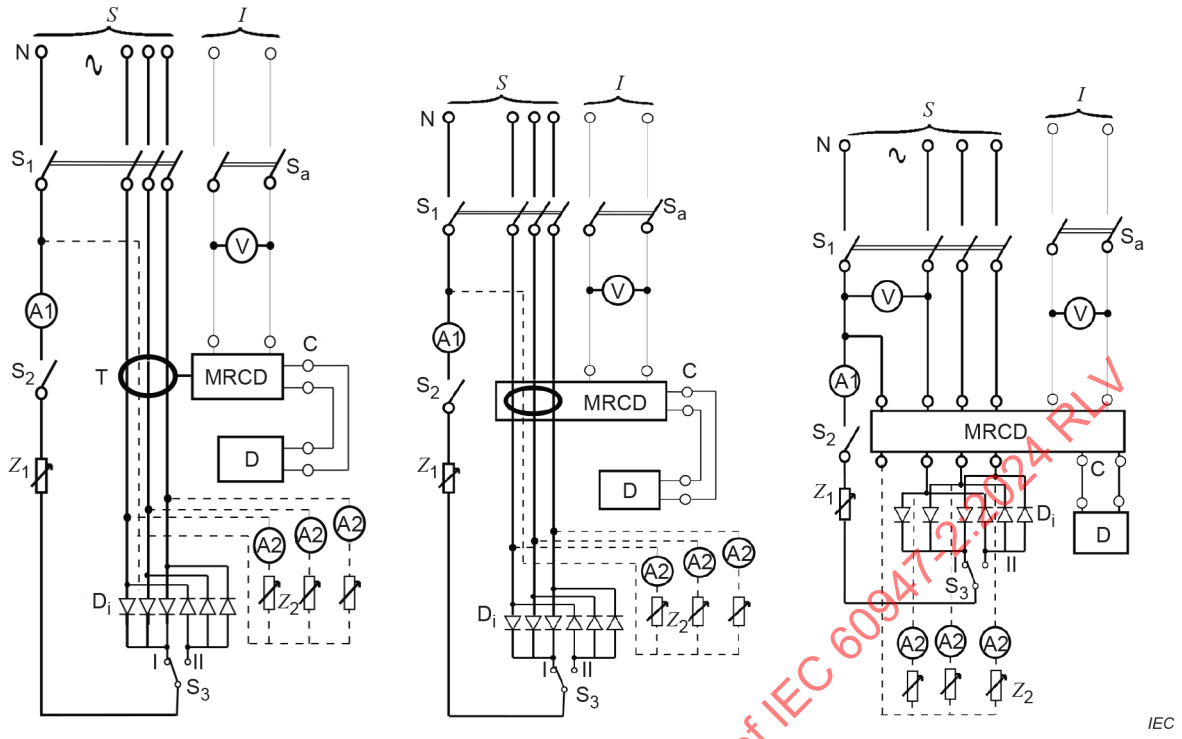
c) **Terminal-type MRCD**

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 DC 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

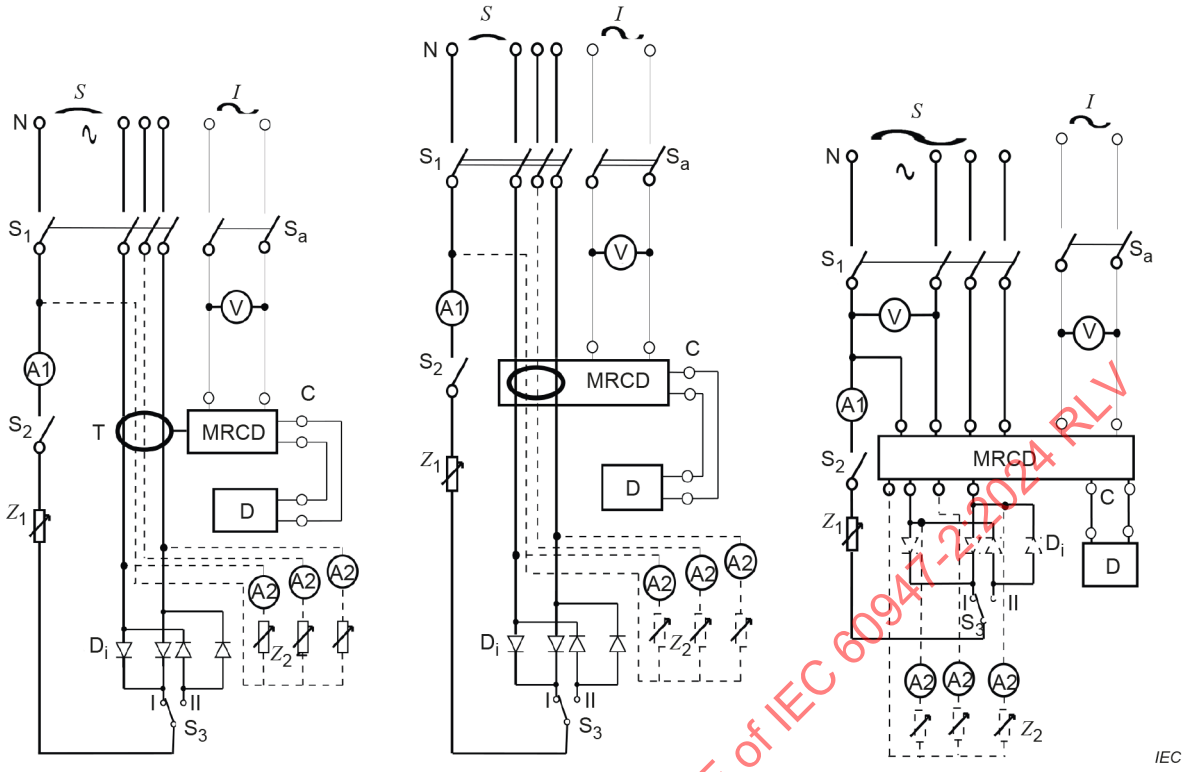
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	adjustable impedances
A1	ammeter measuring AC current	T	sensing means
A2	ammeter measuring AC current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
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

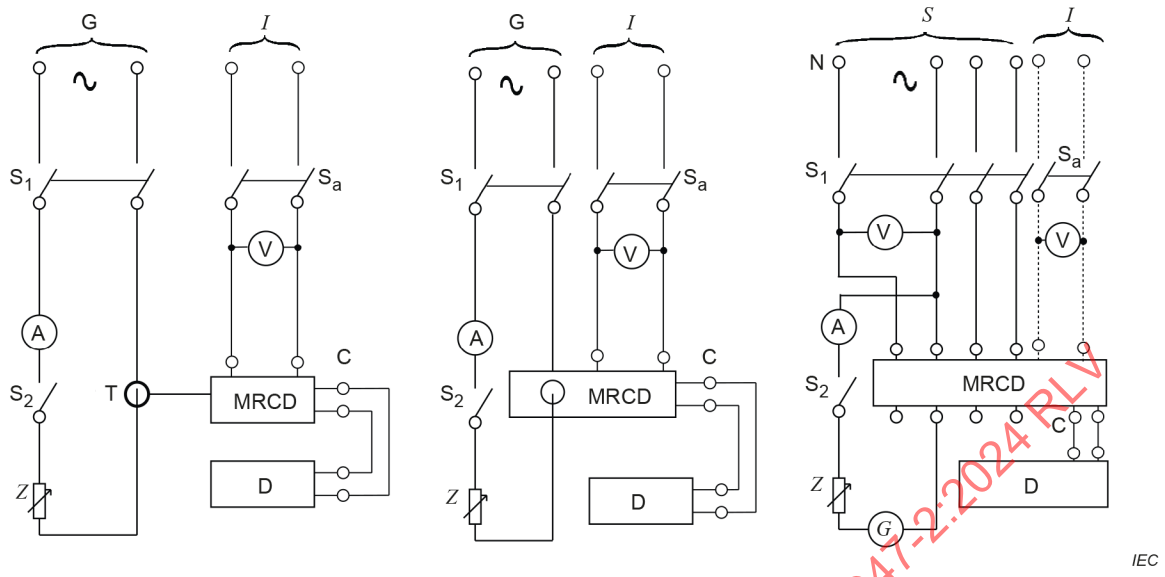
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	adjustable impedances
A1	ammeter measuring AC current	T	sensing means
A2	ammeter measuring AC current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
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

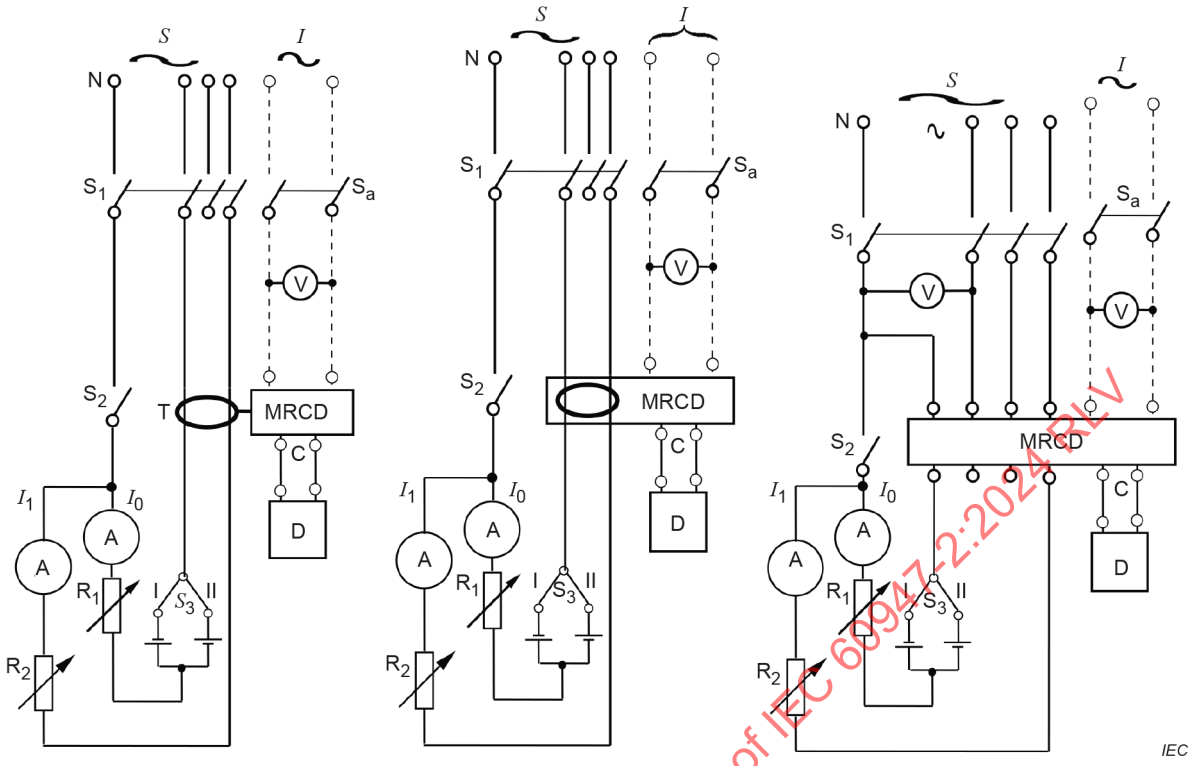
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A	ammeter measuring AC current	T	sensing means
S_1	multi-pole switch	C	output circuit
G	generator	D	instrument indicating the change of status

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

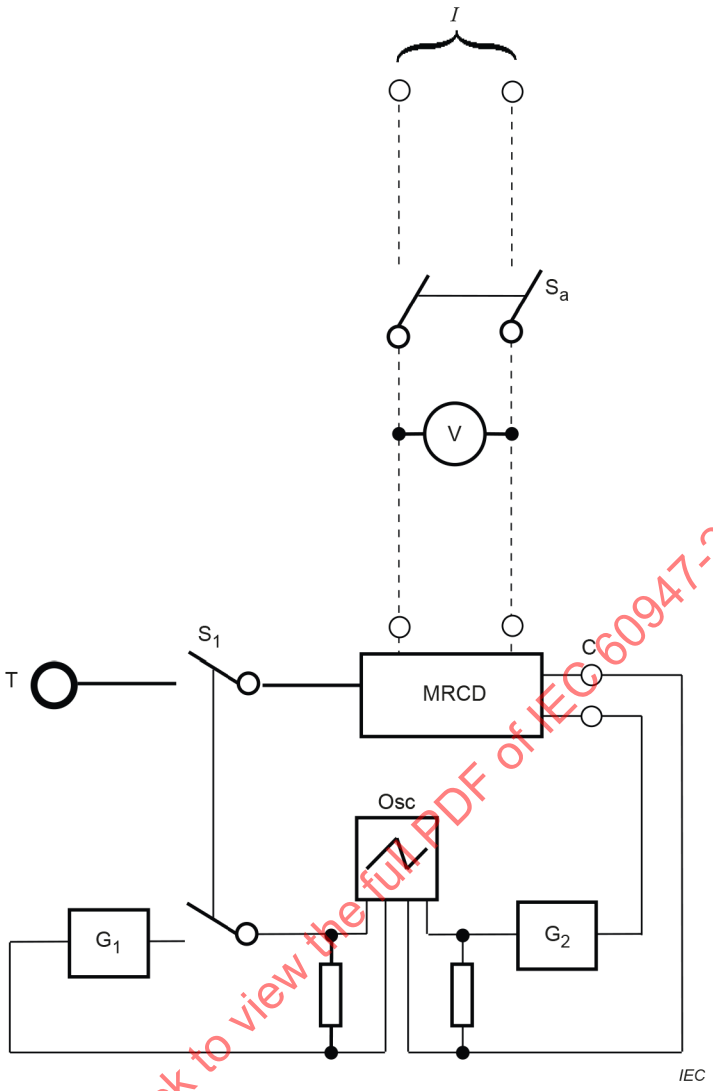
S	power supply	S_3	two-way switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	R_1, R_2	adjustable resistors
A	ammeter measuring AC current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

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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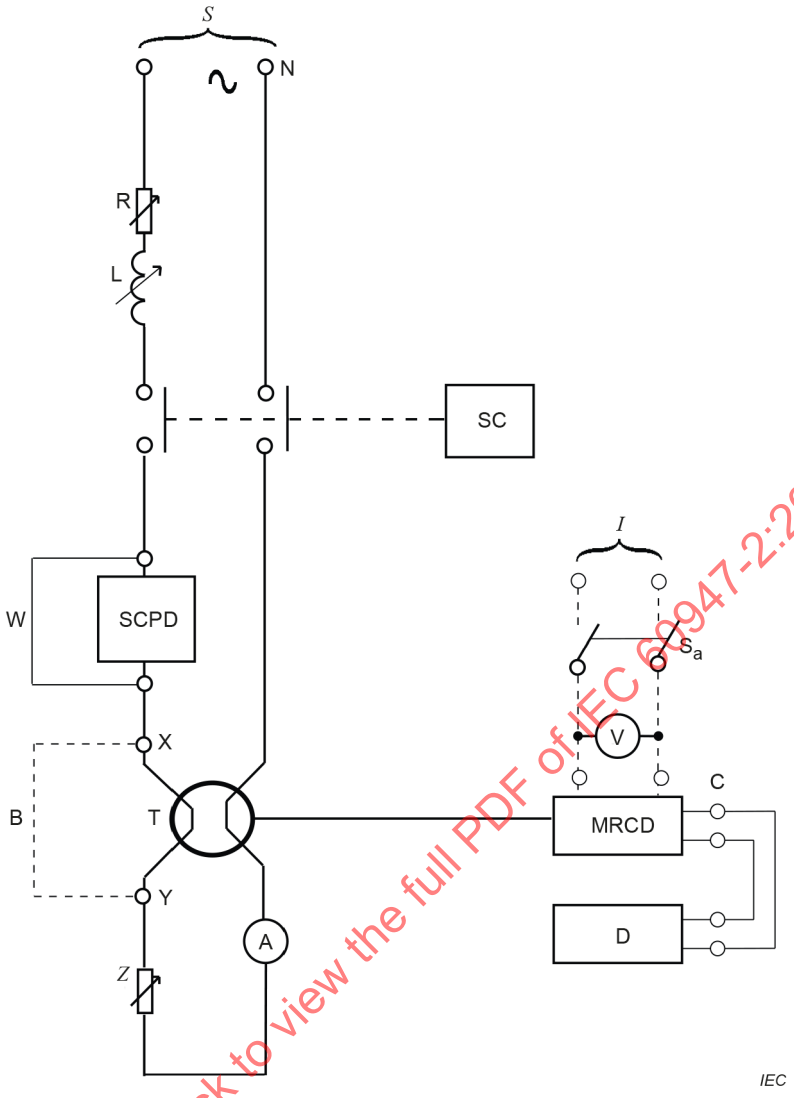


Key

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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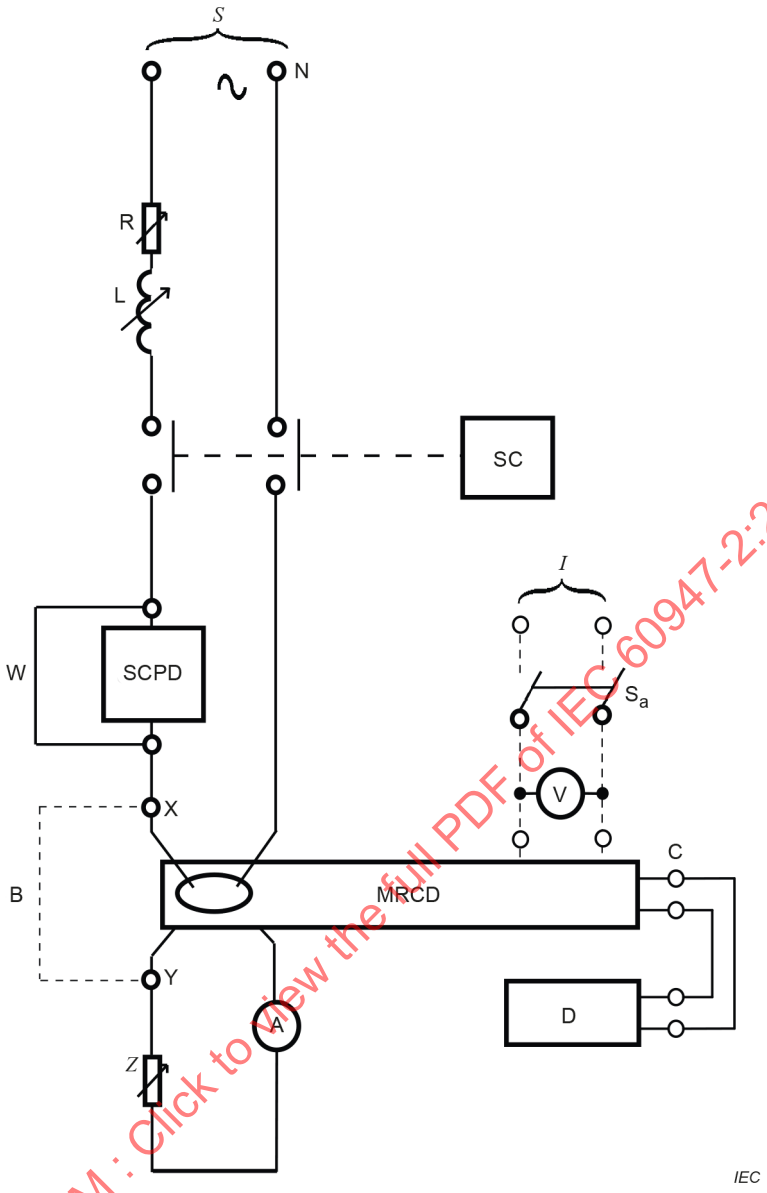


Key

S	power supply	L	adjustable reactor
I	separate voltage source, if applicable	R	adjustable resistor
V	voltmeter	*Z*	adjustable impedance
A	ammeter	T	sensing means
S_a	auxiliary switch	C	output circuit
SC	short-circuit switch	D	instrument indicating the change of status
W	temporary connection	SCPD	short-circuit protective device
B	connection for residual short-circuit test, replacing the connection through the sensing means		

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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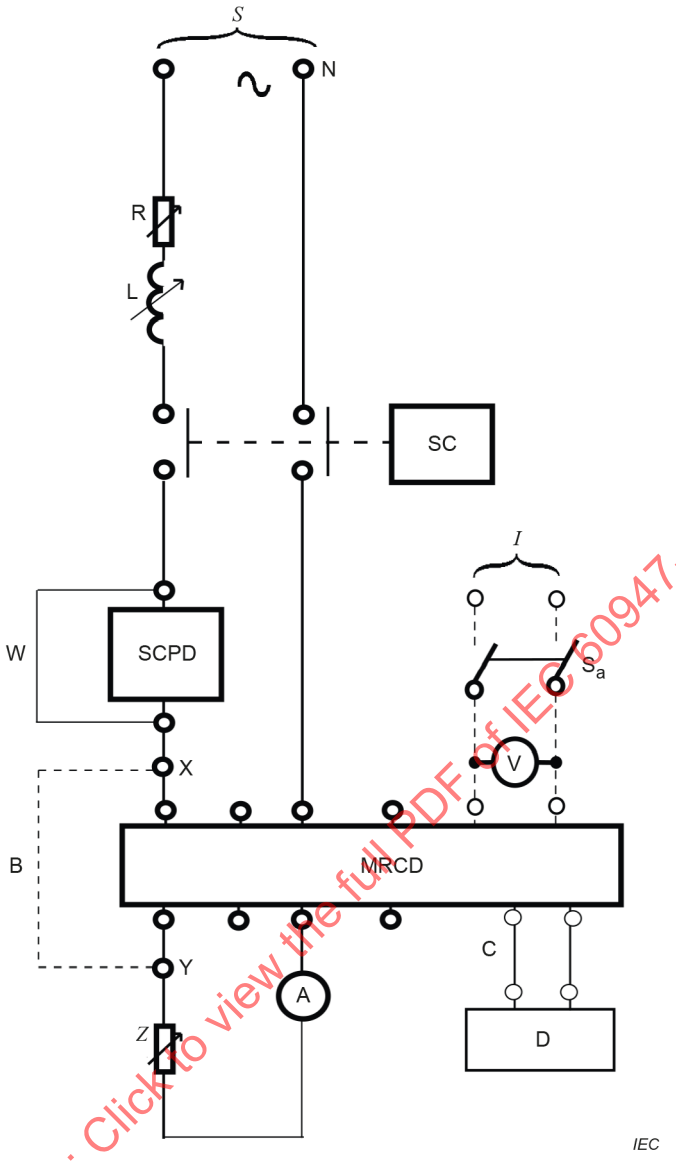


Key

S	power supply	B	connection for residual short-circuit test, replacing the connection through the sensing means
I	separate voltage source, if applicable	L	adjustable reactor
V	voltmeter	R	adjustable resistor
A	ammeter	*Z*	adjustable impedance
S_a	auxiliary switch	C	output circuit
SC	short-circuit switch	D	instrument indicating the change of status
W	temporary connection	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
Sa	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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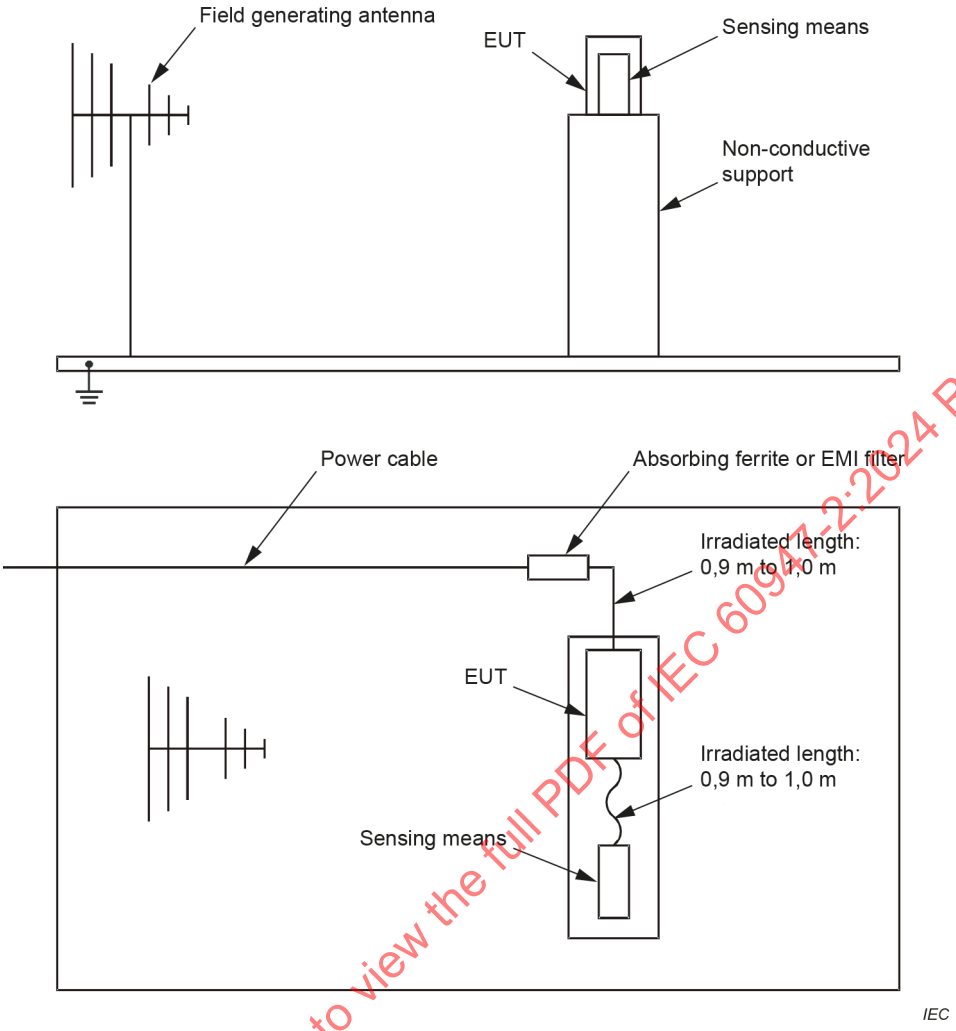


Figure M.22 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCDs with separate sensing means (in addition to the test of Annex B)

Dimensions in metres

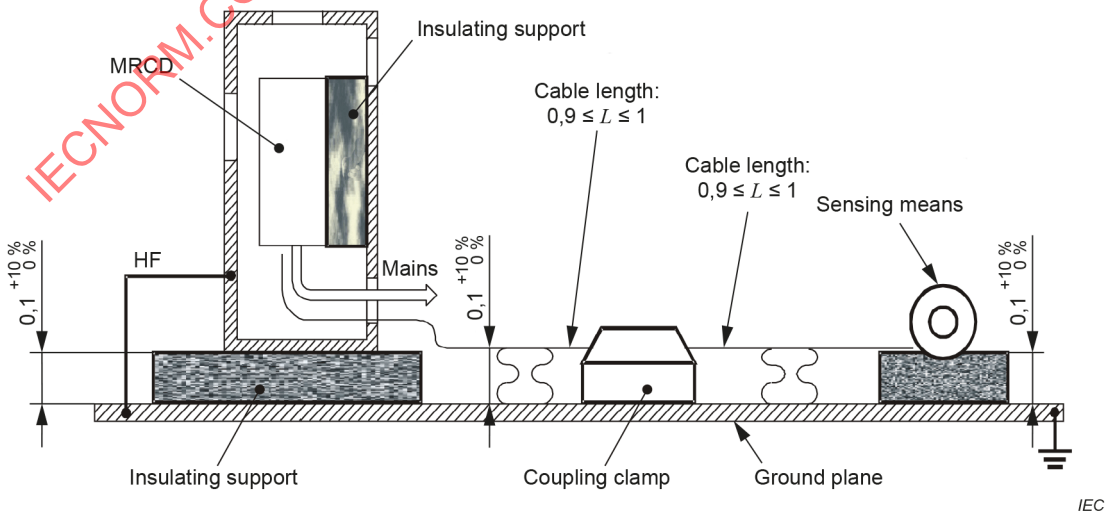
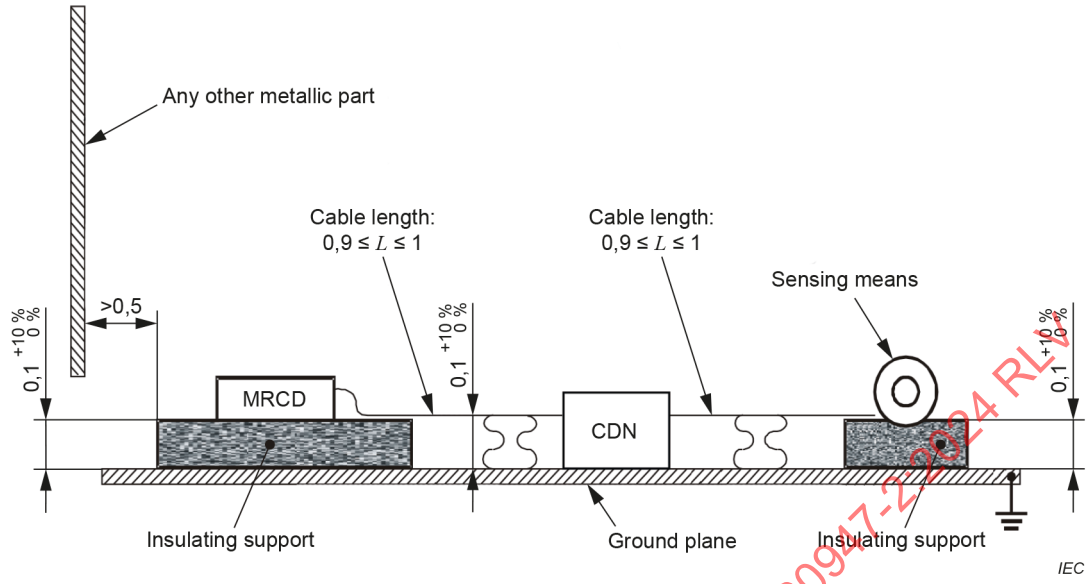


Figure M.23 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (in addition to the test of Annex B)

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Dimensions in metres



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 M~~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~~Overview

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 8.3 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020), 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 9.

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~~ suitable 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~~ suitable 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 document.

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~~ Clause 7 of IEC 61000-4-3:2020, 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 AC 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~~2020.

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 8.3.3 of IEC 60947-1:~~2007/AMD2:2014~~2020), 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~~ 6 000 MHz)

Annex J applies, in particular J.3.3.

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~~Annex N~~Annex O
(normative)

Instantaneous trip circuit-breakers (ICBs)

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 document, 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.

NOTE In some countries, there are circuit-breakers with the function of output of alarm signals without tripping in case of overload. In this case, the alarm signalling can be verified under the same conditions as tripping in the main part of this document. The final user will have to define the correct provisions for thermal protection.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 3, 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 document and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 5 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).

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O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

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 6.2 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 3.15) (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 8, except 8.2.1.2.4, item b).

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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.

In the case of one or more construction breaks (see 3.1.2 and 8.1.6) 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 document 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 9.3.4.2.2 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 O~~Annex P
(normative)

DC circuit-breakers for use in photovoltaic (PV) applications

P.1 Field of application

This annex applies to DC circuit-breakers, rated up to 1 500 V DC, 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 document.

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 DC side of PV applications;
– the tests intended to verify product performance, and ~~their maintaining after exposure~~ resistance to the PV service environmental conditions.

P.2 Terms and definitions

Clause 3 applies.

P.3 Classification

Clause 4 applies.

P.4 Characteristics of PV circuit-breakers

Clause 5 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~~ 1 250	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 6 applies with the modifications and additions listed in Table P.2.

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.2 – Product information

Item	Information	Marking location
P2.1	IEC 60947-2:~~2016 –~~2024, 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 7 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 8.1 applies.

P.7.2 Performance requirements

Subclause 8.2 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 8.2.4.1, 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 subclause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 8.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.3.

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Table P.3 – 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 document 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 8.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 9.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 9.2 applies.

P.8.3 Type tests

Subclause 9.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 9.3.2.2, 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 AC do not cover DC characteristics.

With reference to 9.3.2.4, 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 15.

With reference to 9.3.3.2.5, the time constant for operational performance capability, short-circuit tests and critical DC 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 9.3.4 applies with the following modifications:

With reference to 9.3.4.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.3.

With reference to 9.3.4.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.3, 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 9.3.4.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 9.3.5 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 9.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 9.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 9.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 9.3.9 applies with the modifications listed in P.8.3.2.

P.8.3.9 ~~Critical d.c. load current test~~Test sequence VII

Subclause 9.3.10 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 9.3.4.2.3;

– a verification of temperature-rise at the main terminals in accordance with 9.3.3.5. The temperature-rise shall not exceed the values given in Table 6;

– a verification of dielectric withstand and leakage current according to 9.3.4.6.

The number of samples shall be in accordance with the requirements of Table 15 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 of IEC 60947-1:2020: 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~~2020 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 9.4 of this document, except for the dielectric tests of 9.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014~~2020.

With reference to footnote g) of Table Q.1 of IEC 60947-1:~~2007/AMD1:2010/AMD2:2014,~~2020 during damp heat test, the functional test shall consist of the mechanical operations of 9.4.2 of this document. 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 15 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 9.4 applies.

P.8.5 Special tests

Subclause 9.5 applies.

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~~Annex P~~Annex Q

Vacant

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~~Annex Q~~Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic reclosing functions (CBARs)

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this document 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 document.

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 AC circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs dependent 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 3 and Clause B.2 of this document, 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~~2000, 441-16-10, modified – ~~term and supplemented by "depending on specific conditions"~~ term "auto-reclosing" replaced with "automatic reclosing", and "after a predetermined time" replaced with "depending on specific conditions" in the definition.]

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 4 and Clause B.3 of this document, 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 5 and Clause B.4 of this document 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 6 and Clause B.5 apply with the additions listed in Table R.1.

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Table R.1 – 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 7 applies.

R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 8.1 and B.7.1 of this document, 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 AC or 60 V DC; 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 AC or 2 mA DC.

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

8.2 and B.7.2 apply.

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 9 and Clause B.8 of this document, 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 9.

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.8.13 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 overcurrent 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 9.3.4.2.2). 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 × $I_{\Delta n}$ 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 × $I_{\Delta n}$, 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 × $I_{\Delta n}$. 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 7. 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~~ can be ~~necessary~~ needed 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.8.1.2.1, replacing the operations performed by applying a residual current.

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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 9.3.4.3 (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 9.3.4.6 (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 9.3.5.4 (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 9.3.6.4 (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 9.3.4.3 (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~~2020.

There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

Subclause 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.8.1.2.2 (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.

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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 (see Table R.2) 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.2 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under overcurrent 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	9.3.6
	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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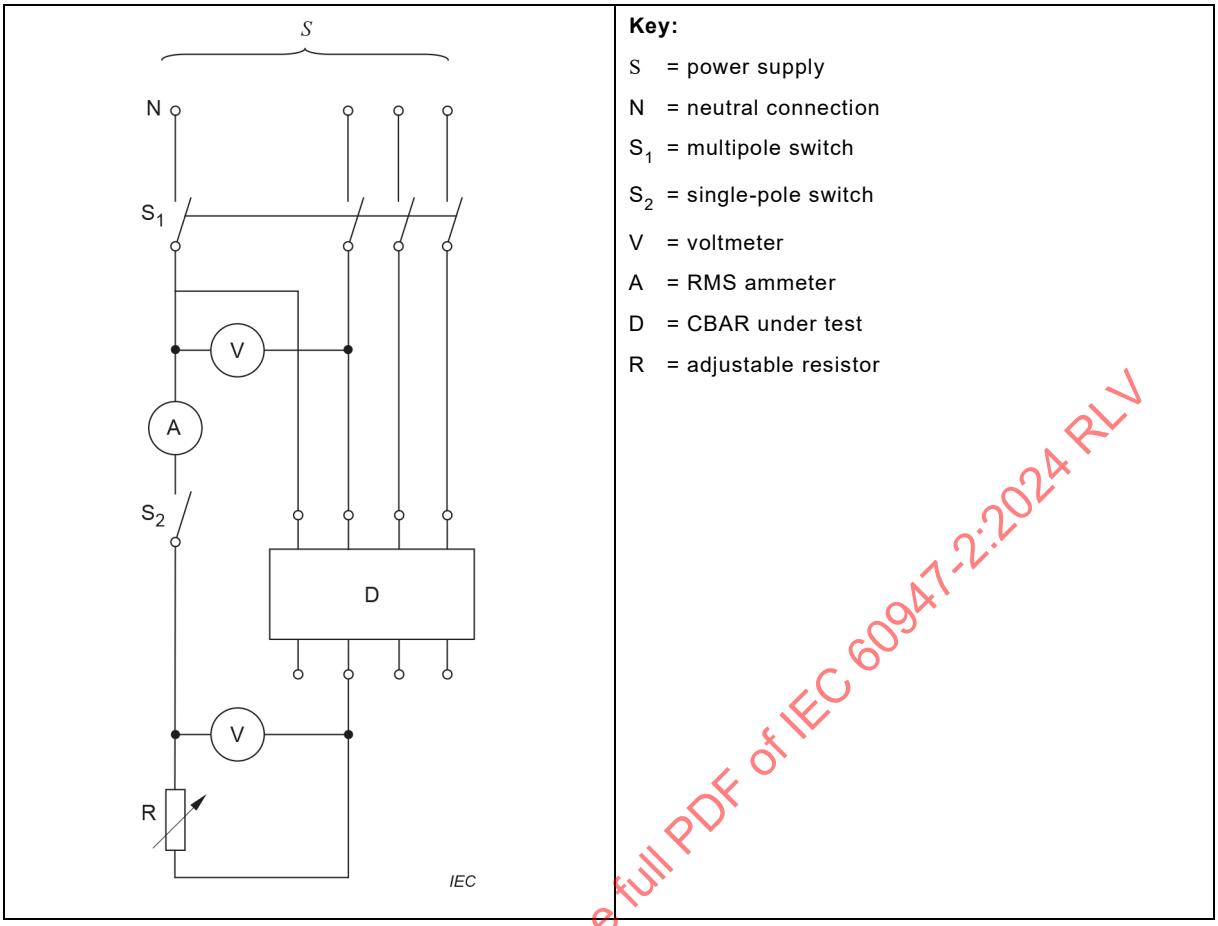


Figure R.1 – Test circuit for the verification of the automatic reclosing functions

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

Appareillage à basse tension – Partie 2: Disjoncteurs



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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

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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. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2016 and its Amendment 1: 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) suitability for isolation (see Clause 1);
b) removal of the classification according to the interrupting medium, according to the design, according to the suitability for isolation (see Clause 4);
c) adjustment of current settings with an external device connectable to the release (see 5.7.3);

d) requirements for circuits with protective separation (see 8.2.3.8);
e) additional tests for ground-fault overcurrent releases (see 9.3.4.2.5);
f) additional tests concerning dielectric properties in tripped position (see 9.3.4.3);
g) use of DC voltage for dielectric tests (see 9.3.4.6.2 and 9.4.6);
h) tests of individual pole breaking capacity under phase-to-neutral AC voltage (see 9.3.11);
i) improvement of measurement of power loss in Annex G;
j) changes in EMC tests (see Annex J);
k) introduction of CBI class W in Annex L.

The text of this International Standard is based on the following documents:

Draft	Report on voting
121A/608/FDIS	121A/621/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 60947-1:2020.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this document, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2020.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 Scope

This document 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 AC or 1 500 V DC; it also contains additional requirements for integrally fused circuit-breakers.

This document also applies to circuit-breakers with ratings at or below 1 000 V AC, additionally having one or more ratings above 1 000 V AC but not exceeding 1 500 V AC.

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

Circuit-breakers per this document are suitable for isolation.

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

Additional requirements for circuit-breakers intended for connection of aluminium conductors are contained in Annex D.

The additional requirements for circuit-breakers with electronic overcurrent 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 overcurrent 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 for instantaneous trip circuit-breakers are contained in Annex O.

The requirements and test methods for DC 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.

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The requirements for circuit-breakers for overcurrent protection for household and similar installations, and designed for use by uninstructed persons, are contained in IEC 60898 series.

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 can be applicable.

NOTE 1 Circuit-breakers can have dedicated accessories.

NOTE 2 Circuit-breakers which are dealt with in this document can be provided with devices for automatic opening under predetermined conditions other than those of overcurrent and undervoltage as, for example, reversal of power or current. This document does not deal with the verification of operation under such pre-determined conditions.

The object of this document is to state:

a) the characteristics of circuit-breakers;
b) the requirements for circuit-breakers with reference to:
   1) operation and behaviour in normal service;
   2) operation and behaviour in case of overload, operation and behaviour in case of short-circuit, including co-ordination in service (selectivity and back-up protection), as well as the operation and behaviour in case of ground-fault;
   3) dielectric properties;
   4) requirements on electromagnetic compatibility, where applicable;
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 circuit-breakers.

NOTE 3 For cybersecurity requirements, see IEC TS 63208.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*

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*

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IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

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 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2023, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11:2020, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

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

IEC 61545:1996, *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 11:2015/AMD2:2019

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1:2020, as well as the following, apply.

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short-circuit

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

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3.1.1
frame size
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 can vary according to the number of poles.

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

3.1.2
construction break
significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing

3.2
integrally fused circuit-breaker
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 line conductor

[SOURCE: IEC 60050-441:1984, 441-14-22, modified – “phase” replaced with “line”.]

3.3
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 can 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.

3.4
plug-in circuit-breaker
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 can be of the plug-in type on the line side only, the load terminals being usually suitable for wiring connection.

3.5
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

3.6
making-current release
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

3.7
short-circuit release
overcurrent release intended for protection against short circuits

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3.8
short-time delay short-circuit release
overcurrent release intended to operate at the end of the short-time delay

3.9
alarm switch
auxiliary switch which operates only upon the tripping of the circuit-breaker with which it is associated

3.10
circuit-breaker with lock-out device preventing closing
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

3.11
short-circuit breaking (or making) capacity
breaking (or making) capacity for which the prescribed conditions include a short circuit

3.11.1
ultimate short-circuit breaking capacity
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

3.11.2
individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage
ultimate short-circuit breaking capacity which is determined for an individual pole at the phase-to-neutral AC voltage

3.11.3
service short-circuit breaking capacity
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

3.12
opening time
<of a mechanical switching device> 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 60947-1:2020, 3.7.39, modified – modification of Note 1 to entry and addition of Note 2 to entry.]

3.13
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 (RMS symmetrical for AC) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

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3.14
resetting time
time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

3.15
instantaneous short-circuit current setting
I_i
current setting of a short-circuit release, above which a current causes its operation without any intentional time-delay

Note 1 to entry: I_i can be non-adjustable

3.16
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.

3.17
short-time pick-up current setting
I_{sd}
current setting of a short-circuit release, above which a current causes its operation with an intentional time-delay (t_{sd})

3.18
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

Note 1 to entry: 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.]

3.19
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.

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4 Classification

4.1 According to the selectivity category, A or B (see 5.4)

4.2 According to the method of controlling the operating mechanism:

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

4.3 According to the provision for maintenance:

– maintainable;
– non-maintainable.

4.4 According to the method of installation:

– fixed;
– plug-in;
– withdrawable.

4.5 According to the degree of protection provided by the enclosure (see 8.1.12 of IEC 60947-1:2020)

5 Characteristics of circuit-breakers

5.1 Summary of characteristics

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

– type of circuit-breaker (5.2);
– rated and limiting values of the main circuit (5.3);
– selectivity categories (5.4);
– control circuits (5.5);
– auxiliary circuits (5.6);
– releases (5.7);
– integral fuses (integrally fused circuit-breakers) (5.8).

5.2 Type of circuit-breaker

The following shall be stated:

– number of poles;
– kind of current (AC or DC) and, in the case of AC, number of phases and rated frequency.

5.3 Rated and limiting values of the main circuit

5.3.1 General

The rated values established of a circuit-breaker shall be stated in accordance with 5.3.2 to 5.4, but it is not necessary to state I_{th} (5.3.3.1), I_{the} (5.3.3.2), rated frequency (5.3.4) in case of a DC only circuit-breaker, rated duty (5.3.5).

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5.3.2 Rated voltages

5.3.2.1 Rated operational voltage (U_e)

Subclause 5.3.1.1 of IEC 60947-1:2020 applies with the following amplification:

– circuit-breakers covered by 5.3.1.1 item a) of IEC 60947-1:2020.

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 5.3.1.1 item b) of IEC 60947-1:2020.

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 5.3.1.1 item b) of IEC 60947-1:2020 are identified by the voltage between phases only.

5.3.2.2 Rated insulation voltage (U_i)

Subclause 5.3.1.2 of IEC 60947-1:2020 applies.

5.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:2020 applies.

5.3.3 Currents

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

Subclause 5.3.2.1 of IEC 60947-1:2020 applies.

5.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:2020 applies.

5.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 5.3.2.4 of IEC 60947-1:2020) and is equal to the conventional free-air thermal current (I_{th}).

5.3.4 Rated frequency

Subclause 5.3.3 of IEC 60947-1:2020 applies.

5.3.5 Rated duty

The rated duties considered as normal are:

– the eight-hour duty (see 5.3.4.1 of IEC 60947-1:2020),

– the uninterrupted duty (see 5.3.4.2 of IEC 60947-1:2020).

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5.3.6 Short-circuit characteristics

5.3.6.1 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 AC, or time constant for DC. It is expressed as the maximum prospective peak current.

For AC, 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 1 (see 5.3.6.3).

For DC, 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.

5.3.6.2 Rated short-circuit breaking capacities

5.3.6.2.1 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.

NOTE A circuit-breaker in accordance with this document is able to break line-to-line, line-to-earth, line-to-neutral (AC) and line-to-mid-point (DC) short-circuits

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 AC, at any power factor not less than those required in 9.3.3.2.4;
– for DC, with any time constant not greater than those required in 9.3.3.2.5.

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 9.3.3.2.6), no short-circuit breaking capacity is guaranteed.

For AC, 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 9.3.3.2.4, irrespective of the value of the inherent DC component, on the assumption that the RMS value of the AC component of the prospective current is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;
– rated service short-circuit breaking capacity.

5.3.6.2.2 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 3.11.1) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.6. It is expressed as the value of the prospective breaking current, in kA (RMS value of the AC component in the case of AC).

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5.3.6.2.3 Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1})

The rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage of a circuit-breaker is the value of individual pole breaking capacity at phase-to-neutral voltage assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.11. It is expressed as a value of the prospective breaking current, in kA (RMS value of the AC component).

5.3.6.2.4 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 3.11.3) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.5. 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}.

5.3.6.3 Standard relationship between short-circuit making and breaking capacities and related power factor for AC circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 1.

Table 1 – Ratio n between short-circuit making capacity and short-circuit breaking capacities and related power factor for AC circuit-breakers

Short-circuit breaking capacity kA RMS I	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

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The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 1. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

5.3.6.4 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 9.3.7.3.

NOTE 1 The rated short-time withstand current is not influenced by a change of a trip unit.

NOTE 2 The attainable time selectivity in an application depends on the actual short-time pick-up current setting (I_{sd}) and the intentional time delay (t_{sd}) of the trip unit.

For AC, the value of this current is the RMS value of the AC 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 2.

Table 2 – 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

5.4 Selectivity categories

Circuit-breakers according to this document 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 5.3.6.4.

  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 2.

– **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 5.3.6.4. In that case, the tests shall include test sequence IV (see 9.3.7) at the assigned short-time withstand current.

Attention is drawn to the differences of the tests applying to the two selectivity categories (see Table 10 and 9.3.5, 9.3.6, 9.3.7 and 9.3.9).

5.5 Control circuits

5.5.1 Electrical control circuits

Subclause 5.5.1 of IEC 60947-1:2020 applies, with the following addition:

If the rated control circuit supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 3.

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Table 3 – Preferred values of the rated control circuit 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

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

Subclause 5.5.2 of IEC 60947-1:2020 applies.

5.6 Auxiliary circuits

Subclause 5.6 of IEC 60947-1:2020 applies.

5.7 Releases

5.7.1 Types

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

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

   NOTE 1 The term "overload release" is used to identify overcurrent releases intended for protection against overloads (see 3.6.31 of IEC 60947-1:2020). The term "short-circuit release" is used to identify overcurrent releases intended for protection against short circuits (see 3.7); it includes the short-time delay short-circuit release (see 3.8).

   NOTE 2 The term "adjustable release" used in this document also includes interchangeable releases.
3) undervoltage release (for opening);
4) closing release;
5) other releases.

5.7.2 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 AC
2) overcurrent release:
   – rated current (I_n);
   – kind of current;
   – rated frequency, if AC;
   – current setting (or range of settings);
   – time setting (or range of settings) if applicable.

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The rated current of an overcurrent release is the value of current (RMS if AC) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 9.3.3.5, without the temperature-rise exceeding the values specified in Table 6.

5.7.3 Current setting of overcurrent releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 5.7.1, item 2), the current settings shall be marked on the release, or displayed on the release's display, or displayed on an external device's display connectable to the release. The settings may be either directly in amperes or as a multiple of the current value. Means shall be provided by the manufacturer to read the display regardless of the status of the circuit-breaker. When applicable, the manufacturer shall specify the characteristics of the external device.

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 5, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

The current settings may be adjusted through an external (local or remote) device connectable to the release, in which case either local setting indications shall not be exceeded, or a local indication shall show that the settings are controlled remotely. The manufacturer shall provide means to the testing laboratory to ensure settings do not change during type tests.

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 state the influence of ambient temperature in the literature (see 8.2.1.2.4, item b)).

5.7.4 Tripping time setting of overcurrent releases

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

1) Definite time-delay overcurrent releases

   The time-delay of such releases is independent of the overcurrent. 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 overcurrent releases

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

   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.

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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 overcurrent 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.

5.8 Integral fuses (integrally fused circuit-breakers)

Subclause 5.8 of IEC 60947-1:2020 applies, replacing "SCPD" with "integral fuse".

6 Product information

6.1 Nature of the information

Subclause 6.1 of IEC 60947-1:2020 applies, as far as appropriate for a particular design.

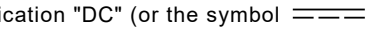
In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 3.1.1). See Annex G.

For the glossary of symbols and graphical representation of characteristics, see Annex K.

6.2 Marking

Each circuit-breaker shall be marked in a durable manner; data to be provided and corresponding locations are indicated in Table 4.

Table 4 – Product information

Item	Information	Location
1.1	rated current (I_n)	Visible
1.2	suitability for isolation with the symbol  (IEC 60617-S00287:2001-07 combined with IEC 60617-S00220:2001-07)	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 8.1.6.1 of IEC 60947-1:2020)	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 this document	Marked
2.4	selectivity category A or B	Marked
2.5	rated operational voltage(s) U_e (see 5.3.2.1 and, where applicable, Annex H)	Marked
2.6	indication that the circuit-breaker is not suitable for IT systems at all rated voltages with the symbol  (IEC 60417-6363:2016-07). For any exception for specific rated voltages, see H.5.	Marked
2.7	rated impulse withstand voltage (U_{imp})	Marked
2.8	value (or range) of the rated frequency, and/or the indication "DC" (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 individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}), at the corresponding rated voltage (U_e), if different from I_{cu}	Marked
2.12	rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B	Marked

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Item	Information	Location
2.13	range of the current setting (I_r) of the adjustable overload release	Marked [a]
2.14	value or range (when adjustable) of the short-time pick-up current setting (I_{sd}) of the release and its intended time-delay (t_{sd}), when applicable	Marked [a]
2.15	range of the ground-fault current (I_g) of the adjustable release, when applicable	Marked [a]
2.16	range of the instantaneous short-circuit current setting (I_i), for adjustable releases	Marked [a]
2.17	reference temperature for non-compensated thermal releases, if different from 30 °C	Marked
2.18	terminals identification, according to 8.1.8.4 of IEC 60947-1:2020	Marked
2.19	Identification of line and load terminals, if applicable	Marked
2.20	neutral pole terminals, if applicable, by the letter N	Marked
2.21	protective earth terminal, where applicable, by the symbol (IEC 60417-5019:2006-08)  (see 8.1.10.3 of IEC 60947-1:2020)	Marked
3.1	rated short-circuit making capacity (I_{cm}) at the corresponding rated voltage (U_e), if higher than the minimum values specified in 5.3.6.1	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 (see 7.1.3.2 of IEC 60947-1:2020)	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 60947-1:2020)	Literature
3.6	when applicable, 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 60947-1:2020, 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, when applicable, for temperatures higher than the reference temperature	Literature
3.13	influence of ambient temperature, if applicable, on the tripping performance of the overcurrent release (see 5.7.3)	Literature
3.14	current derating for terminals and connections, if applicable	Literature
3.15	method and diagram of series connection of poles (as necessary for each rating) for DC circuit-breakers	Literature
3.16	type of ground-fault detection function (see T.4 of IEC 60947-1:2020)	Literature
3.17	value of the instantaneous short-circuit current setting (I_i), for non-adjustable releases	Literature
3.18	number of poles	Literature
3.19	further information concerning aluminum conductors (see D.5.2)	Literature
4.1	for closing releases (see 3.19) and/or motor-operators, rated control circuit voltage, kind of current and rated frequency for AC	Aux

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Item	Information	Location
4.2	rated control circuit voltage of the shunt release and/or of the undervoltage release (or of the no-voltage release), kind of current and rated frequency for AC	Aux
4.3	rated current of indirect overcurrent releases (see 5.7.3)	Aux
4.4	number and type of auxiliary contacts, rated operational currents at the rated operational voltages, and rated frequency for AC	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, settings of I_r, I_i, I_{sd} and I_g may be displayed on the display of the release or of an external device instead of being marked (see 5.7.3).

6.3 Instructions for installation, operation and maintenance

Subclause 6.3 of IEC 60947-1:2020 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.

7 Normal service, mounting and transport conditions

Clause 7 of IEC 60947-1:2020 applies with the following addition:

Pollution degree (see 7.1.3.2 of IEC 60947-1:2020).

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

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 8.1 of IEC 60947-1:2020 applies with the following modifications:

a) Where, in 8.1.2.2 of IEC 60947-1:2020, 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 and 850 °C for the other circuits.

NOTE 1 "Other circuits" cover control circuits (see 5.5), auxiliary circuits (see 5.6) and releases (see 5.7)

b) The requirements of 8.1.2 of IEC 60947-1:2020 do not apply to parts with a mass lower than 2 g (insignificant mass, in accordance with 3.14 of IEC 60695-2-11:2021). For products containing more than one small part, the total mass of non-tested parts located within 3 mm of each other shall not exceed 10 g.

NOTE 2 This distance of 3 mm is defined in 30.2 of IEC 60335-1:2020.

When aluminium conductors are to be used, Annex D applies.

NOTE 3 Guidance for the development of embedded software is offered in IEC TR 63201.

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8.1.2 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.

8.1.3 Isolation

Subclause 8.1.7 of IEC 60947-1:2020 applies.

For additional requirements concerning performance, see 8.2.6.

NOTE In the UK, for circuit-breakers with plug-in line and load connections, isolation is achieved by complete removal of the circuit-breaker from the fixed connecting contacts.

8.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2020 and in Table 15 of IEC 60947-1:2020.

For U_{imp} values exceeding the values given in Table 13 of IEC 60947-1:2020, clearances shall be obtained from Table F.2 of IEC 60664-1:2020.

8.1.5 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 9.3.3.6.1, item b).

8.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 3.1.2) 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 overcurrent 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, or rendering the central pole inaccessible;
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.).

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

Subclause 8.1.9 of IEC 60947-1:2020 applies.

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

Annex S of IEC 60947-1:2020 applies. For the purposes of this document, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 Closing

8.2.1.1.1 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.

8.2.1.1.2 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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8.2.1.1.3 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.

8.2.1.1.4 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 circuit supply voltage, and, when AC, at the rated frequency.

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

At 85 % of the rated control circuit supply voltage, the closing operation shall be performed to establish a current through the circuit-breaker 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.

8.2.1.1.5 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.

8.2.1.1.6 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 circuit 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.

8.2.1.2 Opening

8.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 3.6.24 of IEC 60947-1:2020) and shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

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8.2.1.2.2 Opening by undervoltage releases

Subclause 8.2.1.3 of IEC 60947-1:2020 applies.

8.2.1.2.3 Opening by shunt releases

Subclause 8.2.1.4 of IEC 60947-1:2020 applies.

8.2.1.2.4 Opening by overcurrent releases

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker within a tolerance 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 overcurrent coordination, the manufacturer shall provide information (usually curves) showing:

– maximum cut-off (let-through) peak current (see 3.7.21 of IEC 60947-1:2020) as a function of prospective current (RMS symmetrical for AC currents);

– I^2t characteristics (see 3.13) for circuit-breakers of selectivity category A and, if applicable, category B for circuit-breakers with instantaneous override (see note to 9.3.6.1).

When applicable, the conformity with this information shall be checked during the relevant type tests in test sequences II and III (see 9.3.5 and 9.3.6).

NOTE 1 It is possible to provide other forms of data to verify coordination 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 within a tolerance 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 5.

At the reference temperature (see 5.7.3) and at 1,05 times the current setting (see 3.6.38 of IEC 60947-1:2020), i.e. with the conventional non-tripping current (see 3.7.30 of IEC 60947-1:2020), the overload release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 3.7.30 of IEC 60947-1:2020) 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 3.7.31 of IEC 60947-1:2020), 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 5 – Characteristics of the opening operation of inverse time-delay overcurrent 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 5 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.

c) Opening under ground-fault conditions

The ground-fault overcurrent release shall cause tripping of the circuit-breaker within the tolerance corresponding to the type of detection function (CI-A or CI-B) according to T.4 of IEC 60947-1:2020, for all values of the current setting of the ground-fault overcurrent release.

Ground-fault overcurrent releases may have an intentional time-delay, but the break time shall not exceed the tripping time values indicated in Table T.1 of IEC 60947-1:2020.

NOTE 3 Ground-fault overcurrent releases can have sensors internal or external to the circuit-breaker.

8.2.2 Temperature-rise

8.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 9.3.3.5, shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.4.7. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.5.5 and 9.3.7.4.

8.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 6 are applicable only if the ambient air temperature remains within the limits given in 7.1.1 of IEC 60947-1:2020.

8.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the overcurrent releases that may be associated with it, shall be capable of carrying its rated current I_n, under the conditions of Clause 9, without the temperature-rises exceeding the limits specified in Table 6.

8.2.2.4 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 5.3.5, and also the temperature-rise tests under the test conditions specified in 9.3.3.5, to be made without the temperature-rises exceeding the limits specified in Table 6.

The requirements of this subclause shall be verified on a new sample. Alternatively, at the discretion of the manufacturer, the verification may be made during the temperature-rise test of 9.3.4.7.

8.2.2.5 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 6 when tested in accordance with 9.3.3.5.

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Table 6 – 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 shall 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 9.

8.2.3 Dielectric properties

8.2.3.1 General

Subclauses 8.2.3.1 a) and 8.2.3.1 b) of IEC 60947-1:2020 apply.

Type tests shall be made in accordance with 9.3.4.3.

The verification of dielectric withstand during all test sequences shall be made in accordance with 9.3.4.6.

Routine tests shall be made in accordance with 9.4.6.

8.2.3.2 Impulse withstand voltage

Subclause 8.2.3.2 of IEC 60947-1:2020 applies.

For circuit-breakers rated above 1 000 V AC, 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 AC.

NOTE Table 1 of IEC TS 62993:2017 provides rated impulse voltage values above 1 000 V AC.

8.2.3.3 Power-frequency or DC 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.

8.2.3.4 Clearances

Subclause 8.2.3.4 of IEC 60947-1:2020 applies.

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8.2.3.5 Creepage distances

Subclause 8.2.3.5 of IEC 60947-1:2020 applies.

8.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with 9.3.3.4.1, item 3) of IEC 60947-1:2020, or DC tests (test voltages for DC tests are under consideration).

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

8.2.3.7 Spacing between separate circuits

Subclause 8.2.3.7 of IEC 60947-1:2020 applies.

8.2.3.8 Requirements for circuits with protective separation

Annex N of IEC 60947-1:2020 applies.

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

8.2.4.1 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 9.3.4.5.

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

8.2.4.2 Operational performance capability

Subclause 8.2.4.2 of IEC 60947-1:2020 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 7:

– for the test of operational performance without current in the main circuit under the test conditions specified in 9.3.4.4.3;
– for the test of operational performance with current in the main circuit under the test conditions specified in 9.3.4.4.4.

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).

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Table 7 – 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.

8.2.5 Ability to make and break under short-circuit conditions

Subclause 8.2.5 of IEC 60947-1:2020 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 5.3.6.1 and 5.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 5.3.6.2.

The rated short-time withstand current shall be in accordance with 5.3.6.4.

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.

8.2.6 Requirements for isolation

Subclause 8.2.7 of IEC 60947-1:2020 applies and tests shall be made in accordance with 9.3.4.3, 9.3.4.6, 9.3.4.10, 9.3.5.4, 9.3.6.4 and 9.3.8.8, as applicable.

8.2.7 Specific requirements for integrally fused circuit-breakers

NOTE For the coordination between circuit-breakers and separate fuses associated in the same circuit, see 8.2.8.

An integrally fused circuit-breaker shall comply with this document in all respects up to the rated ultimate short-circuit breaking capacity. In particular, it shall meet the requirements of test sequence V (see 9.3.8).

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

For all overcurrents 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 a circuit-breaker with lock-out device preventing closing (see 3.10), 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.

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8.2.8 Coordination between a circuit-breaker and another short-circuit protective device

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

8.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

9 Tests

9.1 Kind of tests

9.1.1 General

Subclause 9.1 of IEC 60947-1:2020 applies, with the following additions:

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

– type tests (see 9.3);
– routine tests (see 9.4);
– special tests (see 9.5).

For items subject to agreement between manufacturer and user, see Annex E.

9.1.2 Type tests

Type tests include the tests listed in Table 8.

Table 8 – Type tests

Test	Subclause
Temperature-rise	9.3.3.5
Tripping limits and characteristics	9.3.4.2
Dielectric properties	9.3.4.3
Operational performance capability	9.3.4.4
Overload performance (where applicable)	9.3.4.5
Short-circuit breaking capacities	9.3.5 and 9.3.6
Short-time withstand current (where applicable)	9.3.7
Performance of integrally fused circuit-breakers	9.3.8
Critical DC load current	9.3.10
Individual pole short-circuit breaking capacity at phase-to-neutral AC voltage (where applicable)	9.3.11

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

9.1.3 Routine tests

Routine tests comprise the tests listed in 9.4.

9.1.4 Special tests

Special tests comprise the tests listed in 9.5.

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9.2 Compliance with constructional requirements

Subclause 9.2 of IEC 60947-1:2020 applies.

9.3 Type tests

9.3.1 General

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 (9.3.4 to 9.3.9);
– test conditions applicable to temperature-rise tests (9.3.3.5);
– test conditions applicable to short-circuit tests (9.3.3.6).

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 Table 9, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

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Table 9 – Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	9.3.3.1
Arrangement of circuit-breakers for short-circuit tests	9.3.3.6.1
Frequency	9.3.3.2.3
Power factor	9.3.3.2.4
Records (interpretation of)	9.3.3.6.6
Recovery voltage	9.3.3.2.6
Short-circuit test circuits	9.3.3.6.2
Short-circuit test procedure	9.3.3.6.4
Temperature-rise test	9.3.3.5
Time constant	9.3.3.2.5
Tolerances	9.3.3.2.2
Tests (for overall schema of test sequences, see Table 10)	**Subclause**
Critical DC load current	9.3.10
Dielectric properties	9.3.4.3
Dielectric withstand (verification)	9.3.4.6 – 9.3.5.4 – 9.3.6.4 – 9.3.7.6 – 9.3.8.4 – 9.3.8.8 – 9.3.9.6
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	9.3.4.10
Integrally fused circuit-breakers (short-circuit tests)	9.3.8.2 – 9.3.8.6 – 9.3.8.7
Operational performance capability	9.3.4.4 – 9.3.5.3 – 9.3.5.5
Overload performance	9.3.4.5
Overload releases (verification)	9.3.4.8 – 9.3.5.6 – 9.3.6.2 – 9.3.6.5 – 9.3.7.2 – 9.3.7.7 – 9.3.8.5 – 9.3.8.9 – 9.3.9.2 – 9.3.9.8
Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	9.3.11
Service short-circuit breaking capacity	9.3.5.2 – 9.3.9.4
Short-circuit breaking capacity test at maximum short-time withstand current	9.3.7.5
Short-time withstand current	9.3.7.3 – 9.3.9.3
Temperature-rise (verification)	9.3.4.7 – 9.3.5.5 – 9.3.7.4 – 9.3.8.3 – 9.3.9.7
Tripping limits and characteristics	9.3.4.2
Ultimate short-circuit breaking capacity	9.3.6.3
Withdrawable circuit-breakers (additional tests)	9.3.4.4.5

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9.3.2 Test sequences

9.3.2.1 General

Type tests are grouped together in a number of sequences, as shown in Table 10.

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

9.3.2.2 Tests omitted from sequence I and made separately

With reference to 9.1.1 of IEC 60947-1:2020, the following tests of test sequence I (see 9.3.4) may be omitted from the sequence and made on separate samples:

– tripping limits and characteristics (9.3.4.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 9.3.4.2.3 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 (9.3.4.3);

– test of under-voltage releases of 9.3.4.4.2.3 and 9.3.4.4.3 to verify the requirements of 8.2.1.3 of IEC 60947-1:2020, and tests of under-voltage releases at alternative frequencies (see 9.3.3.1);

– test of shunt releases of 9.3.4.4.2.4 and 9.3.4.4.3 to verify the requirements of 8.2.1.4 of IEC 60947-1:2020, and tests of shunt releases at alternative frequencies (see 9.3.3.1);

– additional tests for operational performance capability without current for withdrawable circuit-breakers (9.3.4.4.5).

9.3.2.3 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 11.

Table 10 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (9.3.4)	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
II Rated service short-circuit breaking capacity (9.3.5)	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 (9.3.6)	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

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Test sequence	Applicable to	Tests
IV Rated short-time withstand current (9.3.7)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with an assigned short-time withstand current (see 5.4)	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 (9.3.8)	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 (9.3.9)	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
VII Critical DC load current (9.3.10)	Circuit-breakers with DC ratings	Critical DC load current tests
VIII Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (9.3.11)	AC circuit-breakers, when applicable (see 9.3.11.1)	Verification of overload releases Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}) Verification of dielectric withstand Verification of overload releases
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 11.

[b] Except where Sequence VI is applied.

[c] Except
- where $I_{cs} = I_{cu}$ (but see 9.3.6),
- where sequence VI is applied,
- for integrally fused circuit-breakers.

[d] See note to 9.3.6.1

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Table 11 – 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 5.4).

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9.3.2.4 Alternative test programmes for AC circuit-breakers having a different number of poles

These alternative test programmes may only be applied to AC ratings and when all the ratings are the same or lower than the variant submitted to the full programme of Table 10, 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 10. 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 10 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 13 shall be carried out on the other variants.
– Programme 2: The applicable test sequences according to Table 10 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 14 shall be carried out on the other variants.

The principle for the application of the alternative test programmes is illustrated in Table 12.

Table 12 – Alternative test programmes for AC circuit-breakers

	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 10 □ tested per Table 13 ○ tested per Table 14 – no test required								
[a] Construction 1 is the construction which covers the max rating.									

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Table 13 – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 9.3.2.4

Test sequence	Test subclause	Test	Applicability to 4-pole variant[f, h]	Applicability to 1-pole or 2-pole variants[g]
I	9.3.4.2	Test of tripping limits and characteristics		
	9.3.4.2.1	General	X	X
	9.3.4.2.2	Short-circuit releases	X[a]	X[e]
	9.3.4.2.3 a)[i] or 9.3.4.2.3 b)[i] (as applicable)	Overload releases: – instantaneous/definite time-delay or – inverse time-delay	X	X[e]
	9.3.4.2.4	Additional test for definite time-delay releases:		
	9.3.4.3	Dielectric properties	X	X
	9.3.4.4	Mechanical operation and operational performance capability		
	9.3.4.4.1	General	X	X
	9.3.4.4.2	Construction and mechanical operation	X[d]	X[d, e]
	9.3.4.4.3	Operational performance capability without current	X	X
	9.3.4.4.4	Operational performance capability with current	X	X
	9.3.4.4.5	Withdrawable circuit-breakers	X	
	9.3.4.5	Overload performance	X	X
	9.3.4.6	Verification of dielectric withstand	X	X
	9.3.4.7	Verification of temperature-rise	X	X
	9.3.4.8	Verification of overload releases		
	9.3.4.9	Verification of undervoltage and shunt releases	X	X
	9.3.4.10	Verification of the main contact position	X	X
II	9.3.5	Rated service short-circuit breaking capacity		
III	9.3.6[b, c]	Rated ultimate short-circuit breaking capacity	X	X
IV	9.3.7	Rated short-time withstand current	X 4th pole and adjacent pole only (see 9.3.3.6.4)	
V	9.3.8	Performance of integrally fused circuit-breakers	X	X
VI	9.3.9	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.

[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 10).

[c] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[d] Without verification tests of undervoltage releases (9.3.4.4.2.3) and shunt releases (9.3.4.4.2.4).

[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 shall be tested according to Table 13.

[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 3.1.2 and 8.1.6) within the frame size, a further sample is tested at the maximum rated current corresponding to each construction.

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

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Table 14 – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 9.3.2.4

Test sequence	Test subclause	Test	Applicability to 3-pole variant[e]	Applicability to 1-pole or 2-pole variants[e]
I	9.3.4.2	Test of tripping limits and characteristics		
	9.3.4.2.1	General		X
	9.3.4.2.2	Short-circuit releases		X [d]
	9.3.4.2.3 a)[f] or or 9.3.4.2.3 b)[f] (as applicable)	Overload releases: – instantaneous/definite time-delay – inverse time-delay		X[d]
	9.3.4.2.4	Additional test for definite time-delay releases		
	9.3.4.3	Dielectric properties	X	X
	9.3.4.4	Mechanical operation and operational performance capability		
	9.3.4.4.1	General	X	X
	9.3.4.4.2	Construction and mechanical operation		X[c, d]
	9.3.4.4.3	Operational performance capability without current	X	X
	9.3.4.4.4	Operational performance capability with current	X	X
	9.3.4.4.5	Withdrawable circuit-breakers		
	9.3.4.5	Overload performance	X	X
	9.3.4.6	Verification of dielectric withstand	X	X
	9.3.4.7	Verification of temperature-rise	X	X
	9.3.4.8	Verification of overload releases		
	9.3.4.9	Verification of undervoltage and shunt releases	X	X
	9.3.4.10	Verification of the main contact position	X	X
II	9.3.5	Rated service short-circuit breaking capacity		
III	9.3.6[a, b]	Rated ultimate short-circuit breaking capacity	X	X
IV	9.3.7	Rated short-time withstand current		
V	9.3.8	Performance of integrally fused circuit-breakers	X	X
VI	9.3.9	Combined test sequence		
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] 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 10).

[b] Test at maximum kVA rating (I_{cu} × corresponding U_e).

[c] Without verification tests of undervoltage releases (9.3.4.4.2.3) and shunt releases (9.3.4.4.2.4).

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

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

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

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9.3.3 General test conditions

9.3.3.1 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) are given in Table 15 and, where applicable, for the alternative test programmes in Table 13 and Table 14 (see 9.3.2.4).

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

Unless otherwise specified, tests shall 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 3.1.2 and 8.1.6) within the frame size, further samples shall be tested in accordance with Table 13 and/or Table 15 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 AC, 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 undervoltage and shunt releases (see 8.2.1 of IEC 60947-1:2020 and 8.2.2.7 of IEC 60947-1:2020).

If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as specified in 8.2.1.1.4. 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 3.6.12 of IEC 60947-1:2020), 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.

Unless otherwise stated, the connections of the complete circuit-breaker, and of the separate release (when applicable, see 9.3.4.2.1), shall be made as for normal service, with conductors of cross-section corresponding to the rated current (I_n) (see Table 9 of IEC 60947-1:2020 with a minimum cross section of 1 mm^2, Table 10 of IEC 60947-1:2020, Table 11 of IEC 60947-1:2020) and of length according to 9.3.3.3.4 of IEC 60947-1:2020. In case of aluminium conductors, their cross sections shall be in accordance with Table D.7 or Table D.8, as applicable.

Circuit-breakers shall be tested in free air.

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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 9.3.6, at U_e max, and corresponding I_{cu}, with release settings at maximum (see footnote [a] of Table 15).

b) a temperature-rise test according to the general conditions of 9.3.3.5 on a circuit-breaker having a maximum I_{th}, at the conventional enclosed thermal rating I_{the} (see 5.3.3.2). The temperature-rises shall meet the requirements of 8.2.2 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 9.3.4.1.2, item d) of IEC 60947-1:2020) 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 Table 4, item 3.11).

Unless otherwise stated, all tests shall be performed with forward connections.

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 15 – Number of samples for test

Test sequence	Number of marked U_e or I_{cw} [p] ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Temperature-rise verification	Foot-notes
	1	2	Mul.	Yes	No			Min.	Max.		Corr.	Max.		
I	X	X	X	X	X	1	1		X	U_e max	See 9.3.4		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}) and VIII (I_{cu1})	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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Test sequence	Number of marked U_e or I_{cw} p ratings			Terminals marked line/load		Number of samples	Sample No.	Current setting [a]		Test voltage	Test current		Time delay		Tempe-rature-rise verifica-tion	Foot-notes
	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
VI (combined)	See test sequence II															
VII (I_{crit})	X	X	X	X	X	1	1		X	U_e max DC	X					g
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 15 applies to the test programmes of Table 10. In the case of the alternative test programmes (see 9.3.2.4), Table 13 and Table 14 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] Test at the maximum kVA rating (I_{cu} or I_{cs}, as applicable, multiplied by the corresponding U_e intermediate). This sample is omitted if another sample has previously been tested under the same conditions.

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

[g] In the case of one or more construction breaks (see 3.1.2 and 8.1.6) 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 ($I_{cw}^2 t$; where "t" is the corresponding short-time delay, see 5.3.6.4). 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 with sequence II ($I_{cu} = I_{cs}$, see 9.3.6).

[k] Connections reversed, if terminals unmarked, when sequence III is replaced with sequence II ($I_{cu} = I_{cs}$, see 9.3.6) or when sequence VI replaces sequences II, III and IV ($I_{cu} = I_{cs} = I_{cw}$, see 9.3.9), otherwise this sample is tested forward connected.

[l] Applies only to circuit breakers with a rated short-time withstand current (see 5.4).

[m] This sample, with connections reversed, is only required when terminals unmarked and sequence III is replaced with sequence IV ($I_{cu} = I_{cw}$, see 9.3.6).

[n] This sample is only required when sequence III is replaced with sequence IV ($I_{cu} = I_{cw}$, see 9.3.6).

[p] Read "U_e" for all test sequences except test sequence IV. Read "I_{cw}" for test sequence IV

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9.3.3.2 Test quantities

9.3.3.2.1 Values of test quantities

Subclause 9.3.2.2.1 of IEC 60947-1:2020 applies.

9.3.3.2.2 Tolerances on test quantities

Subclause 9.3.2.2.2 of IEC 60947-1:2020 applies.

9.3.3.2.3 Frequency of the test circuit for AC

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 %.

9.3.3.2.4 Power factor of the test circuit

Subclause 9.3.4.1.3 of IEC 60947-1:2020 applies with the following modification:

Table 16 of IEC 60947-1:2020 is replaced by Table 16 of this document.

Table 16 – 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		

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9.3.3.2.5 Time constant of the test circuit

Subclause 9.3.4.1.4 of IEC 60947-1:2020 applies with the following modification:

Table 16 of IEC 60947-1:2020 is replaced by Table 16 of this document.

9.3.3.2.6 Power-frequency recovery voltage

Subclause 9.3.2.2.3, item a) of IEC 60947-1:2020 applies.

9.3.3.2.7 Ripple of the test current for DC

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

9.3.3.3 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 document 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.

9.3.3.4 Test reports

Subclause 9.3.2.4 of IEC 60947-1:2020 applies.

9.3.3.5 Test conditions for temperature-rise test

The circuit-breaker shall meet the requirements of 8.2.2.

Subclause 9.3.3.3 of IEC 60947-1:2020 applies, except 9.3.3.3.6, with the following addition:

The circuit-breaker shall be mounted in accordance with 9.3.3.1.

During the temperature-rise test of sequence I (see 9.3.4.7) 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 AC circuit-breakers, a test shall first be carried out on the 3-phase poles; for the neutral pole, the additional single-phase test of 9.3.3.3.4 of IEC 60947-1:2020 applies only when there is a construction break between the neutral pole and the phase poles (see 8.1.6), in which case the test current is the rated current of the neutral pole.

DC circuit-breakers shall be connected in accordance with manufacturer's instructions. The details of the connections shall be stated in the test report.

9.3.3.6 Test conditions for short-circuit tests

9.3.3.6.1 General requirements

Subclause 9.3.4.1.1 of IEC 60947-1:2020 is amplified as follows:

a) The circuit-breaker shall be mounted in accordance with 9.3.3.1.

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.

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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 can 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 9.3.3.6.4).

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 overcurrent releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without overcurrent 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 circuit supply voltage of the release (see 8.2.1.2.3), 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 15.

9.3.3.6.2 Test circuit

Subclause 9.3.4.1.2 of IEC 60947-1:2020 applies.

9.3.3.6.3 Calibration of the test circuit

Subclause 9.3.4.1.5 of IEC 60947-1:2020 applies.

9.3.3.6.4 Test procedure

9.3.3.6.4.1 General

Subclause 9.3.4.1.6 of IEC 60947-1:2020 applies, with the following addition.

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

After calibration of the test circuit in accordance with 9.3.3.6.3, 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 10 (see 9.3.2).

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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 9.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2020) 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 9.3.4.2.3 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 9.3.5.2, 9.3.6.3, 9.3.7.5 and 9.3.8.7.

Alternative test programmes for circuit-breakers having three-pole and four-pole variants are given in 9.3.2.4.

9.3.3.6.4.3 Additional tests on four-pole circuit-breakers

Additional sequences of operations on one or more new samples, in accordance with Table 15, 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 9.3.3.6.4.2 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 60947-1:2020 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 9.3.2.4. When programme 1 is chosen, this subclause applies to the four-pole samples listed in Table 13.

9.3.3.6.4.4 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 3.14), 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 3.7.18 of IEC 60947-1:2020) during these tests may be recorded in the test report (see 8.2.1.2.4, item a)).

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

Subclause 9.3.4.1.7 of IEC 60947-1:2020 applies.

9.3.3.6.6 Interpretation of records

Subclause 9.3.4.1.8 of IEC 60947-1:2020 applies.

9.3.3.6.7 Verification after short-circuit tests

After the opening operations of the short-circuit making and breaking capacity tests of 9.3.5.2, 9.3.6.3, 9.3.7.5, 9.3.8.2, 9.3.8.7, 9.3.9.4, 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;

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

9.3.4 Test sequence I: General performance characteristics

9.3.4.1 General

This test sequence applies to all circuit-breakers and comprises the tests in Table 17.

Table 17 – Tests of test sequence I

Test	Subclause
Tripping limits and characteristics	9.3.4.2
Dielectric properties	9.3.4.3
Mechanical operation and operational performance capability	9.3.4.4
Overload performance (where applicable)	9.3.4.5
Verification of dielectric withstand and leakage current	9.3.4.6
Verification of temperature-rise	9.3.4.7
Verification of overload releases	9.3.4.8
Verification of undervoltage and shunt releases (if applicable)	9.3.4.9
Verification of main contact position	9.3.4.10

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

See 9.3.2 for tests that may be omitted from the sequence and made on separate samples.

9.3.4.2 Test of tripping limits and characteristics

9.3.4.2.1 General

Subclause 9.3.3.2 of IEC 60947-1:2020 is amplified as follows:

The ambient air temperature shall be measured as for the temperature-rise tests (see 9.3.3.5).

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When the overcurrent 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 9.3.3.1. The equipment under test shall be protected against undue external heating or cooling.

For circuit-breakers with adjustable overcurrent 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 5.7.2).

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 9.3.3.3.4 of IEC 60947-1:2020. 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 suitable voltage.

9.3.4.2.2 Short-circuit releases

The operation of short-circuit releases (see 5.7.1 item 2) shall be verified at 80 % and 120 % of the short-circuit current setting of the release. For AC tests, the test currents shall have no asymmetry. For DC 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 3.6.25 of IEC 60947-1:2020). Alternatively, in the case of a circuit-breaker having also a short-time delay short-circuit release (see 3.8), the current shall be maintained during the non-tripping duration stated by the manufacturer instead of 0,2 s (if the short-time delay short-circuit release is adjustable, the time-delay shall be adjusted to its maximum setting value for this test);

  NOTE The alternate proposal intends to avoid the unwanted tripping of the short-time delay short-circuit release during the test of the instantaneous release.

– 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 3.15);

– 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.

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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:

– within 0,2 s in the case of instantaneous releases (see 3.15);
– 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 9.3.4.2.4.

9.3.4.2.3 Overload releases

a) Instantaneous or definite time-delay releases

The operation of instantaneous or definite time-delay overload releases (see Note 1 of 5.7.1) shall be verified at 90 % and 110 % of the overload setting of the release. For AC tests, the test currents shall have no asymmetry. For DC 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 9.3.4.2.4.

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 3.15),
– 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 3.15),
– 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 9.3.4.2.1), 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 8.2.1.2.4, item b), 2).

For circuit-breakers having an identified neutral pole provided with an overload release (see 9.3.4.2.1), the test currents for this release shall be those given in Table 5 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 5.7.3 and Table 4 item 2.17), 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 7.1.1 of IEC 60947-1:2020), the release being energized on all phase poles.

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An additional test, at a current value equal to or greater than two times the current setting, 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 9.3.6.2, 9.3.6.5, 9.3.7.2, 9.3.7.7, 9.3.8.5, 9.3.8.9, 9.3.9.2 and 9.3.9.8).

9.3.4.2.4 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 9.3.4.2.1), 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;
- in the case of ground-fault overcurrent releases, on one pole chosen at random, and with the test setup described in 9.3.4.2.5.

The measured time-delay 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 overload, short-circuit and ground-fault overcurrent-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,

- in the case of short-circuit or overload releases, the current is reduced to the value corresponding to the overload current setting (I_r);
- in the case of ground-fault overcurrent releases, the current is reduced to 75 % of the ground-fault current setting (I_g);

and maintained at this value for twice the time-delay stated by the manufacturer. The circuit-breaker shall not trip.

9.3.4.2.5 Additional tests for ground-fault overcurrent releases

Annex T of IEC 60947-1:2020 applies, replacing "relay" by "release" when applicable, with the following additions.

Definite time-delay releases shall comply with the requirements of 9.3.4.2.4.

All tests shall be performed on one pole chosen at random.

For AC tests, the test current shall have no asymmetry. For DC tests, the current shall exhibit no overshoot at switch-on, and the time constant shall be less than 10 ms.

If the circuit-breaker is provided with a ground-fault I^2t characteristic (see Figure K.1), this I^2t characteristic shall be disabled for the tests.

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9.3.4.3 Test of dielectric properties

Subclause 9.3.3.4.1 of IEC 60947-1:2020 applies, with the following additions:

(i) with reference to 9.3.3.4.1, item 2) c) i) and ii), of IEC 60947-1:2020: the normal positions of operation include the tripped position, if any;

(ii) with reference to 9.3.3.4.1, item 3 c), of IEC 60947-1:2020: for the purposes of this document circuits incorporating solid-state devices connected to the main circuit shall be disconnected for the test;

(iii) for circuit-breakers having an operational voltage greater than 50 V, the leakage current, measured through each pole with the circuit-breaker in the open position and in the tripped position (if any), at a test voltage of 1,1 U_e, shall not exceed 0,5 mA;

(iv) circuit-breakers having a rated insulation voltage greater than 1 000 V AC shall be tested at a voltage of U_i + 1 200 V AC RMS or 2 U_i whichever is the greater;

(v) withdrawable circuit-breakers (see 8.1.2) shall be subject to verification of impulse withstand voltage, as per 9.3.3.4.1, item 2) b) of IEC 60947-1:2020. The test voltage shall be selected from Table 14 of IEC 60947-1:2020, and shall be applied between the withdrawable unit's isolating contacts, in the disconnected position. Acceptance criteria are as per 9.3.3.4.1, item 2) d) of IEC 60947-1:2020.

9.3.4.4 Tests of mechanical operation and of operational performance capability

9.3.4.4.1 General test conditions

The circuit-breaker shall be mounted in accordance with 9.3.3.1 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 circuit 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 9.3.4.4.2, 9.3.4.4.3 and 9.3.4.4.4 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 9.3.4.4.2 and 9.3.4.4.3 may, alternatively, be made on a new sample.

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.

9.3.4.4.2 Construction and mechanical operation

9.3.4.4.2.1 Construction

A withdrawable circuit-breaker shall be checked for the requirements stated in 8.1.2.

A circuit-breaker with stored energy operation shall be checked for compliance with 8.2.1.1.6, regarding the charge indicator and the direction of operation of manual energy storing.

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9.3.4.4.2.2 Mechanical operation

Tests shall be made as specified in 9.3.4.4.1 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 8.2.1.1.4.

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 8.2.1.1.6 with the auxiliary supply voltage at 85 % and 110 % of the rated control circuit 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.

9.3.4.4.2.3 Undervoltage releases

Undervoltage releases shall comply with the requirements of 8.2.1.3 of IEC 60947-1:2020. 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 circuit 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 circuit 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 circuit 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 9.3.4.7.

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

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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 circuit 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 circuit 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 circuit supply voltage for 4 h without impairing its functions.

9.3.4.4.2.4 Shunt releases

Shunt releases shall comply with the requirements of 8.2.1.4 of IEC 60947-1:2020. 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 circuit 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 circuit supply voltages, the test voltage shall be 70 % of the minimum rated control circuit supply voltage.

9.3.4.4.3 Operational performance capability without current

These tests shall be made under the conditions specified in 9.3.3.1. The number of operating cycles to be carried out on the circuit-breaker is given in column 3 of Table 7; 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 (column 3 of Table 7) shall be closing/tripping operations, with the shunt release energized at maximum rated control circuit supply voltage.

For circuit-breakers which can be fitted with undervoltage releases, 10 % of the total number of operating cycles (column 3 of Table 7) shall be closing/tripping operations at the minimum rated control circuit 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 circuit 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 6.

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

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9.3.4.4.4 Operational performance capability with current

The circuit-breaker condition and method of installation shall be as specified in 9.3.3.1, the test circuit being in accordance with 9.3.3.5.2 of IEC 60947-1:2020.

The operating rate and the number of operating cycles to be carried out are given in columns 2 and 4 of Table 7.

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 16, the tolerance being in accordance with 9.3.3.2.2.

Tests on AC 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 circuit 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 6.

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

9.3.4.4.5 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.

9.3.4.5 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 9.3.3.1, and the test circuit in accordance with 9.3.3.5.2 of IEC 60947-1:2020.

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 18 (see also 9.3.2.2.3 a) of IEC 60947-1:2020).

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.

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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 suitable 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 7. If the circuit-breaker does not latch in at the specified rate, this rate may be reduced so that the circuit-breaker can be closed, the full current being established.

The values of the test current and of the recovery voltage shall be in accordance with Table 18, at the power factor or time constant, as applicable, in accordance with Table 16, the tolerances being in accordance with 9.3.3.2.2.

Table 18 – 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 AC 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.

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

The number of manual and automatic operations, the on durations and, if different from that indicated in Table 7, the operating rate shall be stated in the test report.

9.3.4.6 Verification of dielectric withstand and leakage current

9.3.4.6.1 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.

9.3.4.6.2 Test voltage for dielectric withstand

Subclause 9.3.3.4.1, item 4) b), of IEC 60947-1:2020 applies with the following modification.

The test voltage shall be AC in case of an AC circuit-breaker, DC in case of a DC circuit-breaker.

The test voltage for an AC circuit-breaker shall be 2 U_e with a minimum of 1 000 V RMS. Only if an AC test voltage cannot be applied to the AC circuit-breaker, for example due to EMC filter components, the test shall be conducted using a DC test voltage of 2 U_e × 1,415 with a minimum of 1 415 V DC.

The test voltage for a DC circuit-breaker shall be 2 U_e with a minimum of 1 415 V DC.

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For dielectric tests involving the main circuit, the value of U_e referred to in this subclause is that at which the preceding switching and/or short-circuit tests have been conducted.

9.3.4.6.3 Application of the test voltage for dielectric withstand

The test voltage shall be applied for 5 s in accordance with 9.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2020 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 9.3.3.4.1, item 1), of IEC 60947-1:2020 is not required. For the purposes of this document, 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.

9.3.4.6.4 Acceptance criteria for dielectric withstand

Subclause 9.3.3.4.1, item 3) d), of IEC 60947-1:2020 applies.

9.3.4.6.5 Leakage current measurement

The leakage current shall be measured in open position only, in accordance with 9.3.4.3, item (iii), except that the leakage current shall not exceed 2 mA. The corresponding test voltage shall be applied for 5 s.

9.3.4.7 Verification of temperature-rise

Following the test according to 9.3.4.6, a temperature-rise test shall be made at the conventional thermal current according to 9.3.3.5. At the end of the test, the values of temperature-rise shall not exceed those specified in Table 6.

9.3.4.8 Verification of overload releases

Immediately following the test according to 9.3.4.7, the operation of overload releases shall be verified at 1,45 times the value of their current setting at the reference temperature (see 8.2.1.2.4, item b), 2)).

For this test, all poles shall be connected in series. If applicable, ground-fault overcurrent releases shall be deactivated during the test.

Alternatively, this test may be made using a 3-phase supply.

This test may be made at any suitable voltage.

The operating time shall not exceed the conventional tripping time.

With the manufacturer's consent, a time interval between the tests of 9.3.4.7 and 9.3.4.8 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.

9.3.4.9 Verification of undervoltage and shunt releases

Circuit-breakers fitted with undervoltage releases shall be subjected to the test of 9.3.4.4.2.3 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 rated control circuit supply voltage and shall operate at 35 % of the maximum rated control circuit supply voltage.

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Circuit-breakers fitted with shunt releases shall be subjected to the test of 9.3.4.4.2.4, 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 circuit supply voltage.

9.3.4.10 Verification of the main contact position

Following the verification of 9.3.4.8, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 9.2.6 of IEC 60947-1:2020. For the first criterion of 9.2.6.3.1 of IEC 60947-1:2020 (actuator being left free), Figure 2 applies for the application of the test force (see 9.2.6.2.1 of IEC 60947-1:2020).

NOTE For circuit-breakers in accordance with this document, the operating handle of which moves rotating around an axis, the term "extremity" in 9.2.6.2.1 of IEC 60947-1:2020 is the maximum lever arm length perpendicular to this axis.

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

9.3.5.1 General

Except when the test sequence VI (combined) applies (see 9.3.9), this test sequence applies to all circuit-breakers and comprises the tests in Table 19.

Table 19 – Tests of test sequence II

Test	Subclause
Rated service short-circuit breaking capacity	9.3.5.2
Verification of operational performance capability	9.3.5.3
Verification of dielectric withstand and leakage current	9.3.5.4
Verification of temperature-rise	9.3.5.5
Verification of overload releases	9.3.5.6

For the case where $I_{cs} = I_{cu}$, see 9.3.6.

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

9.3.5.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 9.3.3, with a value of prospective current I_{cs}, as declared by the manufacturer, in accordance with 5.3.6.2.4.

The power factor for this test shall be according to Table 16, 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 be extended for this purpose.

9.3.5.3 Verification of operational performance capability

Following the test according to 9.3.5.2, the operational performance capability shall be verified in accordance with 9.3.4.4.4 except that this verification shall be made at the same rated operational voltage as used for the test of 9.3.5.2, and that the number of operations shall be 5 % of the number given in column 4 of Table 7.

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This verification need not be made where, for a given frame size, the test of 9.3.5.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting as specified in Table 15.

9.3.5.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.5.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

9.3.5.5 Verification of temperature-rise

Following the test according to 9.3.5.4, the temperature-rise at the main terminals shall be verified in accordance with 9.3.3.5. The temperature-rise shall not exceed the values given in Table 6.

This verification need not be made where, for a given frame size, the test of 9.3.5.2 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

9.3.5.6 Verification of overload releases

Immediately following the test according to 9.3.5.5, the operation of overload releases shall be verified in accordance with 9.3.4.8.

With the manufacturer's consent, a time interval between the tests of 9.3.5.5 and 9.3.5.6 may occur.

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

9.3.6.1 General

Except where the test sequence VI (combined) applies (see 9.3.9), 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 2 (5.3.6.4); 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 15) and the following verifications shall additionally be made in test sequence II:

– the verification of 9.3.6.2, at the beginning of the test sequence;
– the verification of 9.3.6.5, at the end of the test sequence.

This test sequence comprises the tests in Table 20.

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Table 20 – Tests of test sequence III

Test	Subclause
Verification of overload releases	9.3.6.2
Rated ultimate short-circuit breaking capacity	9.3.6.3
Verification of dielectric withstand and leakage current	9.3.6.4
Verification of overload releases	9.3.6.5

The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15.

9.3.6.2 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 suitable voltage. If applicable, ground-fault overcurrent releases shall be deactivated during the test; alternatively, each pole shall be tested in series with 2 other poles connected in parallel.

This test is omitted for electronic trip units.

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. magnetic releases), connection data (type, cross-section, length) may be different from those required in 9.3.3.3.4 of IEC 60947-1:2020. 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.

9.3.6.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to 9.3.6.2, 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 9.3.3.

The sequence of operations shall be:

$$O - t - CO$$

9.3.6.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.6.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

9.3.6.5 Verification of overload releases

Following the test according to 9.3.6.4, the operation of overload releases shall be verified in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature.

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For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

9.3.7 Test sequence IV: Rated short-time withstand current

9.3.7.1 General

Except where the test sequence VI (combined) applies (see 9.3.9), this test sequence applies to circuit-breakers with a rated short-time withstand current (see 5.4); it comprises the tests in Table 21.

Table 21 – Tests of test sequence IV

Test	Subclause
Verification of overload releases	9.3.7.2
Rated short-time withstand current	9.3.7.3
Verification of temperature-rise	9.3.7.4
Short-circuit breaking capacity at maximum short-time withstand current	9.3.7.5
Verification of dielectric withstand and leakage current	9.3.7.6
Verification of overload releases	9.3.7.7

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 15.

9.3.7.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

9.3.7.3 Test of rated short-time withstand current

Subclause 9.3.4.3 of IEC 60947-1:2020 applies with the following addition:

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

9.3.7.4 Verification of temperature-rise

Following the test according to 9.3.7.3, the temperature-rise at the main terminals shall be verified according to 9.3.3.5. The temperature-rise shall not exceed the value given in Table 6.

With the manufacturer's agreement the verification of the temperature-rise may be made after the verification of the dielectric withstand (9.3.7.6). This verification need not be made where, for a given frame size, the test of 9.3.8.3 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

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

Following the test according to 9.3.7.4, 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 9.3.3, with a value of prospective current equal to that of the short-time withstand current test (see 9.3.7.3) 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 3.6), 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 9.3.3.6.4.3.

9.3.7.6 Verification of dielectric withstand and leakage current

Following the test carried out according to 9.3.7.5, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

9.3.7.7 Verification of overload releases

Following the test according to 9.3.7.6, the operation of overload releases shall be verified in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

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

9.3.8.1 General

This test sequence applies to integrally fused circuit-breakers. It replaces test sequence III and comprises the tests in Table 22.

Table 22 – Tests of test sequence V

	Test	Subclause
Stage 1	Short-circuit at the selectivity limit current	9.3.8.2
	Verification of temperature-rise	9.3.8.3
	Verification of dielectric withstand and leakage current	9.3.8.4
Stage 2	Verification of overload releases	9.3.8.5
	Short-circuit at 1,1 times take-over current	9.3.8.6
	Short-circuit at ultimate short-circuit breaking capacity	9.3.8.7
	Verification of dielectric withstand and leakage current	9.3.8.8
	Verification of overload releases	9.3.8.9

This test sequence is divided into two stages:

– Stage 1 comprises the tests according to 9.3.8.2 to 9.3.8.4;
– Stage 2 comprises the tests according to 9.3.8.5 to 9.3.8.9.

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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 9.3.8.4 may be omitted.

The test according to 9.3.8.3 need only be made if $I_{cs} > I_s$.

Tests according to 9.3.8.2, 9.3.8.6 and 9.3.8.7 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 15.

9.3.8.2 Short-circuit at the selectivity limit current

A short-circuit test is made under the general conditions of 9.3.3, with a value of prospective current equal to the selectivity limit current, as declared by the manufacturer.

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.

9.3.8.3 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, 9.3.5.2, in which case the test of 9.3.8.2 is more severe.

Following the test according to 9.3.8.2, the temperature-rise at the main terminals shall be verified, in accordance with 9.3.3.5.

The temperature-rise shall not exceed the value given in Table 6.

9.3.8.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.8.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

9.3.8.5 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

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

Following the test according to 9.3.8.5, a short-circuit test is made under the same general conditions as in 9.3.8.2, with a value of prospective current equal to 1,1 times the take-over current declared by the manufacturer.

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 three of the fuses for a four-pole circuit-breaker;
– at least two of the fuses for a three-pole circuit-breaker;
– at least one of the fuses for a two-pole circuit-breaker;
– the fuse for a one-pole circuit-breaker;

shall have blown.

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

Following the test according to 9.3.8.6, a short-circuit test is made under the same general conditions as in 9.3.8.2, 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 be extended for that purpose.

9.3.8.8 Verification of dielectric withstand and leakage current

Following the test according to 9.3.8.7 and with a new set of fuses fitted, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

9.3.8.9 Verification of overload releases

Following the test according to 9.3.8.8, the operation of overload releases shall be verified in accordance with 9.3.6.2 except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

9.3.9 Test sequence VI: Combined test sequence

9.3.9.1 General

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; or

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 tests of Table 23.

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Table 23 – Tests of test sequence VI

Test	Subclauses
Verification of overload releases	9.3.9.2
Rated short-time withstand current	9.3.9.3
Rated service short-circuit breaking capacity*	9.3.9.4
Verification of operational performance capability	9.3.9.5
Verification of dielectric withstand and leakage current	9.3.9.6
Verification of temperature-rise	9.3.9.7
Verification of overload releases	9.3.9.8
* For circuit-breakers falling into the case of 9.3.9.1 b) 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 15.

9.3.9.2 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.6.2.

9.3.9.3 Test of rated short-time withstand current

Following the test according to 9.3.9.2, a test shall be made at the rated short-time withstand current according to 9.3.7.3.

This test does not need to be made on the sample of minimum I_n specified in Table 15.

9.3.9.4 Test of rated service short-circuit breaking capacity

Following the test according to 9.3.9.3, a test shall be made at the rated service short-circuit breaking capacity according to 9.3.5.2, 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 during the closing operation only.

9.3.9.5 Verification of operational performance capability

Following the test according to 9.3.9.4, the operational performance capability shall be verified in accordance with 9.3.5.3.

9.3.9.6 Verification of dielectric withstand and leakage current

Following the test according to 9.3.9.5, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6.

9.3.9.7 Verification of temperature-rise

Following the test according to 9.3.9.6, the temperature-rise at the main terminals shall be verified in accordance with 9.3.5.5.

The temperature-rise shall not exceed the value given in Table 6.

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This verification need not be made where, for a given frame size, the test of 9.3.9.4 has been made on a circuit-breaker of minimum I_n or at the minimum overload release setting.

9.3.9.8 Verification of overload releases

After cooling down following the test according to 9.3.9.7, the operation of overload releases shall be verified in accordance with 9.3.4.8.

Thereafter, the operation of the overload releases shall be verified on each pole individually in accordance with 9.3.6.2, except that the test current shall be 2,5 times the value of their current setting, and testing of electronic trip units is required.

For electromagnetic overcurrent releases the operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting of a single pole at the reference temperature.

For electronic overcurrent releases the operating time shall comply with the tolerance band stated by the manufacturer for 2,5 times the value of the current setting of a single pole.

9.3.10 Test sequence VII: Critical DC load current

This test applies only to circuit-breakers with DC ratings.

NOTE A common procedure for the determination of the critical DC load current is under revision for integration in IEC 60947-1.

The circuit-breaker condition and method of installation shall be as specified in 9.3.3.1, and the test circuit in accordance with 9.3.3.5.2 of IEC 60947-1:2020 except that the metallic screen and the fusible element shall not be used.

Samples to be tested shall be selected according to Table 15 – test sequence I, except that for application of footnote g, construction breaks relative to the overcurrent tripping devices shall not be considered.

The test shall be made at the maximum operational DC 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 16 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 7.

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

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The test current values shall be: 4 A, 8 A, 16 A, 32 A and 63 A DC, 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 9.3.3.2.2.

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 and the leakage current shall be verified according to 9.3.4.6 with a DC test voltage.

9.3.11 Test sequence VIII: Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage

9.3.11.1 General

A circuit-breaker shall be able to interrupt a fault to earth. In this case, the short-circuit current shall be interrupted by only one phase pole, at the phase-to-neutral voltage.

For:

– 1-pole circuit-breakers,
– 3-pole and 4-pole circuit-breakers where all phase poles are of the same design,
– 2-pole circuit-breakers the poles of which are of the same design as those of a 3-pole or 4-pole circuit-breaker compliant with this document

the performance is covered by 9.3.6 and no additional tests are required. In these cases, I_{cu1} is considered as equal to I_{cu}.

The tests in 9.3.11.2 to 9.3.11.5 apply to 2-pole circuit-breakers the poles of which are not of the same design as to those of a 3-pole or 4-pole circuit-breaker compliant with this document, or to 3-pole or 4-pole circuit-breakers the phase poles of which are not of the same design.

This test sequence comprises the tests of Table 24.

Table 24 – Tests of test sequence VIII

Test	Subclause
Verification of overload releases	9.3.11.2
Rated ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	9.3.11.3
Verification of dielectric withstand and leakage current	9.3.11.4
Verification of overload releases	9.3.11.5

9.3.11.2 Verification of overload releases

The operation of the overload releases shall be verified according to 9.3.6.2.

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9.3.11.3 Rated ultimate short-circuit breaking capacity at phase-to-neutral AC voltage

A short-circuit test is made on each individual phase pole of the circuit-breaker under the general conditions of 9.3.3, at a value of current equal to I_{cu1}. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The test voltage(s) shall be the corresponding phase-to-neutral voltage of the test voltage(s) listed in Table 15, corresponding to the maximum rated operational voltage of the circuit-breaker, taking into account the requirements for recovery voltage of 9.3.3.2.6. The power factor appropriate to the test current shall be in accordance with Table 16. The short-time or instantaneous pick-up setting shall be adjusted to its maximum value.

The test circuit shall be in accordance with 9.3.4.1.2 of IEC 60947-1:2020 and Figure 9 of IEC 60947-1:2020.

The sequence of operations shall be: O – *t* – CO.

9.3.11.4 Verification of dielectric withstand and leakage current

Following the test according to 9.3.11.3, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

9.3.11.5 Verification of overload releases

The operation of the overload releases shall be verified according to 9.3.6.5.

9.4 Routine tests

9.4.1 General

For the definition of routine tests, see 3.8.2 of IEC 60947-1:2020 and 9.1.3 of IEC 60947-1:2020.

The following tests apply:

– mechanical operation (9.4.2);
– verification of the calibration of overcurrent releases (9.4.3);
– verification of the operation of undervoltage and shunt releases (9.4.4);
– additional tests for CBRs to Annex B (9.4.5);
– dielectric tests (see note) (9.4.6);
– verification of clearances (9.4.7).

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 ISO 2859-1).

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 9.4.3, 9.4.4 and 9.4.5 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 9.4.2, 9.4.3, 9.4.4, 9.4.6 and 9.4.7, the term "circuit-breakers" covers CBRs, where applicable.

9.4.2 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.

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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 3.6.24 of IEC 60947-1:2020.

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

9.4.3 Verification of the calibration of overcurrent releases

9.4.3.1 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 5.7.3).

9.4.3.2 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 9.3.4.2.2 or 9.3.4.2.3, 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.

9.4.4 Verification of the operation of undervoltage and shunt releases

9.4.4.1 Undervoltage releases

Tests shall be made to verify that the release will operate in accordance with 8.2.1.3 of IEC 60947-1:2020 as follows:

a) Hold-in voltage

The release shall close on to a voltage corresponding to 85 % of the minimum rated control circuit 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 circuit supply voltage, adjusted to take account of the need to operate under the conditions specified in 9.3.4.4.2.3 i). In the case of releases having a range of rated control circuit supply voltages, the upper limit shall correspond to the minimum of the range and the lower limit to the maximum of the range.

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9.4.4.2 Shunt releases (for opening)

A test shall be made to verify that the release will operate in accordance with 8.2.1.4 of IEC 60947-1:2020. 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 9.3.4.4.2.4. In the case of a release having a range of rated control circuit supply voltages, the test voltage shall be related to 70 % of the minimum rated control circuit supply voltage.

9.4.5 Additional tests for CBRs

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

a) Operation of the test device

The CBR shall be subjected to two close-trip operations or, in the case of RC 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.

9.4.6 Dielectric tests

The test conditions shall be in accordance with 9.3.3.4.1, item 1), of IEC 60947-1:2020, 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

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2) power frequency or DC withstand voltage

The test apparatus shall be as stated in 9.3.3.4.1, item 3) b), of IEC 60947-1:2020, 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 RMS or 1 415 V DC, applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency or DC test in accordance with item a) 2) above. For AC tests, the test voltage shall be 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 or 1 000 V RMS. For DC tests, the test voltage shall be equal to the highest of the values of the following: 30 % of U_{imp}, 2 U_i or 1 415 V DC.

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

For tests a) 2) and b), the following requirements apply:

– AC circuit-breakers shall be tested with power frequency voltage. Alternatively, they may be tested with a DC voltage equal to the peak value of the AC test voltage.

– DC circuit-breakers shall be tested with DC voltage. Alternatively, they may be tested with an AC voltage the RMS value of which shall be equal to the value of the DC test voltage.

If dielectric properties are tested according to a sampling plan in accordance with the note to 9.4.1, a power frequency withstand test shall be made according to 9.4.6, item a) 2) of this subclause, but with a test voltage in accordance with Table 19 of IEC 60947-1:2020. Circuit-breakers having a rated insulation voltage greater than 1 000 V AC shall be tested at a voltage of U_i + 1 200 V AC RMS or 2 U_i whichever is the greater.

9.4.7 Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2020

Subclause 9.3.3.4.3 of IEC 60947-1:2020 applies, except that for the purposes of this document this test shall be a routine test.

NOTE The case of clearances greater than or equal to case A of Table 13 of IEC 60947-1:2020 is covered by the tests of 9.4.6.

9.5 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 3.8.4 of IEC 60947-1:2020). 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 document.

Annex Q of IEC 60947-1:2020 applies.

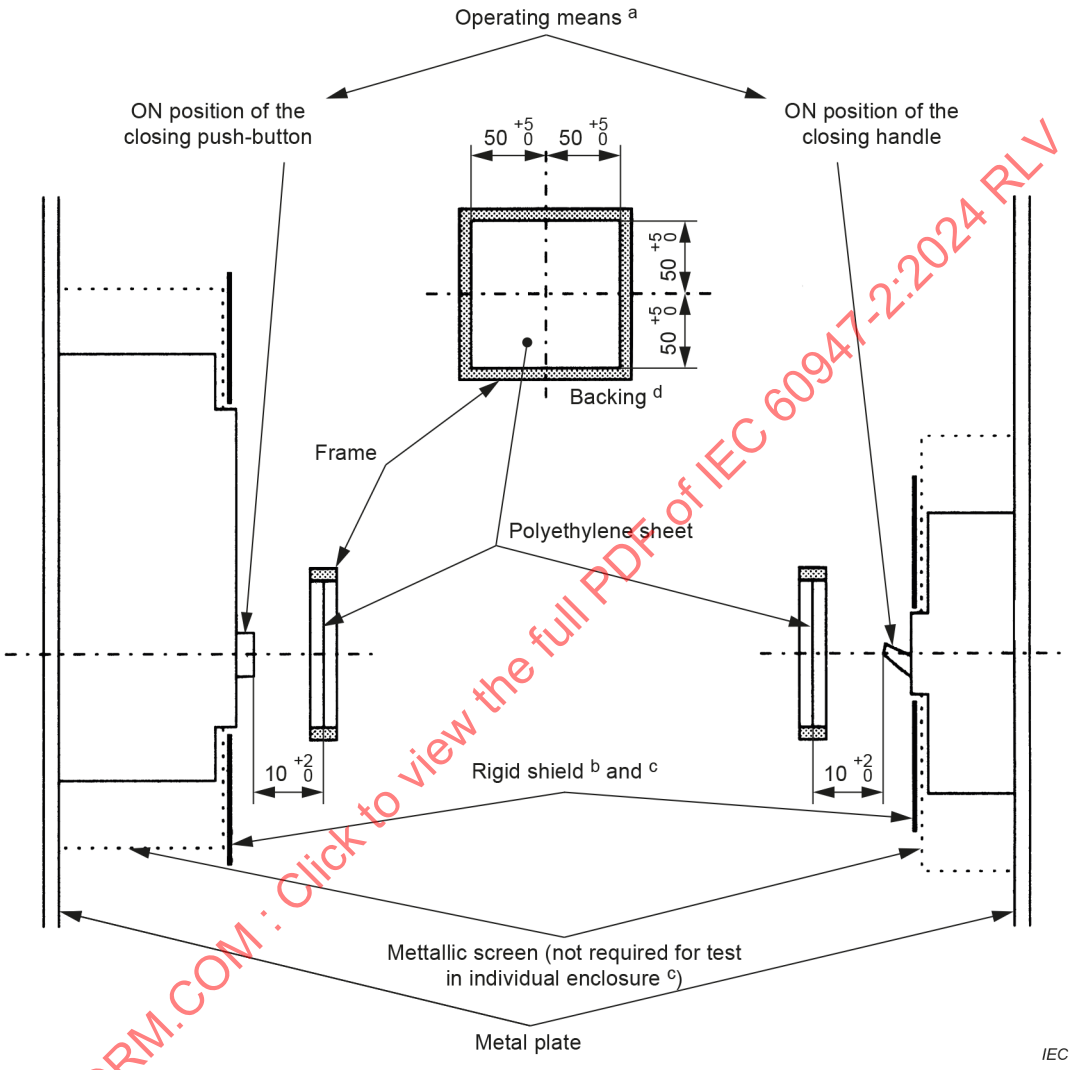
During the test sequences according to Table Q.1 of IEC 60947-1:2020, only the final verification of operational performance capability is required. It shall be made by carrying out the routine tests of 9.4, except for the dielectric tests of 9.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2020.

With reference to footnote e) of Table Q.1 of IEC 60947-1:2020, for dry heat test, the circuit-breaker shall not carry current. Where an under-voltage release is fitted, it shall be energized with rated voltage. The circuit-breaker shall be operated according to 9.4.2 during the last hour of the test.

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With reference to footnote g) of Table Q.1 of IEC 60947-1:2020, during damp heat test, the functional test shall consist of the mechanical operations of 9.4.2 of this document. When only manual operating means are available, this test can be done during the beginning of the following cold period.

Dimensions in millimetres



Case of circuit-breaker with closing push-button **Case of circuit-breaker with a closing handle**

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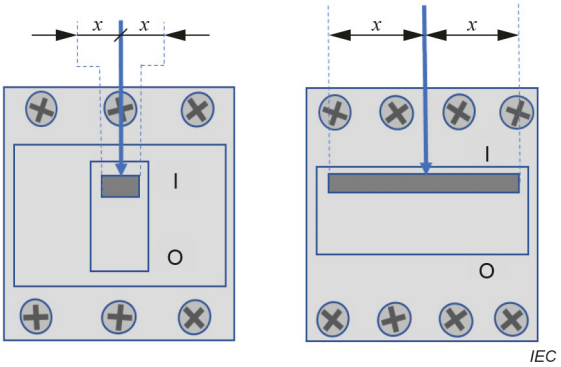
[a] The operating means includes any extension which is normally fitted for the closing operation.

[b] 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).

[c] The rigid shield and the front of the metallic screen may be combined into one single conductive metal plate.

[d] 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



For the application of the test force, see 9.2.6.2.1 of IEC 60947-1:2020.

For the first criterion, actuator being left free, see 9.2.6.3.1 of IEC 60947-1:2020.

Figure 2 – Examples of application of the test force for the verification of the effectiveness of the indication of the main contact position (first criterion, actuator being left free)

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Annex A
(normative)

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

A.1 General

Clause X.1 of IEC 60947-1:2020 applies with the following change:

In Figure X.1 of IEC 60947-1:2020, "I_{cn}" is replaced with "I_{cu}" (see 5.3.6.2.2).

A.2 Object

Clause X.2 of IEC 60947-1:2020 applies.

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

Clause X.3 of IEC 60947-1:2020 applies, with the following addition:

The association shall also comply with the information required in the 2nd paragraph of 8.2.1.2.4 item a).

A.4 Type and characteristics of the associated SCPD

Clause X.4 of IEC 60947-1:2020 applies.

A.5 Verification of selectivity

Clause X.5 of IEC 60947-1:2020 applies with the following change:

In Figure X.1 of IEC 60947-1:2020, "I_{cn}" is replaced with "I_{cu}" (rated ultimate short-circuit breaking capacity, see 5.3.6.2.2).

A.6 Verification of back-up protection

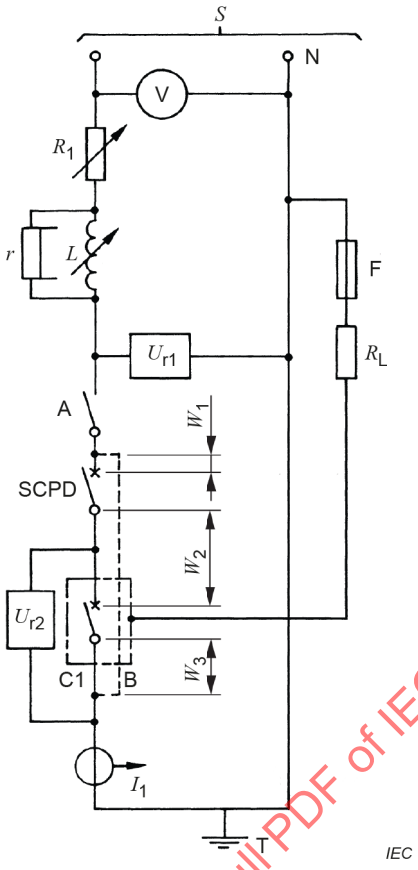
Clause X.6 of IEC 60947-1:2020 applies, with following additions:

Following the tests, if C1 is a circuit-breaker, it shall comply with 9.3.6.4 and 9.3.6.5.

For the verification of the individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}, see 9.3.11), Figure A.1 applies.

NOTE "Back-up protection" is defined in 535.5 of IEC 60364-5-53:2019 as "Combined short-circuit protection".

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Key

S	supply
U_{r1}, U_{r2}	voltage sensors
V	voltage measuring device
A	closing device
R_1	adjustable resistor
N	neutral of supply (or artificial neutral)
F	fusible element (9.3.4.1.2, item d) of IEC 60947-1:2020)
L	adjustable reactors
R_L	fault-current limiting resistor
B	temporary connections for calibration
I_1	current sensing device
T	earth: one earthing point only (load side or supply side)
r	shunting resistor (9.3.4.1.2, item b) of IEC 60947-1:2020)
W_1	75 cm of cable rated for SCPD
W_2	50 cm of cable rated for C1
W_3	25 cm of cable rated for C1
SCPD	circuit-breaker C2 or set of 3 fuses
C1	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.

Figure A.1 – Cable connections for conditional short-circuit breaking capacity tests in the case of a single pole under phase-to-neutral AC voltage (C1)

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Annex B
(normative)

Circuit-breakers incorporating residual current protection (CBRs)

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 fault protection, i.e. hazardous increases of ground potential due to defective insulation.

NOTE 1 In IEC 61140, "fault protection" was previously referred to as "protection of persons against indirect contact".

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 overcurrent protective device.

Residual current devices having a rated residual current not exceeding 30 mA are also used as additional means for basic protection in the event of failure of the relevant protective means.

NOTE 2 In IEC 61140, "basic protection" was previously referred to as "protection of persons against direct contact".

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 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 RC 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.

NOTE 1 RC units do not have an adverse impact on the performance of the circuit-breaker, as verified by the performance tests per Clause 9.

NOTE 2 The current sensing means can be external to the CBR.

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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 AC circuits.

NOTE 3 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 dependent on an alternative supply source are not covered by this annex.

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 3 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 RMS value

[SOURCE: IEC 60050-442:2019, 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 60050-442:2019, 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 60050-442:2019, 442-05-21, modified – "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 3.1) 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 60050-442:2019, 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 60050-442:2019, 442-05-25, modified – In the term, "(of 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 60050-442:2019, 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 causing it to operate

[SOURCE: IEC 60050-442:2019, 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 60050-442:2019, 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 RC 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 overcurrent in the case of a single-phase load
maximum value of a single-phase overcurrent 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 AC component of a prospective residual 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 DC 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 RMS 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.

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.

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B.4.1.2 Rated residual non-operating current ($I_{\Delta no}$)

The RMS 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 RMS value of the AC 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 applicable.

$I_{\Delta n}$ 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 overcurrent in the case of a single-phase load

The limiting value of non-operating overcurrent 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 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 $I_{\Delta n}$ ≤ 30 mA, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.				
[b] For CBRs having $I_{\Delta n}$ ≤ 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 $I_{\Delta n}$ ≤ 30 mA shall be of the non-time-delay type.

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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}.

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 DC 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 DC 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 DC (± 6 mA), whether suddenly applied or slowly rising.

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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 6.2 and, in addition, in accordance with Table B.3.

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Table B.3 – Product information

Item	Information	Marking location	
		Integral CBR	RC 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 DC 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 [a]	Marked [a]
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 [a]	Marked [a]
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 $I_n \leq$ ...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 RC 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

[a] See 5.7.3.

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B.6 Normal service, mounting and transport conditions

Clause 7 applies.

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 RC unit device and a circuit-breaker shall be so designed and built that:

– the coupling system of the RC unit and the associated circuit-breaker does not require any mechanical and/or electrical connection that can adversely affect the installation or result in injury to the user;

– the addition of the RC unit does not adversely affect in any way either the normal operation or the performance capabilities of the circuit-breaker;

– the RC 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, whatever the phase angle of the current regarding the supply voltage.

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.

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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.

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 overcurrent in the case of a single-phase load

CBRs shall withstand the smaller of the following two overcurrent 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 DC component

The behaviour of CBRs in the case of an earth fault current comprising a DC 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.

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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.

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.

For CBRs of type B with rated residual current of 0,006 A, respectively 0,01 A, the value of 3 mA, respectively 5 mA, shall be used for this test.

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 $I_{\Delta n}$ > 0,03 A or 2 $I_{\Delta n}$ for CBRs with $I_{\Delta n}$ ≤ 0,03 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.

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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).

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 9.3.4.4.4 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.

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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.

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 subclause 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 RMS value.

Tests specified in this annex are supplementary to the tests of Clause 9.

a) Type tests

CBRs shall be submitted to all relevant test sequences of Clause 9. For the dielectric withstand verifications during these test sequences (see 9.3.4.6), 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 RC 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.

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b) Routine tests

Subclause 9.4.5 applies.

B.8.1.2 Tests to be carried out during the test sequences of Clause 9

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 (9.3.4.2) 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 9.3.4.4.4) specified in Table 7 (see 8.2.4.2), a third of the breaking operations shall be performed by actuating the test device, 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, the remaining operations being tested in accordance with 9.3.4.4.4.

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 (9.3.4.4.4).

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 9.3.5, 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 9.3.6.2 and 9.3.6.5 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 9.3.6.2 and 9.3.6.5 but applicable to two poles.

Following the tests of 9.3.6, 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 9.3.7.3 or 9.3.9.3, 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 9.3.7.2 and 9.3.7.7, the single pole tests specified in 9.3.6.2 shall be replaced by two-pole tests, made on all possible combinations of phase poles in turn.

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– for the combined test sequence

For the purpose of verifying the correct operation of the overload releases in accordance with 9.3.9.2, the single pole test specified in 9.3.6.2 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 9.3.9.7, the test specified in 9.3.4.8 shall be carried out using a three-phase supply.

c) Verification of the residual current tripping device

Following the tests of 9.3.7 or 9.3.9, 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 CBRs (test sequence V)

For the purpose of verifying the correct operation of the overload releases, the single-pole tests specified in 9.3.8.5 and 9.3.8.9 shall be replaced by two-pole tests, on all possible combinations of phase poles in turn, the test conditions being as specified in 9.3.8.5 and 9.3.8.9 but applicable to two poles.

Following the tests of 9.3.8, verification of the correct operation of the CBR shall be performed in accordance with B.8.2.4.4.

B.8.1.2.2.5 Test sequence VI (combined)

Following the tests of 9.3.9, 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 overcurrent 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

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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 suitable 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 suitable 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 laboratory, 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.8.2.4.1), 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.8.2.4.6 Verification of correct operation in case of sudden appearance of residual currents higher than 5 $I_{\Delta n}$

The test circuit shall be calibrated at any two values of residual current chosen by the testing laboratory from the following list: 5 A, 10 A, 20 A, 50 A, 100 A and 200 A. The switch S1 and the CBR being in the closed position, the residual current shall be suddenly established by closing the switch S2.

The test shall be carried out once for each of the two chosen values. The CBR shall trip during each test and the break time shall not exceed the limiting value specified in B.4.2.4.1 or B.4.2.4.2.2, as applicable.

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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 5.7.3) 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.

For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the CBR shall be loaded again with its rated current until the thermal steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

B.8.3 Verification of dielectric properties

CBRs shall comply with 9.3.4.3.

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.

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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 overcurrent 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 suitable 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.

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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.

B.8.7 Additional verifications for CBRs of types A and B

B.8.7.1 Test conditions

The test conditions of B.8.1.1 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.

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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 DC 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 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 $I_{\Delta n} \geq$ 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 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.

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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 %.

Table B.7 – Composite test current definition and starting current value

Frequency component values of composite starting current			**Resulting composite current starting value** (RMS)
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.			

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Table B.8 – Operating current range for composite residual current

Operating current (RMS)	
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 performed 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.

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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 $I_{\Delta n}$ ≥ 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.

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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 performed 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 performed 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 performed 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.13, 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 condition. 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 (see B.8.2.3), shall be connected to its maximum rated voltage. For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the CBR shall be loaded again with its rated current until the steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

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 9.3.3.6, using Figure 9 of IEC 60947-1:2020, 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 9.3.3.4.1 item 4) of IEC 60947-1:2020. 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 $I_{\Delta n}$ ≤ 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 a 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 test 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 Clause 7 of IEC 61000-4-3:2020, 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 a 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 6 000 MHz)

Annex J applies, in particular J.3.3.

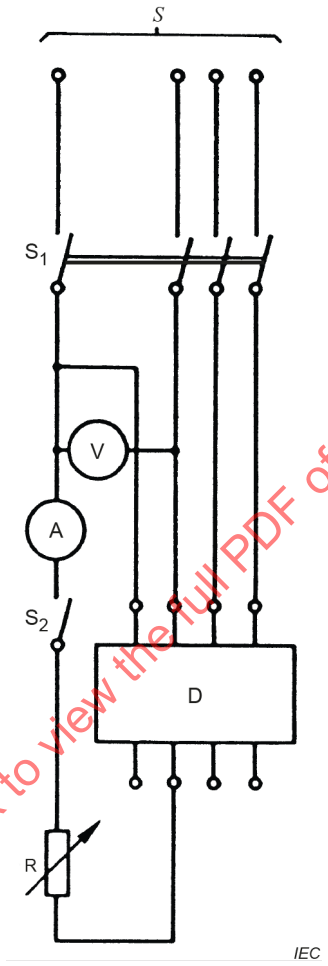
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B.8.14 Test for variations or interruptions of voltage and for voltage dips

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.

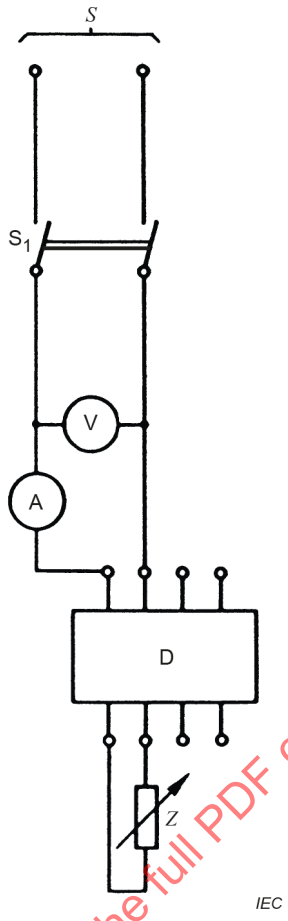


Key

S	supply	S_2	single-pole switch
V	voltmeter	D	CBR under test
A	ammeter	R	adjustable resistor
S_1	multi-pole switch		

Figure B.1 – Test circuit for the verification of the operating characteristic (see B.8.2)

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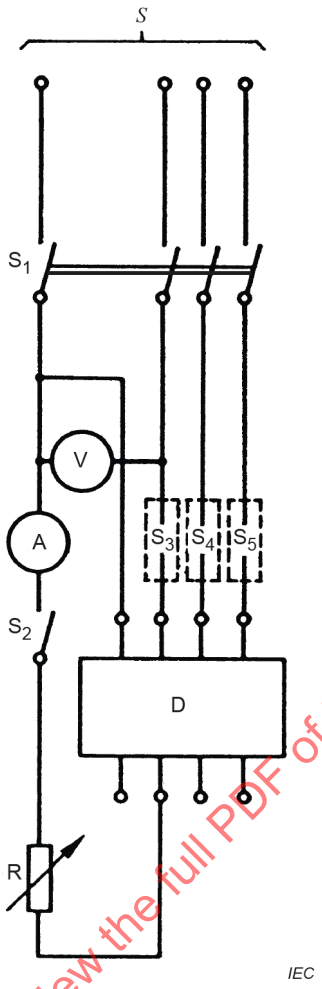


Key

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 overcurrent 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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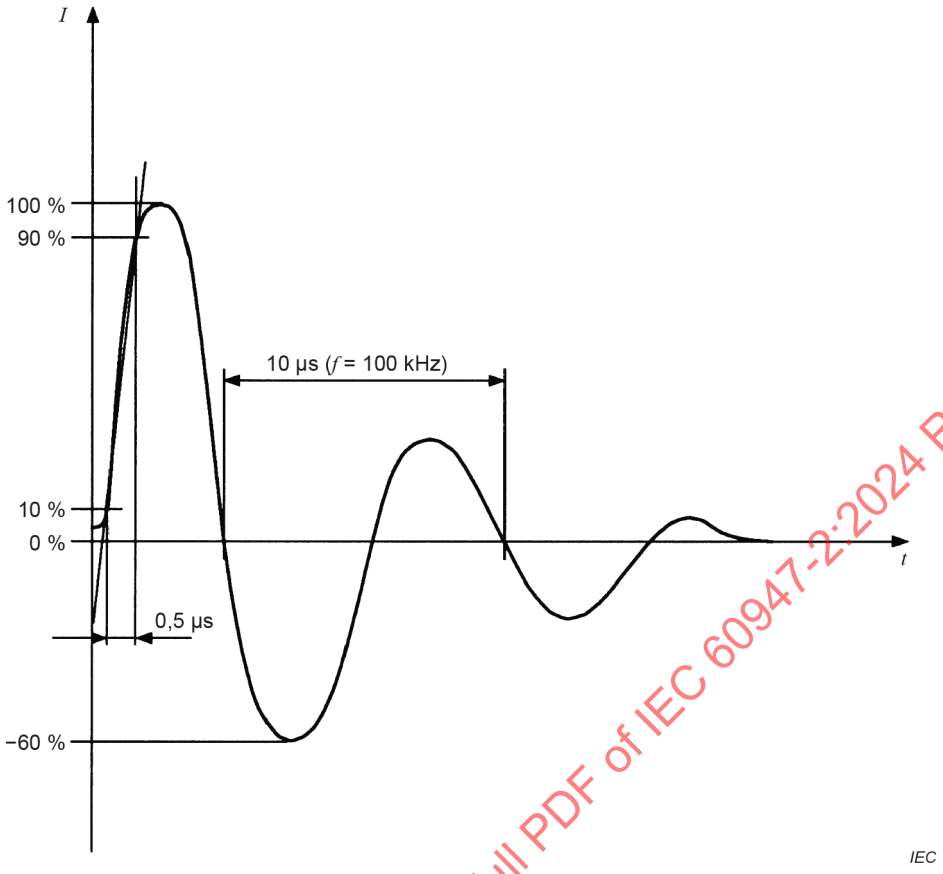
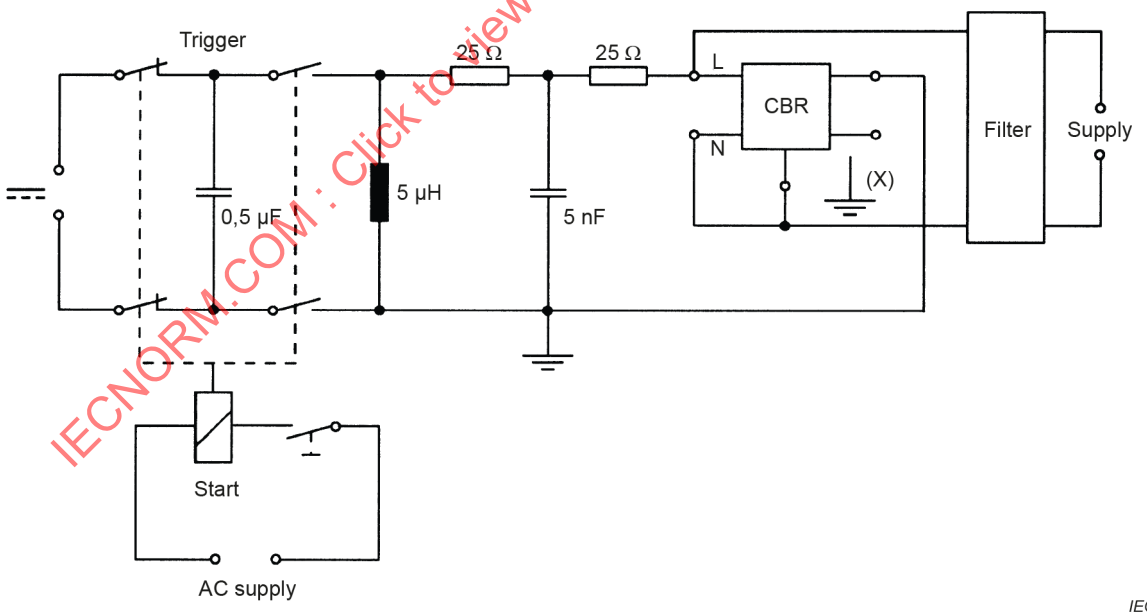


Figure B.4 – Current ring wave 0,5 µs/100 kHz



(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 can 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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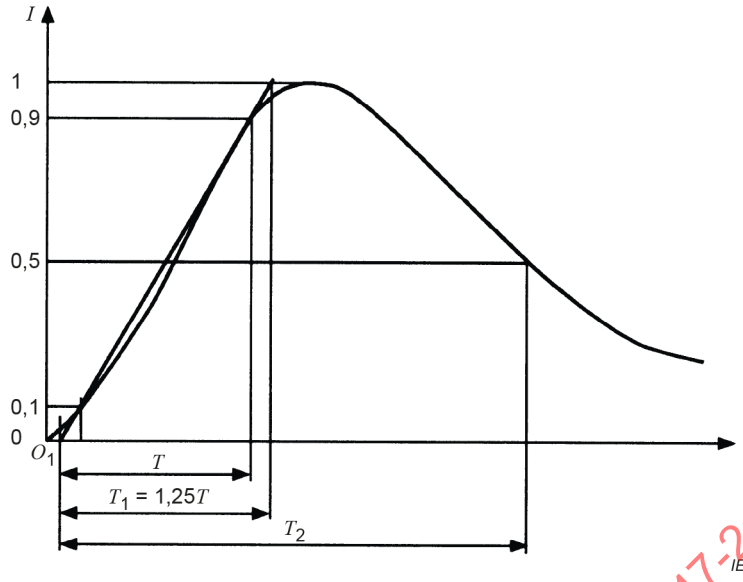
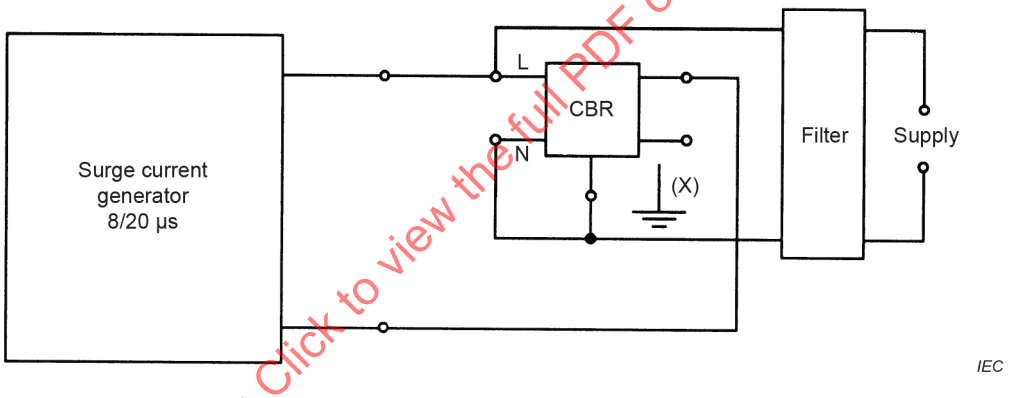


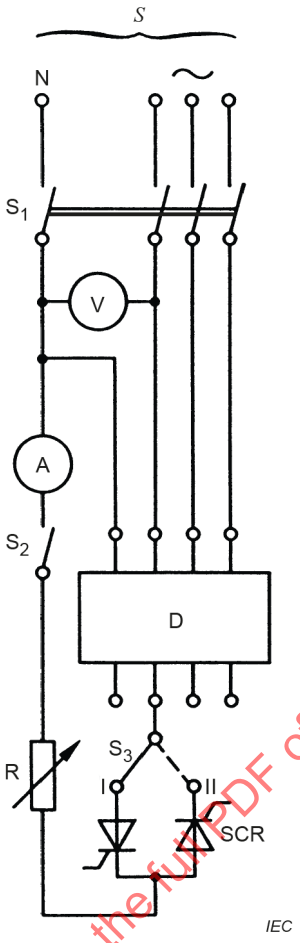
Figure B.6 – Surge current wave 8/20 µs



(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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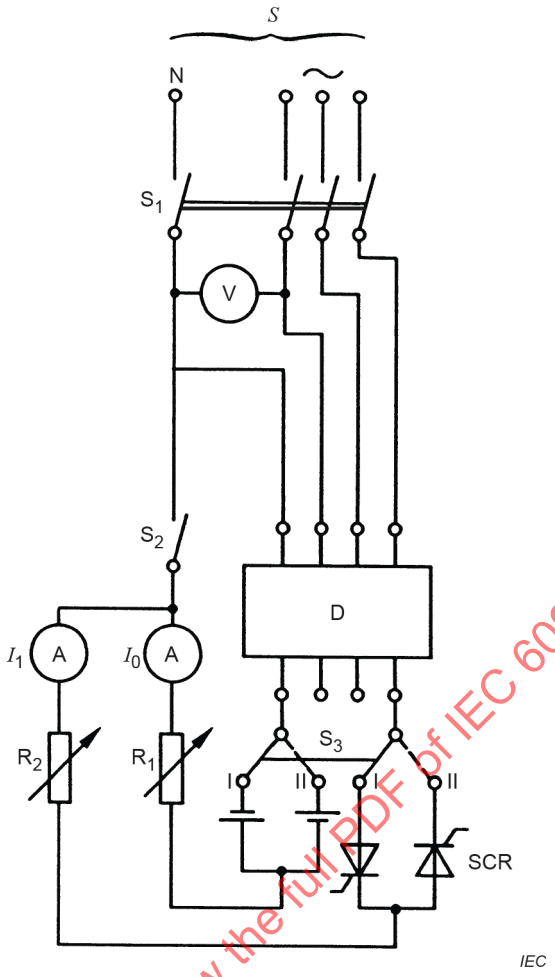


Key

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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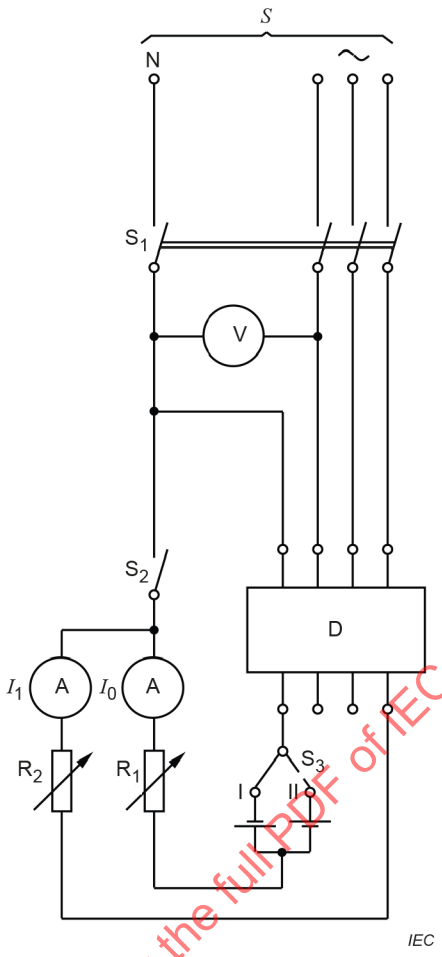


Key

S	supply	R_1, R_2	adjustable 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.9 – Test circuit for residual pulsating direct current superimposed by a smooth direct current

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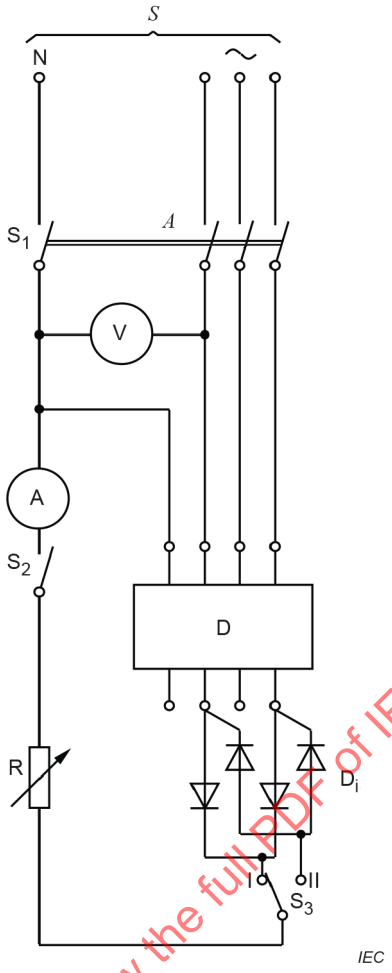


Key

S	supply	R_1, R_2	adjustable 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.10 – Test circuit for residual alternating currents superimposed by a smooth direct current

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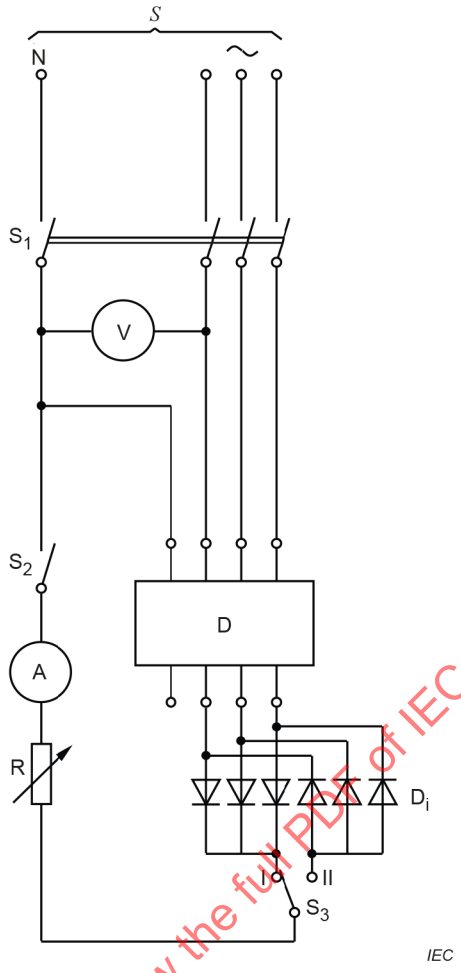


Key

Point A	supply by 2 phases chosen at random	D_i	diodes
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.11 – Test circuit for residual pulsating direct currents which can result from rectifying circuits supplied from two phases

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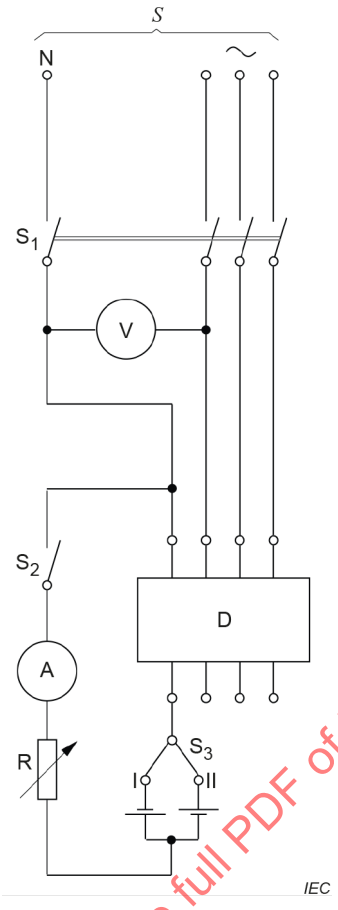


Key

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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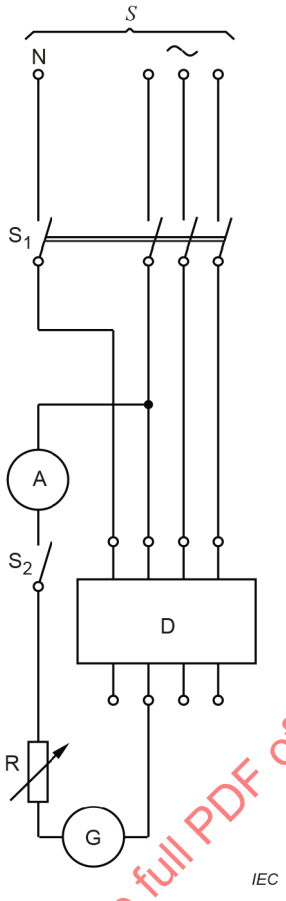


Key

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 5.3.2.1; it comprises the tests in Table C.1.

Table C.1 – Tests of Annex C

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 9.3.3, 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 9.3.3.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The power factor shall be according to Table 16, appropriate to the test current.

The test circuit shall be according to 9.3.4.1.2 of IEC 60947-1:2020 and Figure 9 of IEC 60947-1:2020, 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 and leakage current

Following the test according to Clause C.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

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 9.3.6.5.

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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 bars, having a cross-section of at least 10 mm^2, for the connection of 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 60947-1:2020 for terminals as depicted in Figures D.2, D.3, D.4, D.5, D.6 (including busbars) and D.7 of IEC 60947-1:2020 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.2, D.3, D.4, D.5 and D.7 of IEC 60947-1:2020 or similar clamping units. Testing of lug terminals depicted in Figure D.6 of IEC 60947-1:2020 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.8 of IEC 60947-1:2020 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.

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D.2 Terms and definitions

Clause 3 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
S_f
measure of temperature stability of a terminal unit during the current cycling test

Note 1 to entry: Definitions for different types of terminals can be found in Annex D of IEC 60947-1:2020.

D.3 Classification

Clause 4 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 5 applies.

D.5 Product information

D.5.1 Nature of information

Subclause 6.1 applies.

D.5.2 Marking

Subclause 6.2 applies with the following addition:

The suitability of the terminal for use with aluminium conductors only (Al) or copper and aluminium conductors (Cu/Al or Al/Cu) 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 'AL/CU' or 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 in the manufacturer literature (see Table 4, item 3.14).

Further information concerning the number of conductors, the tightening torque value of the terminal screws (if different between Al and Cu), the type of conductor (solid or stranded) and the cross-sections shall be provided in the literature.

D.5.3 Instructions for installation, operation and maintenance

Subclause 6.3 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 7 applies.

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D.7 Constructional and performance requirements

Clause 8 applies with the following addition:

Clamping units of devices and their accessories (including the terminals) which are not made of aluminium or aluminium alloy 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 60947-1:2020.

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.

Aluminium alloy grade 1350 or 1370, as referred to in IEC 61545, shall be used for testing purposes.

NOTE 1 Grades 1350 and 1370 aluminium are generally considered to be the worst case.

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
Climatic test		D.8.3	Terminal specimen	1 specimen
Mechanical properties of terminals	Flexion test	D.8.4.1	Circuit-breaker	As per 9.2.5.3 of IEC 60947-1:2020
	Pull-out test	D.8.4.2		As per 9.2.5.4 of IEC 60947-1:2020
Insertion test		D.8.5	Circuit-breaker	As per 9.2.5.5 of IEC 60947-1:2020

[a] Type of connection limited to clamping unit types of Figure D.2, D.3, D.4, D.5 and D.7 as per Annex D of IEC 60947-1:2020.

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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.

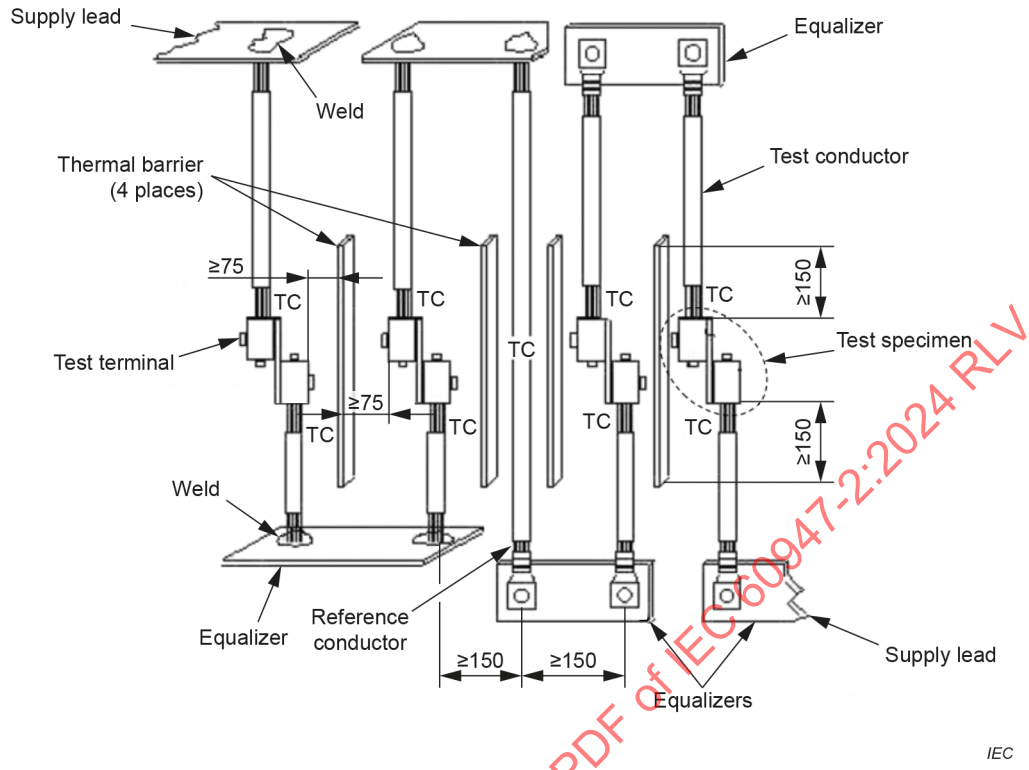
The wire shall be positioned so that 6 mm to 13 mm of the bare conductor is exposed between the wire-entry face of the terminal and the beginning of the insulation. There shall be no mechanical removal or chemical treatment of any oxide on the surface of the conductor entering the terminal, unless it 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.

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Dimensions in millimetres



Key

TC thermocouple

Figure D.1 – General test arrangement

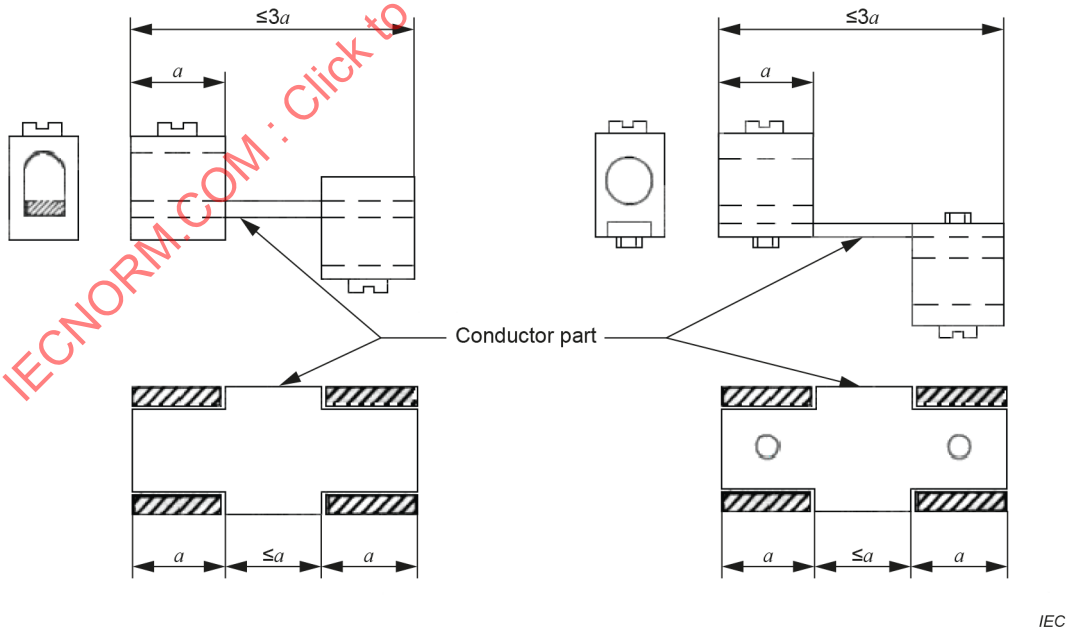


Figure D.2 – Mounting of terminals for the current cycling test

The test shall be carried out with conductors in accordance with Table D.7, specifying the equivalent cross-section of aluminium conductors.

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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.

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
10	8	200
16 to 25	6 to 3	300
35 to 240	2 to 500	460
Larger than 240	Larger than 500	660

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 60947-1:2020, 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.

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.

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	0,125 × 0,5	3,2 × 12,7	0,125 × 0,5
50	125	3,2 × 25	0,125 × 1	3,2 × 32	0,125 × 1,25
125	225	3,2 × 48	0,125 × 1,875	3,2 × 57	0,125 × 2,25
225	400	6,4 × 38	0,25 × 1,5	6,4 × 50	0,25 × 2
400	600	6,4 × 50	0,25 × 2	6,4 × 76	0,25 × 3
600	800	6,4 × 76	0,25 × 3	6,4 × 102	0,25 × 4
800	1 000	6,4 × 102	0,25 × 4	9,5 × 89	0,375 × 3,5
1 000	1 400	12,7 × 76	0,5 × 3	12,7 × 89	0,5 × 3,5
1 400	2 000	12,7 × 102	0,5 × 4	12,7 × 127	0,5 × 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.

The distance between the test and reference conductors shall be at least 150 mm.

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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 test current shall be DC, unless the terminals only have an AC rating, in which case the test current shall be AC.

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.

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.

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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 9.3.3.3.4 of IEC 60947-1:2020, 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 Climatic test

This subclause only applies to terminals with a DC rating.

A test specimen connected with its 2 cables shall be submitted to the damp heat test of Table Q.1 of IEC 60947-1:2020, category C, except that the number of cycles shall be 28. For practical reasons, the length of the cables may be adjusted. Once placed in the climatic chamber, the whole test arrangement, including the conductors, shall not be moved until all the following voltage drop measurements have been completed.

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The voltage drop of the test specimen shall be measured, using the same test current and the same measurement points:

– before the damp heat test
– and after a recovery duration of 24 hours following the damp heat test

The difference of the two voltage drops shall not exceed 10 % of the voltage drop before the damp heat test.

The measurement points of the voltage drop and the value of the test current shall be stated in the test report.

D.8.4 Mechanical properties of terminals

D.8.4.1 Flexion test

Subclause 9.2.5.3 of IEC 60947-1:2020 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.4.2 Pull-out test

Subclause 9.2.5.4 of IEC 60947-1:2020 applies with the following modification:

The test values shall be in accordance with Table D.6.

D.8.5 Test for insertability of unprepared round aluminium conductors having the maximum cross-section

Subclause 9.2.5.5 of IEC 60947-1:2020 applies. Table 7 of IEC 60947-1:2020 applies, except the column relating to flexible conductors.

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	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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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.

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
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 This table 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, b]

Range of test current A		Cable size		
>	≤	Number	mm^2	AWG/kcmil
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 9.3.3.3.4 of IEC 60947-1:2020.

[b] 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 9.3.3.3.4 of IEC 60947-1:2020.

[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 laboratories.

Annex J of IEC 60947-1:2020 applies with regard to clauses and subclauses of this document, with the additions of Table E.1.

Table E.1 – List of items subject to agreement between manufacturer and user

Clause or subclause number of this document	Item
5.3.6.3	Circuit-breakers for higher short-circuit making capacity than given in Table 1
8.2.3.2	Impulse withstand voltage for circuit-breakers rated above 1 000 V AC
9.3.3.6.4.3	Value of test current for short-circuit tests on the fourth pole of four-pole circuit-breakers
9.3.4.2.3, item b)	Test current value for the verification of inverse time/current characteristics
9.3.4.5	Test method if the testing means do not withstand the let-through energy occurring during the automatic operation
9.3.4.5, Note 2	To increase the severity of the conditions for testing overload performance
9.3.4.8 9.3.5.6	Permissible delay between the verification of temperature-rise and that of overload release in test sequences I and II
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B.8.1.1	Applicability of tests when $I_{\Delta n}$ > 30 A
B.8.2.3	Details of the modification for the use of a low-power source for the loading with current
B.8.2.5	Extension of the test ambient temperature limits
Table D.8, footnote e	Sizes of aluminium bars if different from Table D.8
Table D.8, footnote f	All relevant items of the test for rated currents greater than 3 150 A

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Annex F
(normative)

Additional tests for circuit-breakers with electronic overcurrent protection

F.1 General

This annex applies to circuit-breakers intended to be installed on AC circuits and providing overcurrent 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 overcurrent 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 overcurrent 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 9.

NOTE Where a standard for specific environmental conditions exists, reference is systematically made to this document, 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 Table 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 time current characteristic provided by the manufacturer, and the monitoring functions, if any, shall correctly indicate the status of the circuit-breaker. The disturbance shall be applied until the circuit-breaker trips.

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 time current characteristic provided by the manufacturer 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 9.

The figures in this annex, showing 3-pole circuit-breakers, apply also to 1-pole, 2-pole and 4-pole circuit-breakers.

In the case of the EMC tests, Annex J applies with the additional requirements specified in F.4 and F.5.

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. For devices having different numbers of poles, only the design with the highest number of poles shall be tested.

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.

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NOTE This enables comparisons to be made between test results obtained on different phase pole combinations in the different test sequences.

For circuit-breakers incorporating a residual current function (see also Annex B and Annex M) or a ground-fault release (5.7.1 item 2 d):

– 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 or by ground-fault 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 or by ground-fault current is avoided.

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 declared by the manufacturer to be RMS responsive (see Table 4, item 3.9).

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.

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This test current for option b) shall have at least the following harmonic content of the fundamental component:

– third harmonic > 60 %;
– fifth harmonic > 14 %;
– seventh harmonic > 7 %;
– twenty-first harmonic > 1 %.

Other harmonics can also be present.

NOTE 1 The peak factor is the peak value of the current divided by the RMS value of the current wave. For the relevant formula, see Figure F.1.

NOTE 2 The test current waveform for option b) can be produced by, for example, two back-to-back thyristors (see Figure F.1).

NOTE 3 The test currents 0,9 I_r and 2,0 I_r (see performance criterion A of F.2.2.2) are the RMS 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 8.2.1.2.4 carrying the test current at any suitable 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.

NOTE The suitable voltage is that chosen by the testing laboratory, not exceeding the rated voltage of the circuit-breaker

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.

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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.

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 AC 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.

F.4.5 Surges

Annex J, in particular J.2.5, applies with the following additions.

On AC 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 AC 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.

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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.

The tests shall be performed with a sinusoidal current at any suitable 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.

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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 low power. These circuit-breakers have been shown not to create disturbances and therefore no tests are required.

F.5.4 Radiated RF disturbances (30 MHz to 6 000 MHz)

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.

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 suitable 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.

Undervoltage 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 5) 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 5) is applied.

c) a further test starting from the cold state is made at 2,0 times the current setting.

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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 5);
– 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.

F.7 Dry heat test

F.7.1 Test procedure

The test shall be performed on the circuit-breaker in accordance with 8.2.2 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 4, 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, or during a temperature-rise test with a new sample. The method of determining the temperature-rise of the air surrounding the electronic components shall be stated in the test report;
– install the electronic controls in the test chamber;
– supply the electronic controls with their energizing input quantity;
– adjust the temperature of the test chamber to a value of 40 °C plus the temperature-rise recorded for the air surrounding the electronic components and maintain this temperature for 168 h.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

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 8.2.1.2.4, 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.

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The test may be performed with only the electronic controls in the test chamber.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

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 8.2.1.2.4, 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.

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.

After the test, a recovery shall be allowed at normal atmospheric conditions for 24 h, or a shorter time as specified by the manufacturer.

F.9.3 Test results

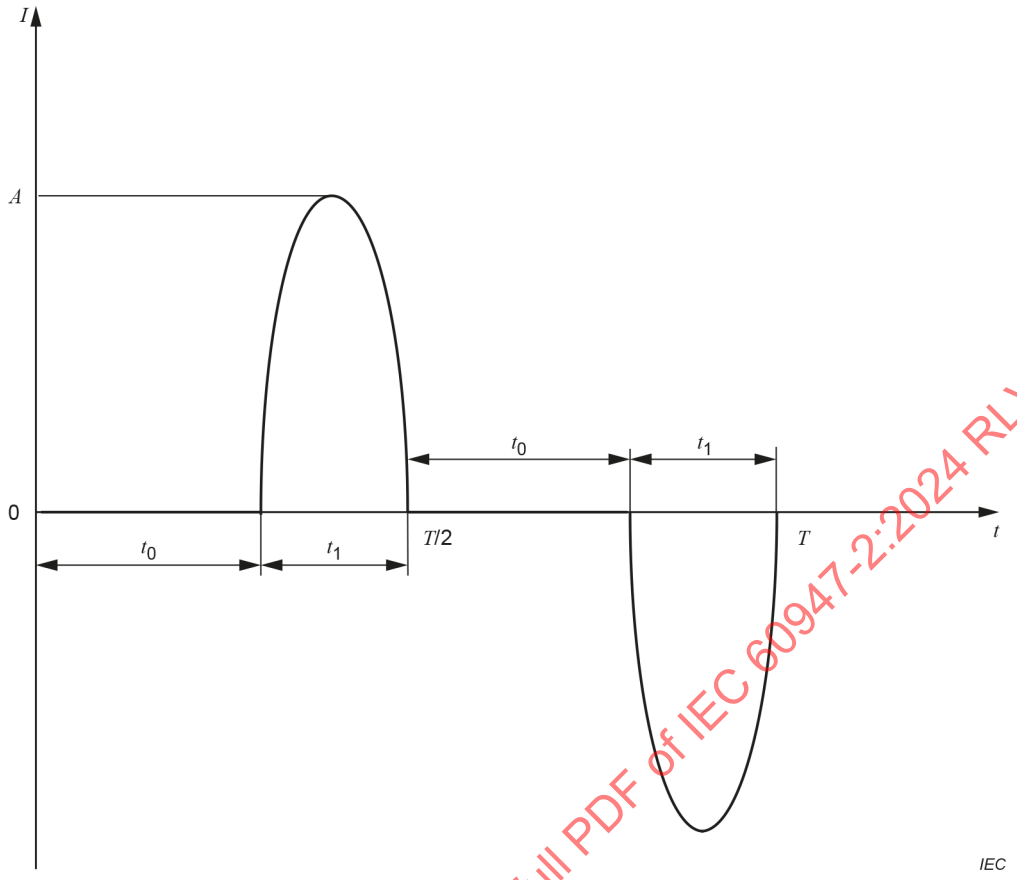
The electronic controls shall meet the following requirement.

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 8.2.1.2.4, 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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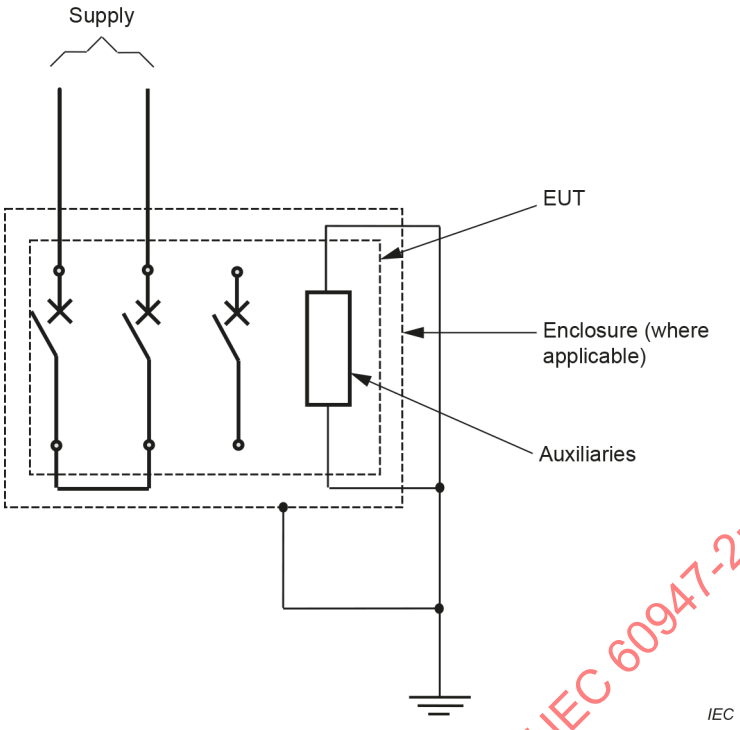


Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series

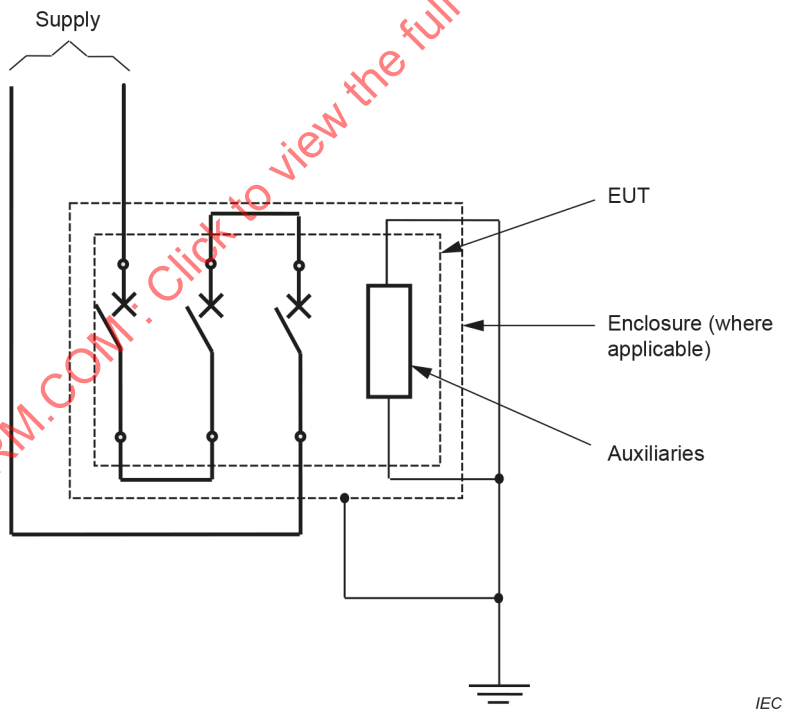
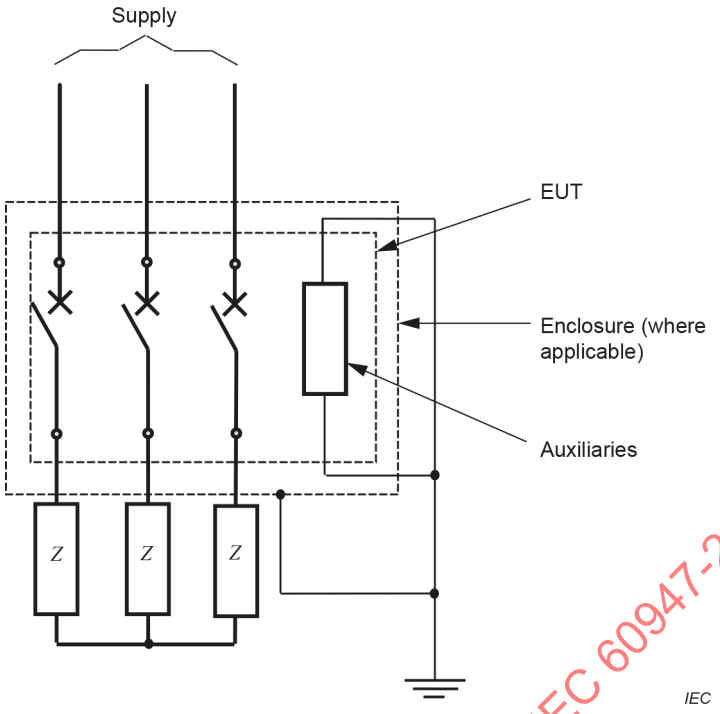


Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series

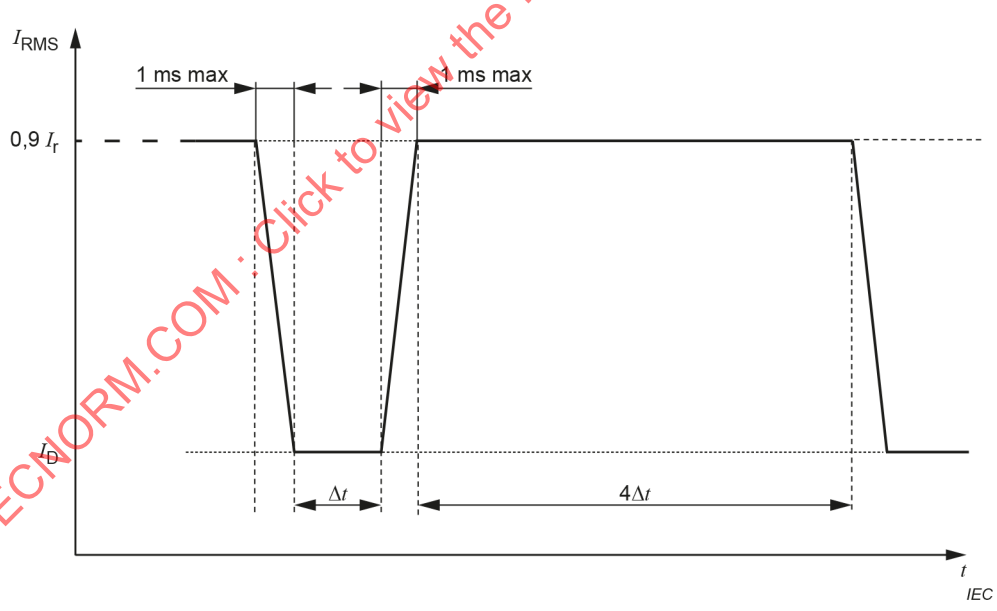
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Key

Z impedance for adjusting the current (where applicable)

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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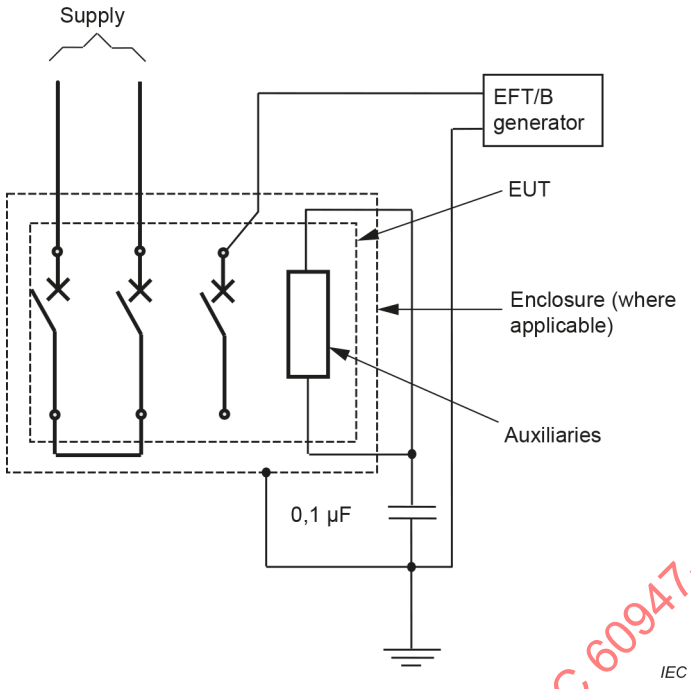


Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series

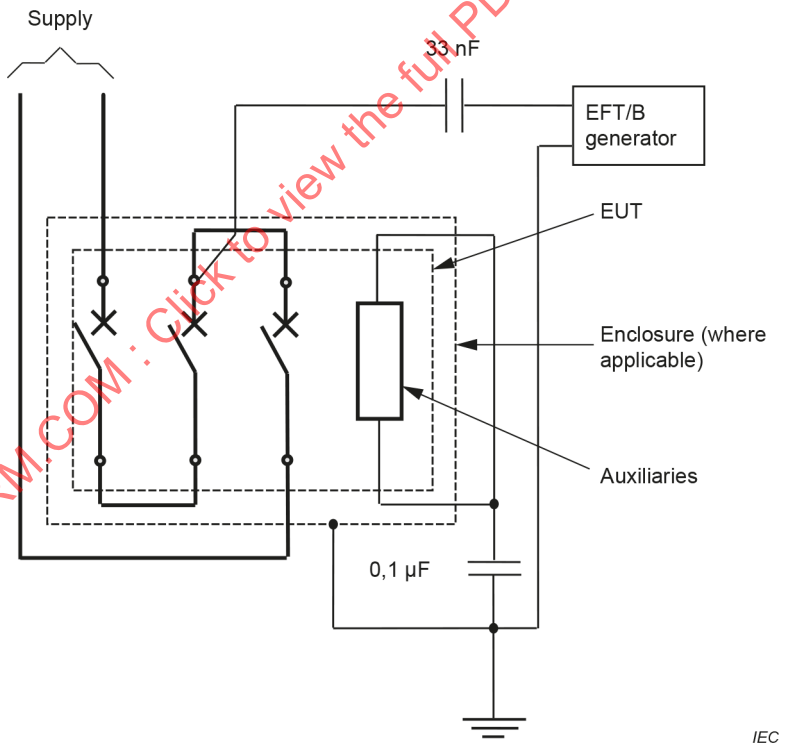
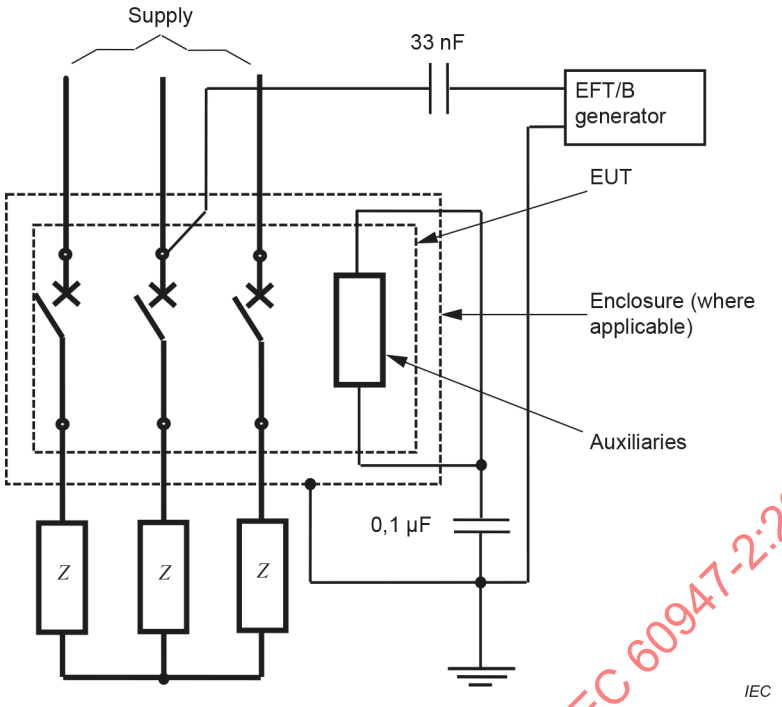


Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series

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Key

Z impedance for adjusting the current (where applicable)

Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection

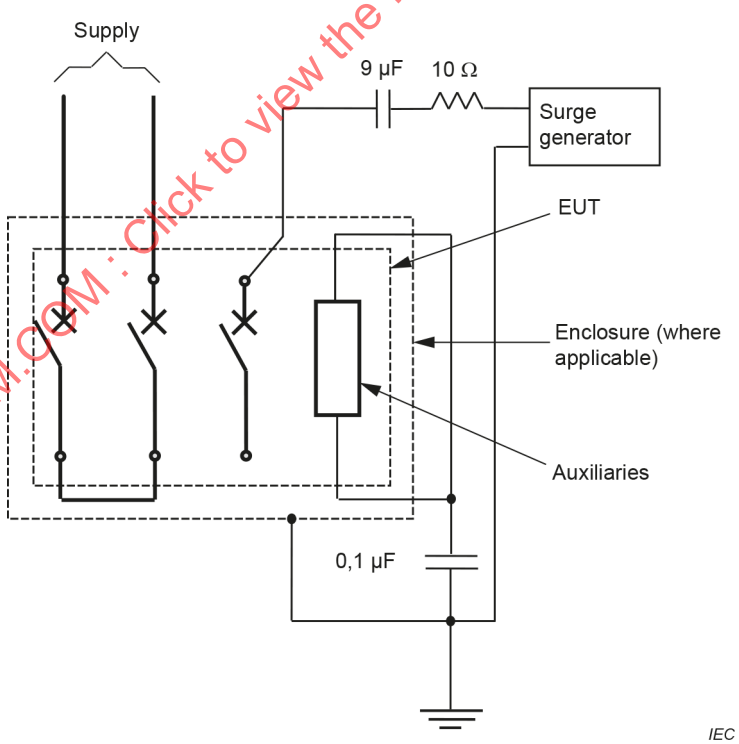


Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series

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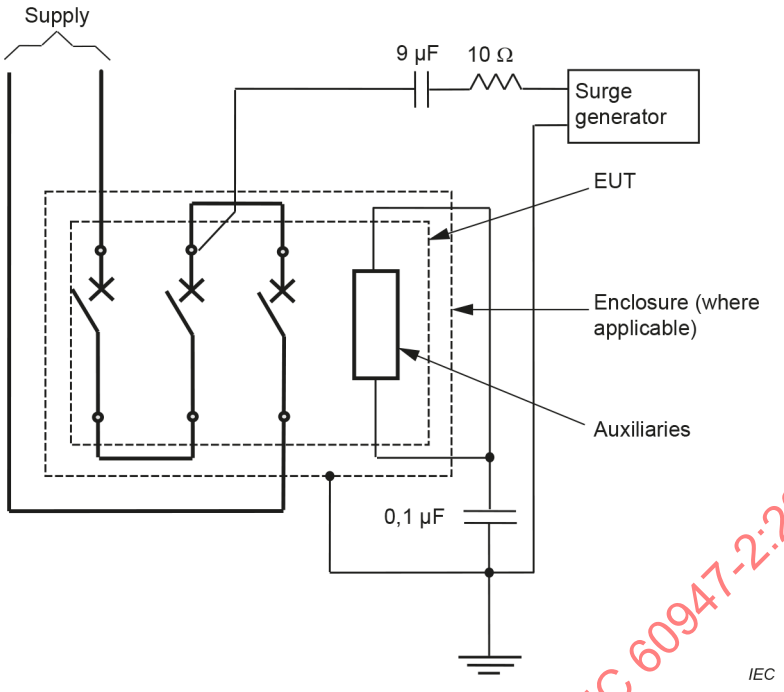
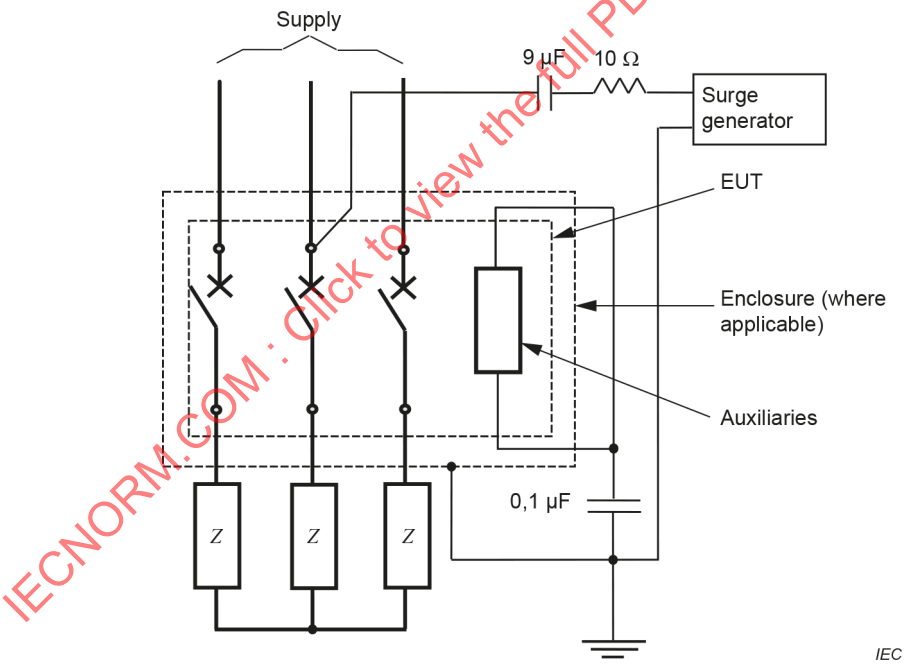


Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series



Key

Z impedance for adjusting the current (where applicable)

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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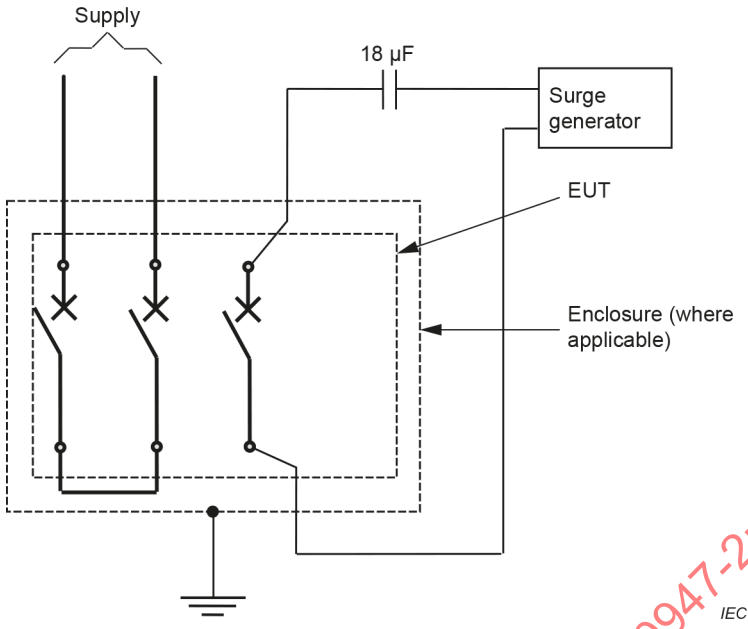


Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series

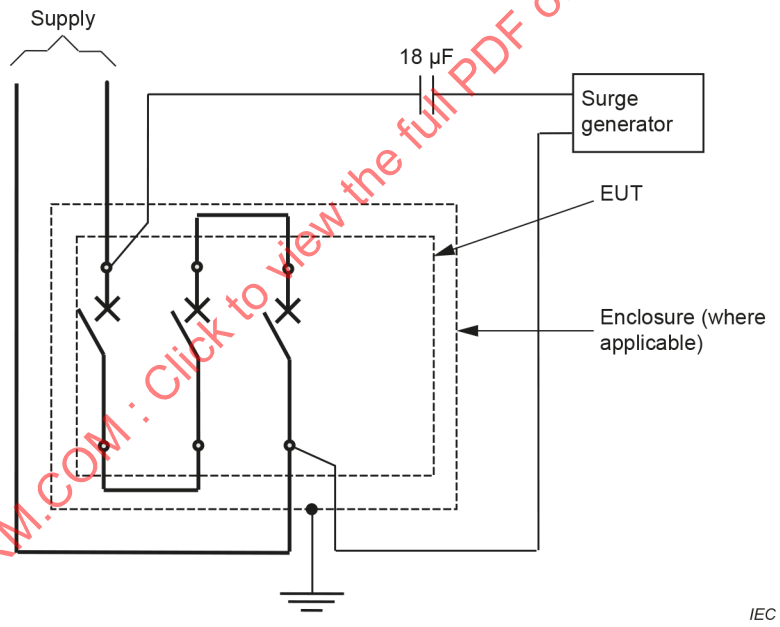
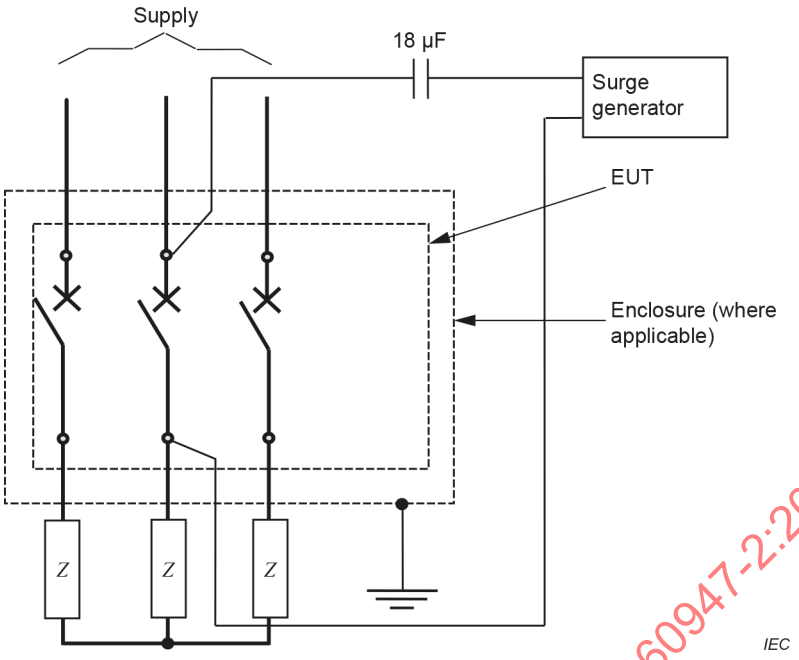


Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series

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Key

Z impedance for adjusting the current (where applicable)

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

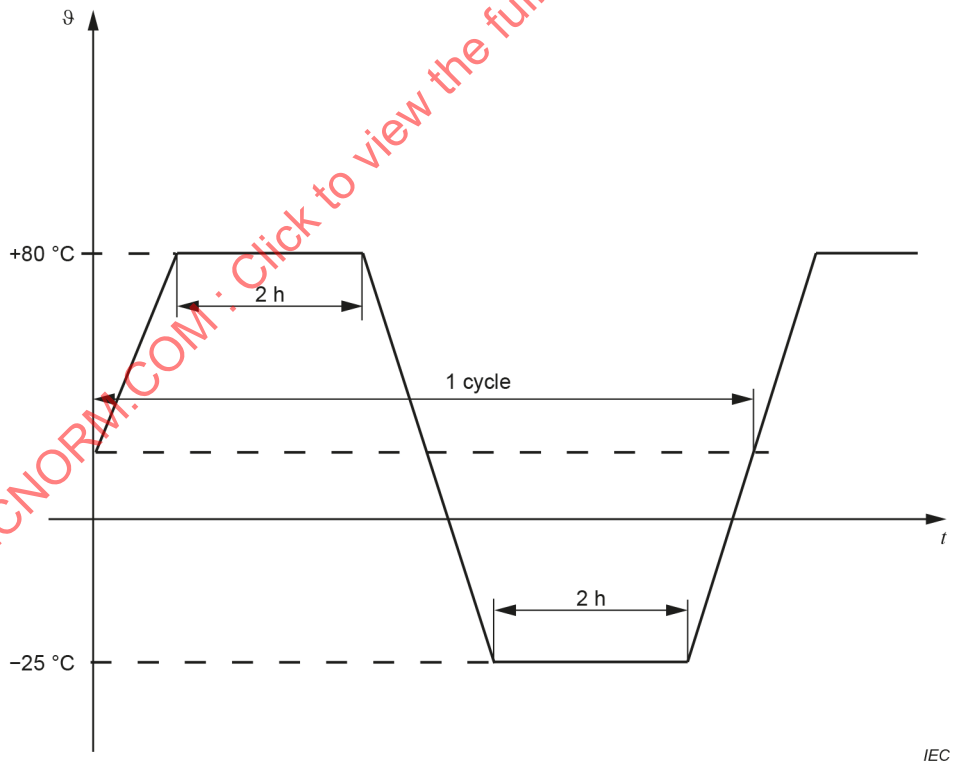
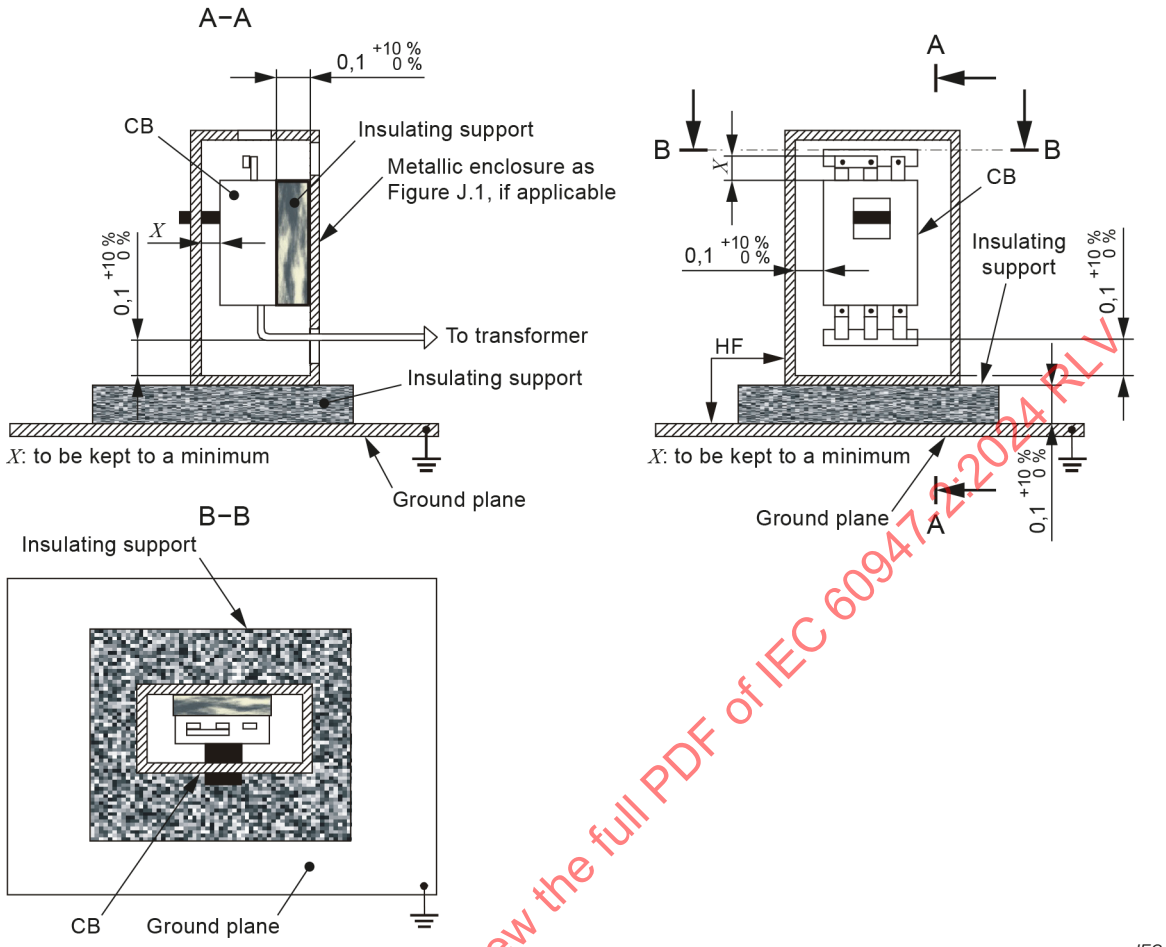


Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1

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Dimensions in metres



Key

CB circuit-breaker

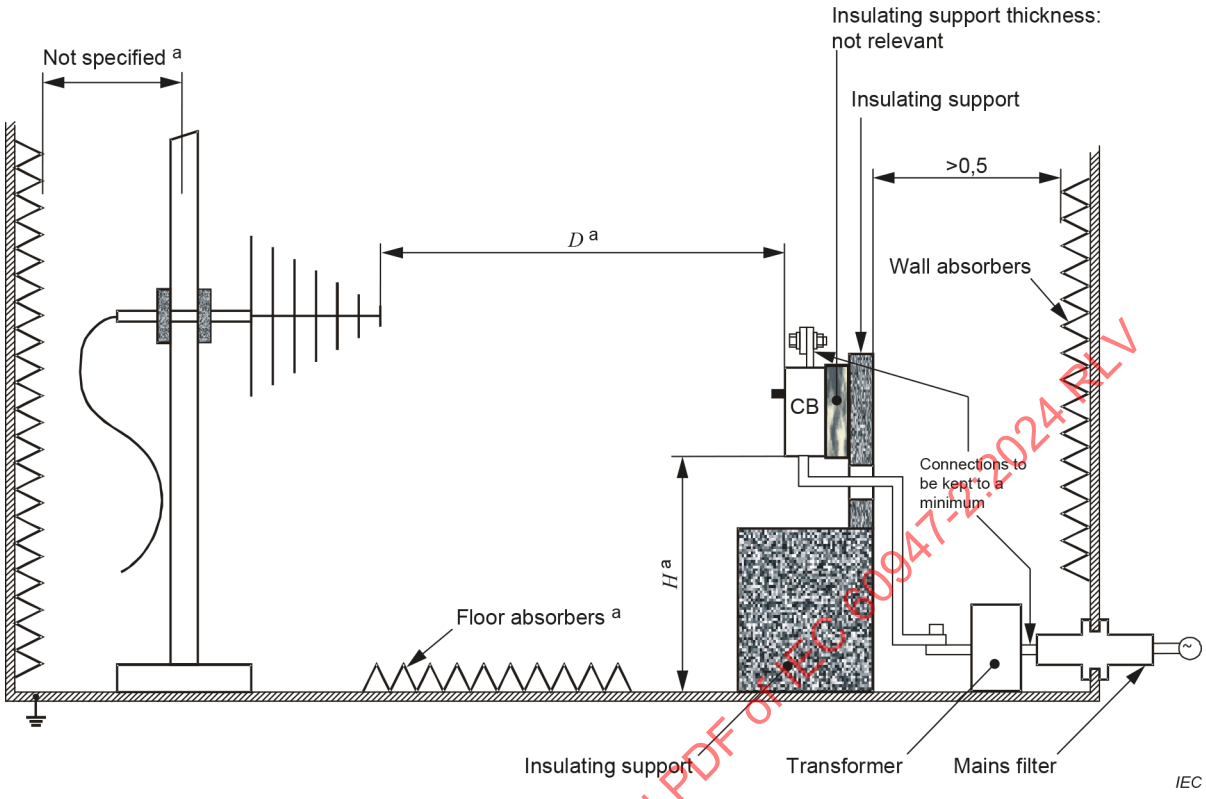
HF high frequency connection

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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Dimensions in metres



Key

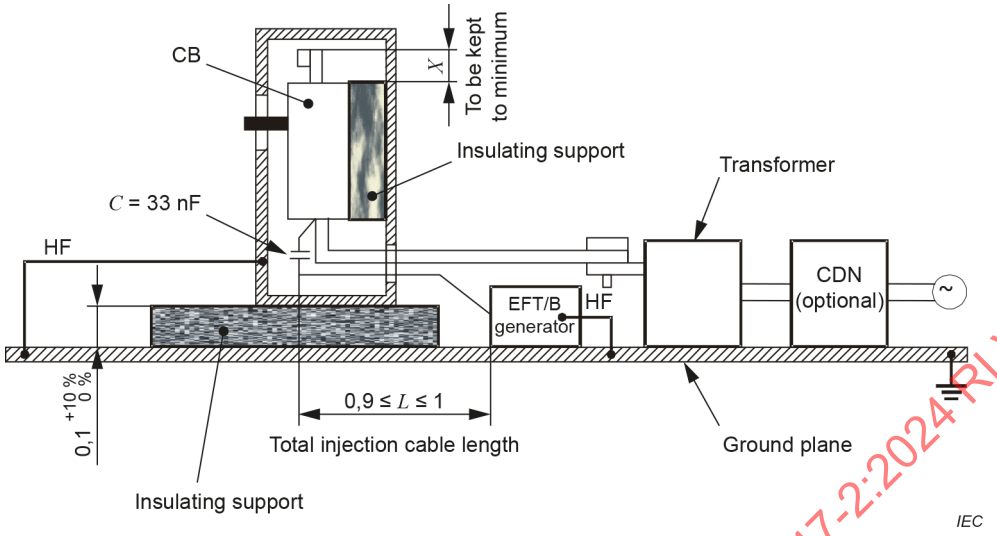
CB circuit-breaker

[a] See IEC 61000-4-3.

Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields

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Dimensions in metres

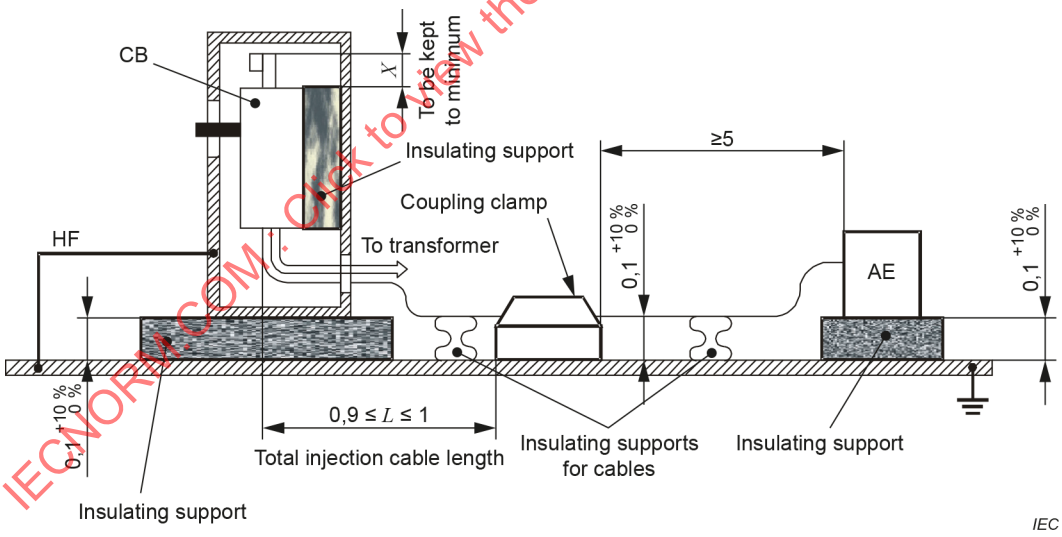


Key

CB	circuit-breaker	HF	high frequency connection
CDN	coupling-decoupling network		

Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines

Dimensions in metres



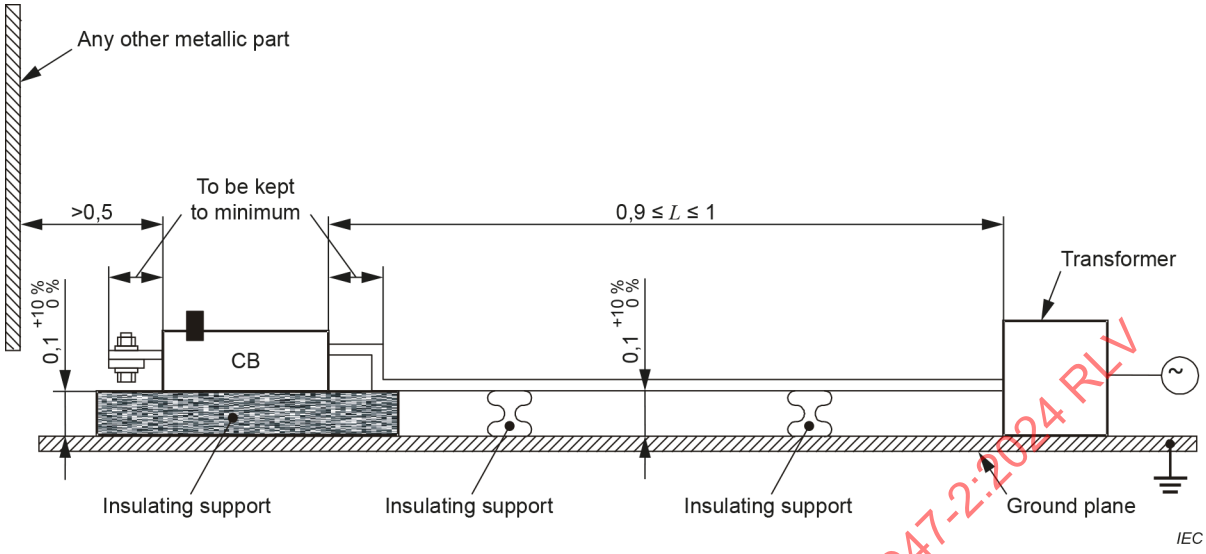
Key

AE	auxiliary equipment	HF	high frequency connection
CB	circuit-breaker		

Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

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Dimensions in metres

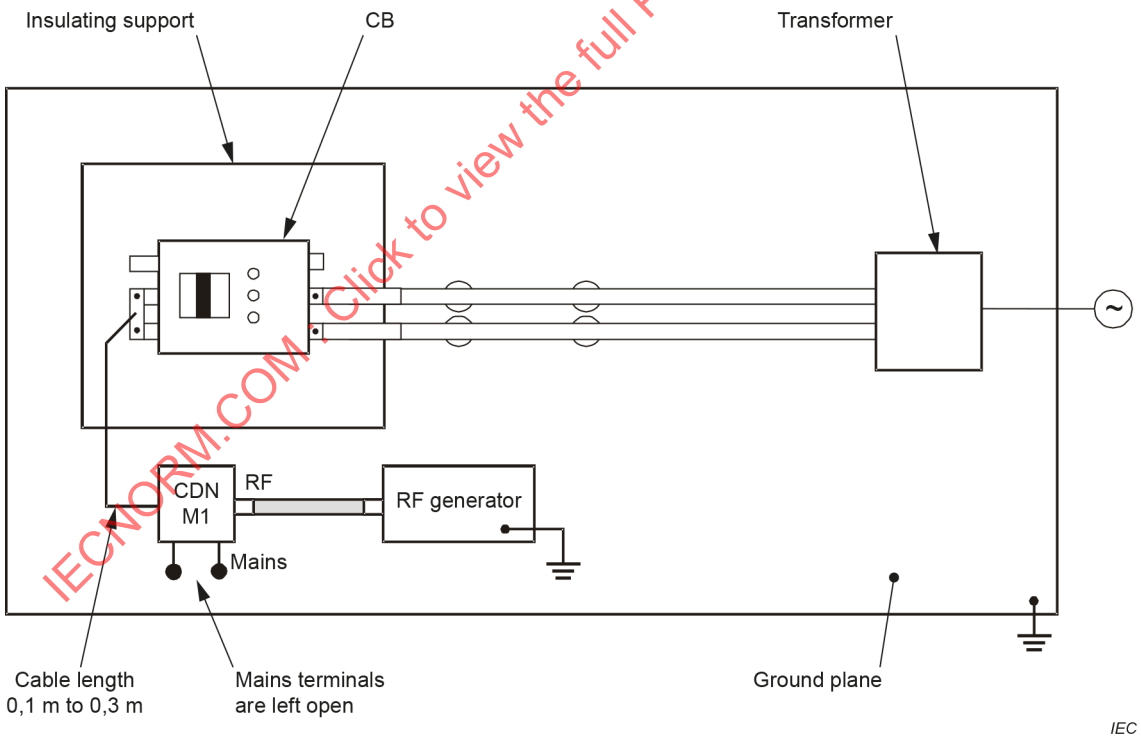


Key

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)



Key

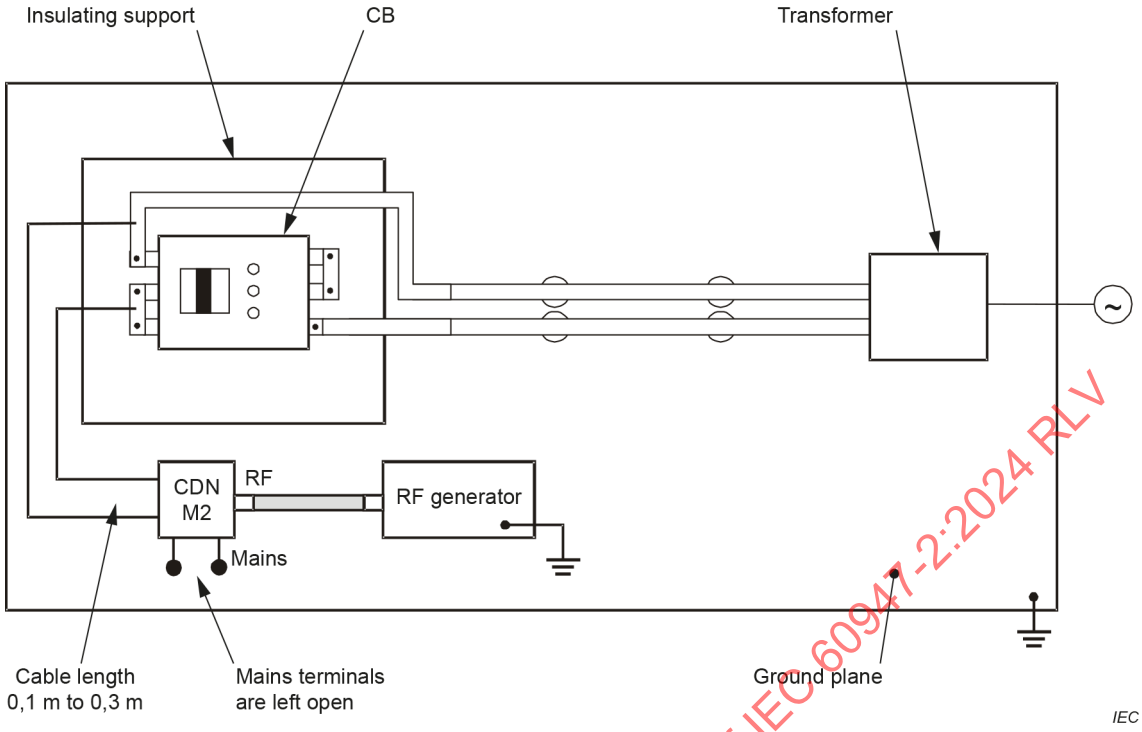
CB circuit-breaker

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

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Key

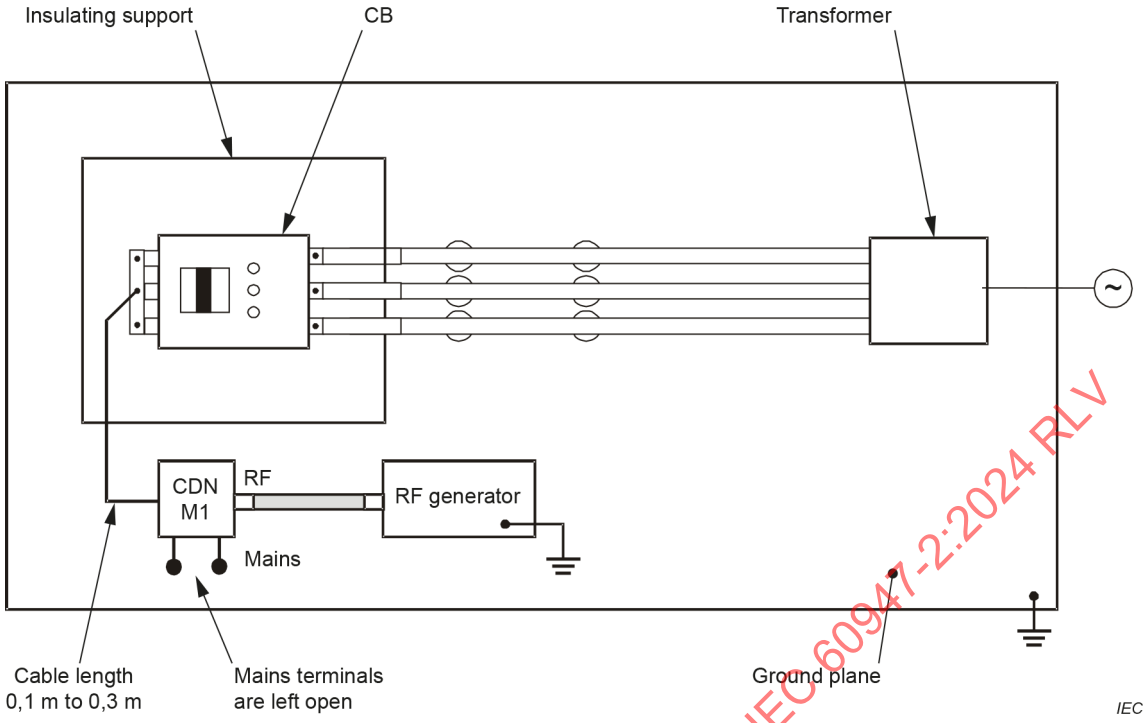
CB circuit-breaker

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

The power loss value gives 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 Determination method

G.2.1 AC circuit-breakers of rated current exceeding 400 A

For AC circuit-breakers of rated current exceeding 400 A，power loss shall be determined with one of the following methods:

a) Power factor method

The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \Delta U_k I_k cos\varphi_k$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop, see G.4.2;

I is the test current, see G.3 and G.4.3;

$cos\varphi$ is the power factor.

A wattmeter may be used instead of measuring independently on each pole.

For a circuit breaker with multiple poles per phase, the power loss of each phase is the sum of the power losses of each pole.

b) Integral method

The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \left(\frac{1}{T} \int_{0}^{T} \Delta u i dt \right)$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

T is the duration of the measurement;

Δu is the instantaneous value of voltage drop, see G.4.2;

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i is the instantaneous value of the test current, see G.3 and G.4.3.

The duration of the measurement shall be at least 10 cycles for AC. For a circuit breaker with multiple poles per phase, the power loss of each phase is the sum of the power losses of each pole.

NOTE For circuit-breakers with a rated current more than 1 000 A and with current transformers with iron cores, the integral method is preferred.

G.2.2 AC circuit-breakers of rated current not exceeding 400 A

All methods described in G.2.1 may be applied. It is also acceptable to use single-phase AC measurement without power factor measurement, as described below.

The power loss is evaluated as follows:

$$P = \sum_{k=1}^{p} \Delta U_k I$$

where

P is the power loss;

p is the number of phase poles;

k is the pole number;

ΔU is the voltage drop, see G.4.2;

I is the test current, see G.3 and G.4.3.

G.2.3 DC circuit-breakers

For DC circuit-breakers, the power loss shall be measured with DC current.

It is evaluated as in G.2.2.

G.3 Test conditions

The circuit-breaker under test shall be installed according to 9.3.3.1.

The conductor size for the power loss measurement shall be suitable for the test current and comply with 9.3.3.3.4 of IEC 60947-1:2020.

The power loss shall be evaluated at the rated current at steady-state temperature, under the conditions of 9.3.3.2.2

Tests can be made at any suitable voltage.

The power loss test shall be conducted at the rated frequency of the circuit-breaker. For circuit-breakers rated 50/60 Hz, 50 Hz covers 60 Hz and vice-versa.

The waveforms of AC current and AC voltage shall be practically sinusoidal, meaning that the ratio between the peak value and the RMS value is $\sqrt{2} \pm 3$ %.

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G.4 Test method

G.4.1 General

The power loss measurement circuit for AC circuit-breakers of rated current exceeding 400 A shall be according to Figure G.1. For other circuit-breakers, Figure G.1 or Figure G.2 may be used.

For evaluating the power loss of four-pole AC circuit-breakers, the test shall be performed without current in the neutral pole.

G.4.2 Voltage drop measurements

The voltage drop measurement depends on the design of the circuit-breaker.

a) Circuit-breakers with a single pole per phase

The voltage drop shall be measured between incoming and outgoing terminals on each pole as in Figure G.3.

b) Circuit-breakers with multiple poles per phase

The voltage drop shall be measured between incoming and outgoing terminals on each of the multiple poles as in Figure G.4.

G.4.3 Current measurement

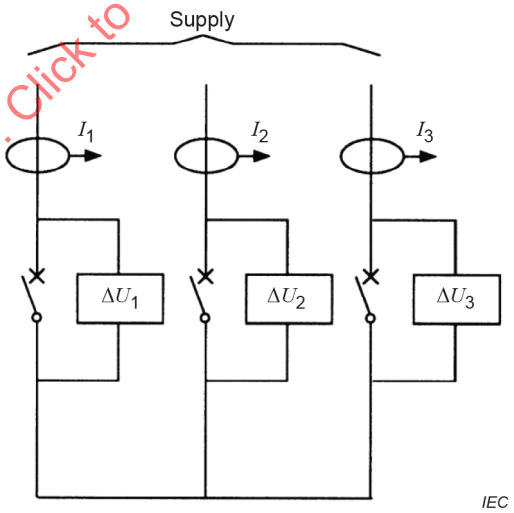
The current measurement depends on the design of the circuit-breaker.

a) Circuit-breakers with single pole each phase

The current shall be measured on each pole as in Figure G.3.

b) Circuit-breakers with multiple poles per phase

The current shall be measured on each of the multiple poles as in Figure G.4.

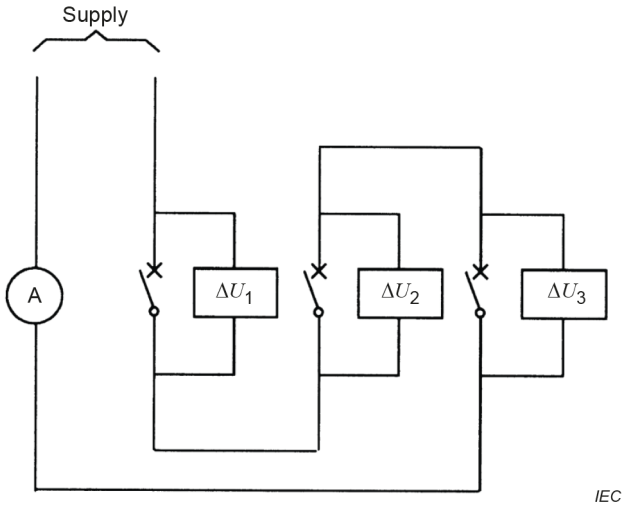


Key

I_1, I_2, I_3	current sensing devices
ΔU_1, ΔU_2, ΔU_3	voltage sensing devices

Figure G.1 – Power loss measurement circuit for AC circuit-breakers

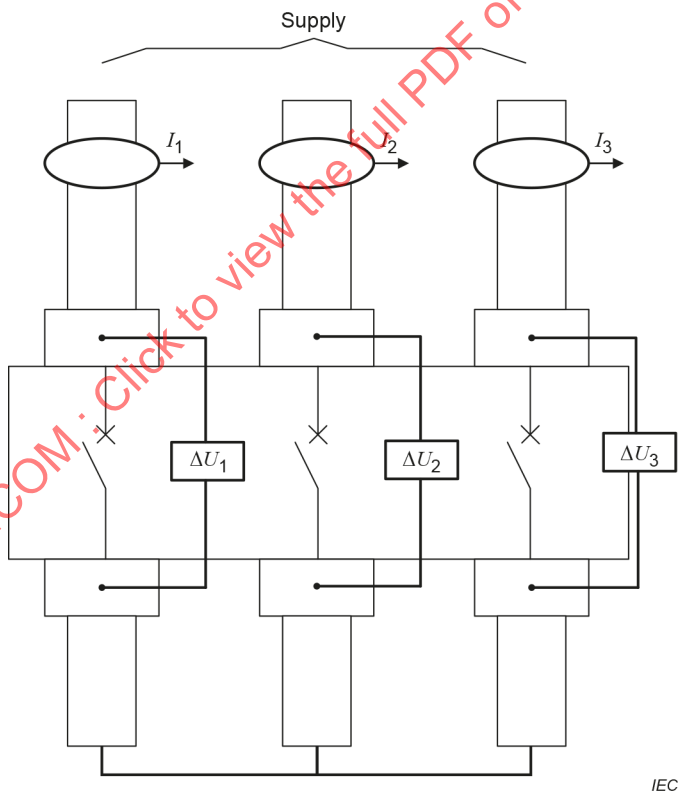
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Key

ΔU_1, ΔU_2, ΔU_3 voltage sensing devices

Figure G.2 – Power loss measurement circuit for AC circuit-breakers with rated current not exceeding 400 A and DC circuit-breakers



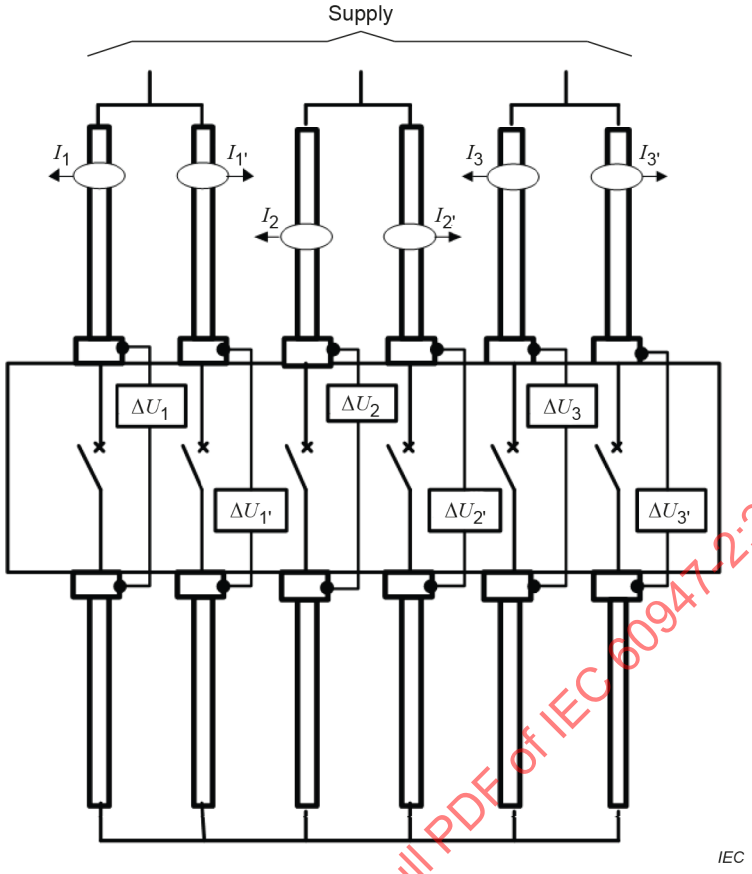
Key

I_1, I_2, I_3 current sensing devices

ΔU_1, ΔU_2, ΔU_3 voltage sensing devices

Figure G.3 – Measurement points for circuit-breakers with a single pole per phase

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Key

I_1, $I_{1'}$, I_2, $I_{2'}$, I_3, $I_{3'}$	current sensing devices
ΔU_1, $\Delta U_{1'}$, ΔU_2, $\Delta U_{2'}$, ΔU_3, $\Delta U_{3'}$	voltage sensing devices

Figure G.4 – Measurement points for circuit-breakers with multiple poles per phase

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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 5.3.2.1).

H.1 General

This test sequence applies to multipole circuit-breakers for application on IT systems, in accordance with 5.3.2.1; it comprises the tests of Table H.1.

Table H.1 – Tests of Annex H

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 9.3.3, at a value of current I_{IT} equal to

– 1,2 times the maximum setting of the short-time delay short-circuit release or, in the absence of such a release, 1,2 times the maximum setting 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.

The prospective current of the test circuit may 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 Values higher than I_{IT} can be 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 9.3.3.2.6. The number of samples to be tested and the setting of adjustable releases shall be in accordance with Table 15. The power factor shall be according to Table 16, 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 $\sqrt{3}$. 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 9.3.4.1.2 of IEC 60947-1:2020 and Figure 9 of IEC 60947-1:2020, 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.

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The sequence of operations shall be

$$O - t - CO$$

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 and leakage current

Following the test according to H.2, the dielectric withstand and the leakage current shall be verified according to to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

H.4 Verification of overload releases

Following the test according to H.3, the operation of the overload releases shall be verified according to 9.3.6.5.

H.5 Marking

Subclause 6.2 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.2.

Table H.2 – Product information

Item	Information	Marking location
H.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 I

Vacant

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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 document.

The test methods in J.2 and J.3 are supplemented by specific procedures in the relevant parts of this document to verify the performance based on the acceptance criteria.

Supplementary requirements and test details are given in the relevant parts of this document, 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. Devices rated 50 Hz/60 Hz shall be tested at either one of the rated frequencies.

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 8.3.2 of IEC 60947-1:2020 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 60947-1:2020, 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 performance criteria are as follows:

– performance criterion A: during the test, the immunity to 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).

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 [b]
Electrical fast transients/bursts	IEC 61000-4-4	Power port: U_e ≥ 100 V, AC / DC: 4 kV 5 kHz and 100 kHz [j] U_e < 100 V, AC / DC [f]: 2 kV 5 kHz and 100 kHz [j] Signal port [f]: 2 kV 5 kHz and 100 kHz	B (unless otherwise stated)	Enclosure Figure J.1

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Description	Reference standard	Test level	Performance criterion	Mounting
Surges	IEC 61000-4-5	Power port, U_e ≥ 100 V AC: 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)[d] Power port, U_e < 100 V AC: 2 kV line-to-earth 1 kV line-to-line Power port, DC [e]: 1 kV line-to-earth 0,5 kV line-to-line Signal port [g, i]: 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 AC / DC: 10 V (150 kHz to 80 MHz) Signal port [f]: 10 V (150 kHz to 80 MHz)	A	Free air [b]
Power frequency magnetic fields	Not applicable [h]	Not applicable [h]	Not applicable[h]	Not applicable[h]
Voltage dips and interruptions	IEC 61000-4-11 [c]	[c]	[c]	Free air
Harmonics	IEC 61000-4-13 [a]	[a]	[a]	Free air
Current dips	[a]	[a]	[a]	Free air

[a] A specific test procedure is defined in the case of electronic overcurrent devices in Annex F, in the absence of an appropriate basic standard.

[b] 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.

[c] 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, as specified in F.4.7.

[d] The immunity level is higher for residual current devices because they perform safety functions.

[e] Not applicable to input ports intended for connection to a battery or a rechargeable battery, which shall be removed or disconnected from the circuit-breaker for recharging. Circuit-breakers with a DC power input port intended for use with an AC – DC power adapter shall be tested on the AC power input of the AC – DC power adapter specified by the manufacturer; where no adapter is specified, the test shall be done on the DC power port using the specified test level.

[f] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

[g] 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 specified, this test is applied only to the shield.

[h] Power frequency magnetic fields tests are covered by short-circuit tests of Clause 9.

[i] Signal lines with direct connection to AC power ports shall be treated as AC power ports.

[j] In Japan, tests are done only at 100 kHz for electrical fast transients/bursts (IEC 61000-4-4), based on IEC TR 63216:2019. For retesting of already evaluated circuit-breakers, the repetition frequency of 5 kHz can be used.

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The appropriate test set-up and circuit diagram for each immunity test are as shown in Table J.2.

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's immunity to unwanted operation is tested 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 6 000 MHz, in accordance with Clause 8 of IEC 61000-4-3:2020. 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 and 5 800 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 EM 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 8.3.3 of IEC 60947-1:2020 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 6 000 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 11 and 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.8.13.2.2	a	a
	CB	J.3.2, F.5.3	No test	No test
	MRCD	J.3.2, B.8.13.2.2	a	a
	Other devices	J.3.2, N.3.2	a	a
Radiated RF disturbances	CBR	J.3.3, B.8.13.2.3	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.8.13.2.3	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 32, as relevant.

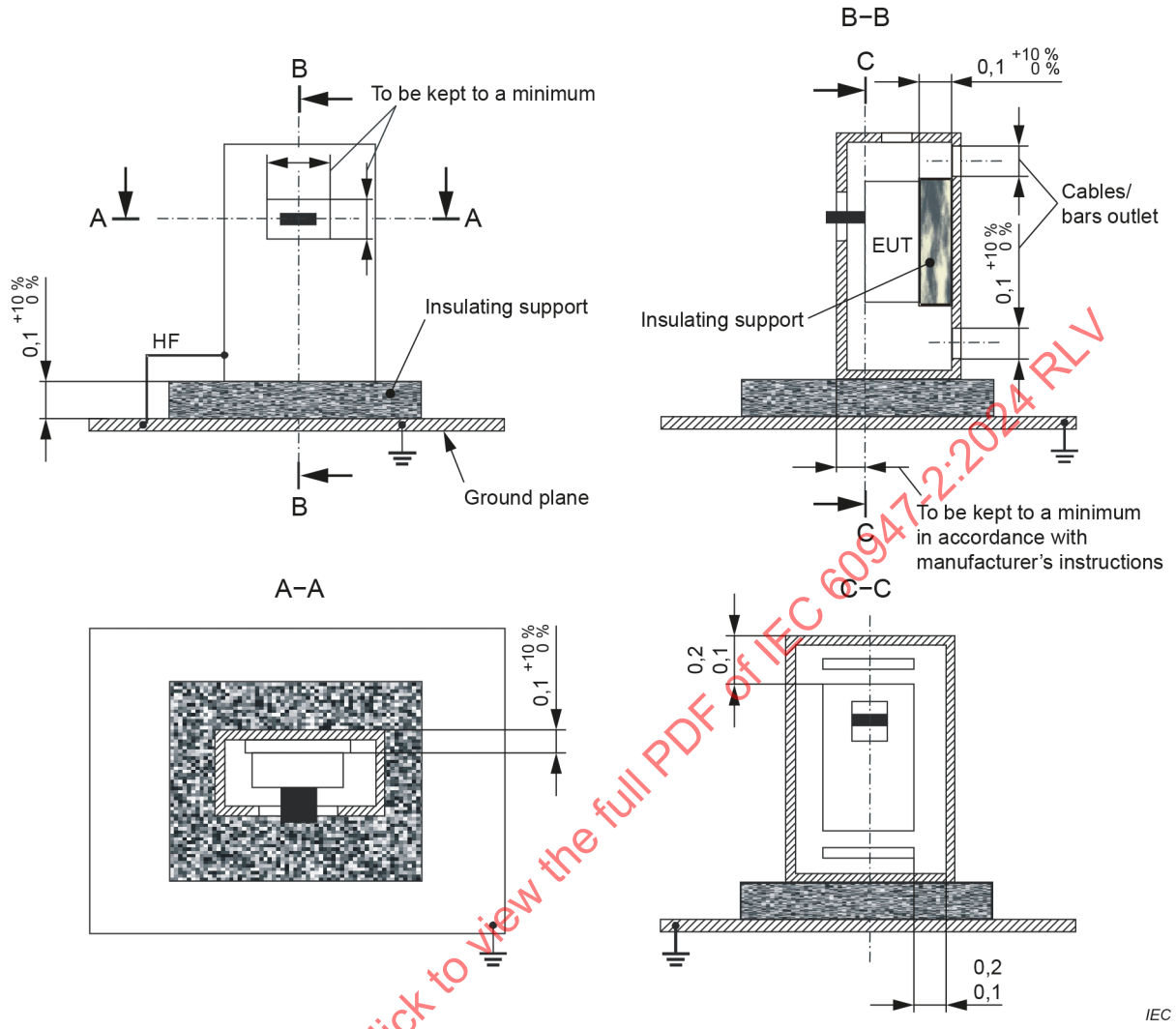
The particular test set-up, including the type of cable, shall be detailed in the test report.

J.3.3 Radiated RF disturbances (30 MHz to 6 000 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.

Dimensions in metres

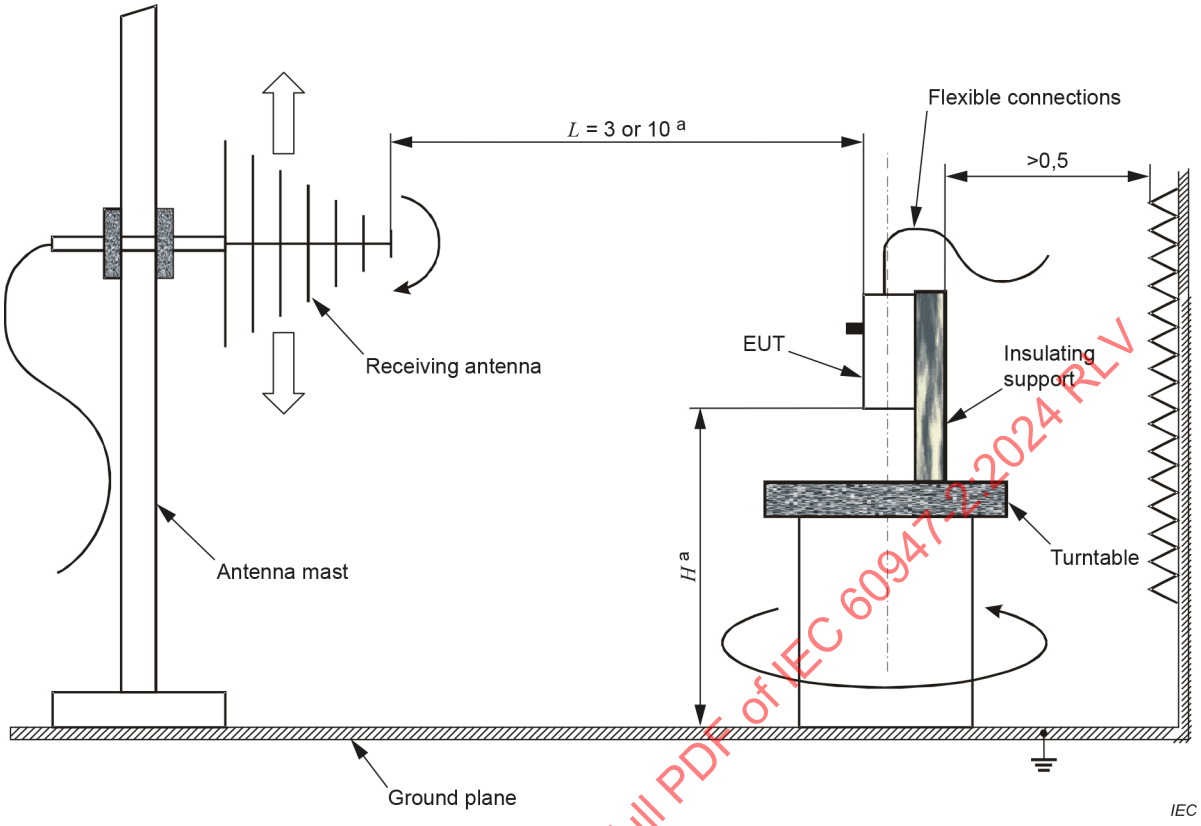


NOTE In the case of a withdrawable circuit-breaker, the EUT includes the draw-out cradle.

Figure J.1 – EUT mounted in a metallic enclosure

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Dimensions in metres



[a] See CISPR 11 and CISPR 32.

Figure J.2 – Test set up for the measurement of radiated RF emissions

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Dimensions in metres

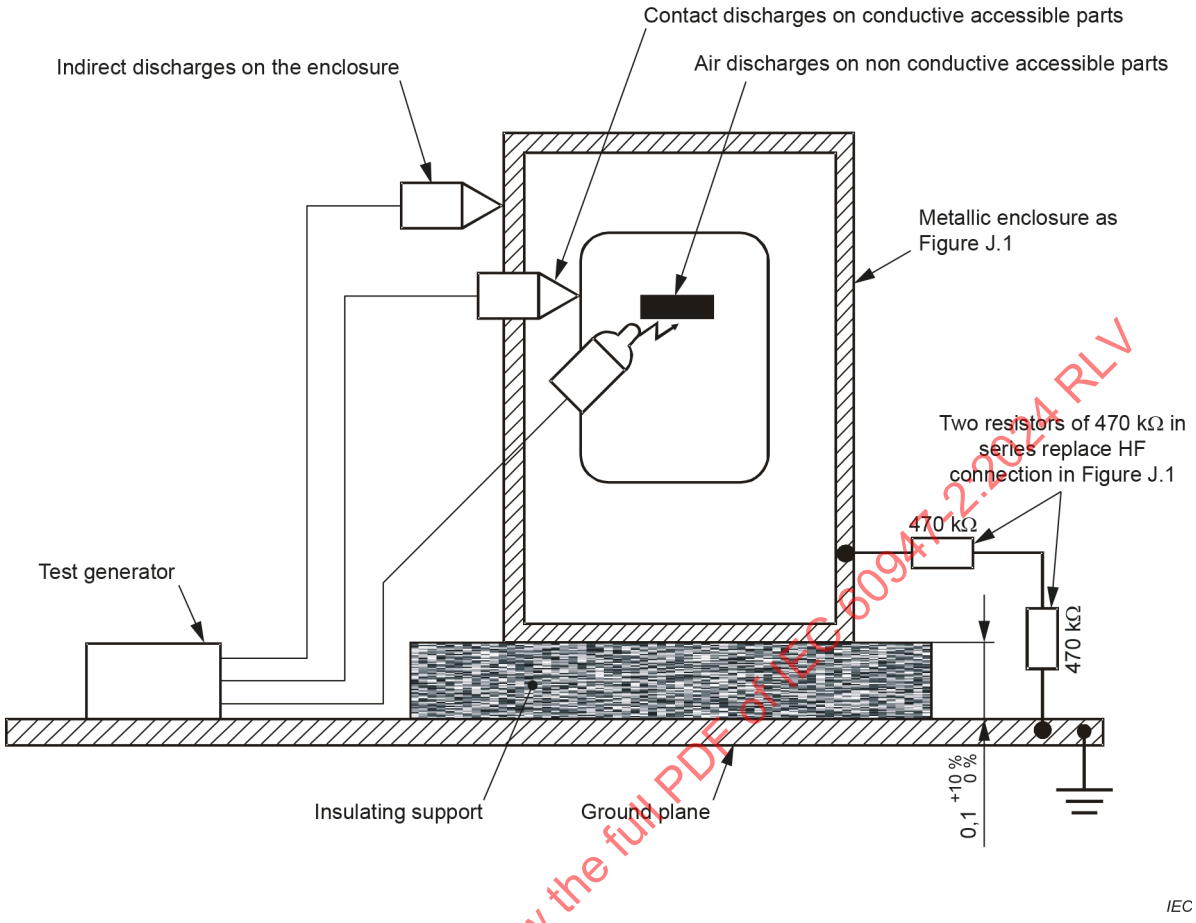
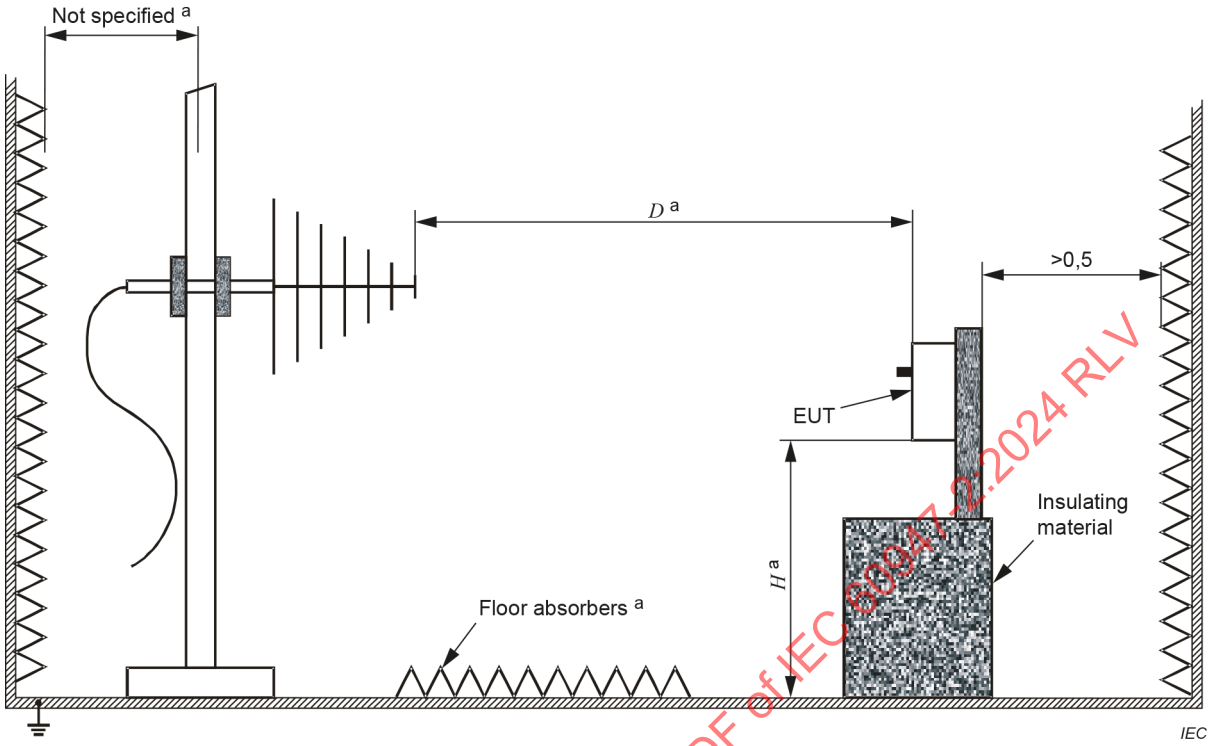


Figure J.3 – Test set up for the verification of immunity to electrostatic discharges

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Dimensions in metres

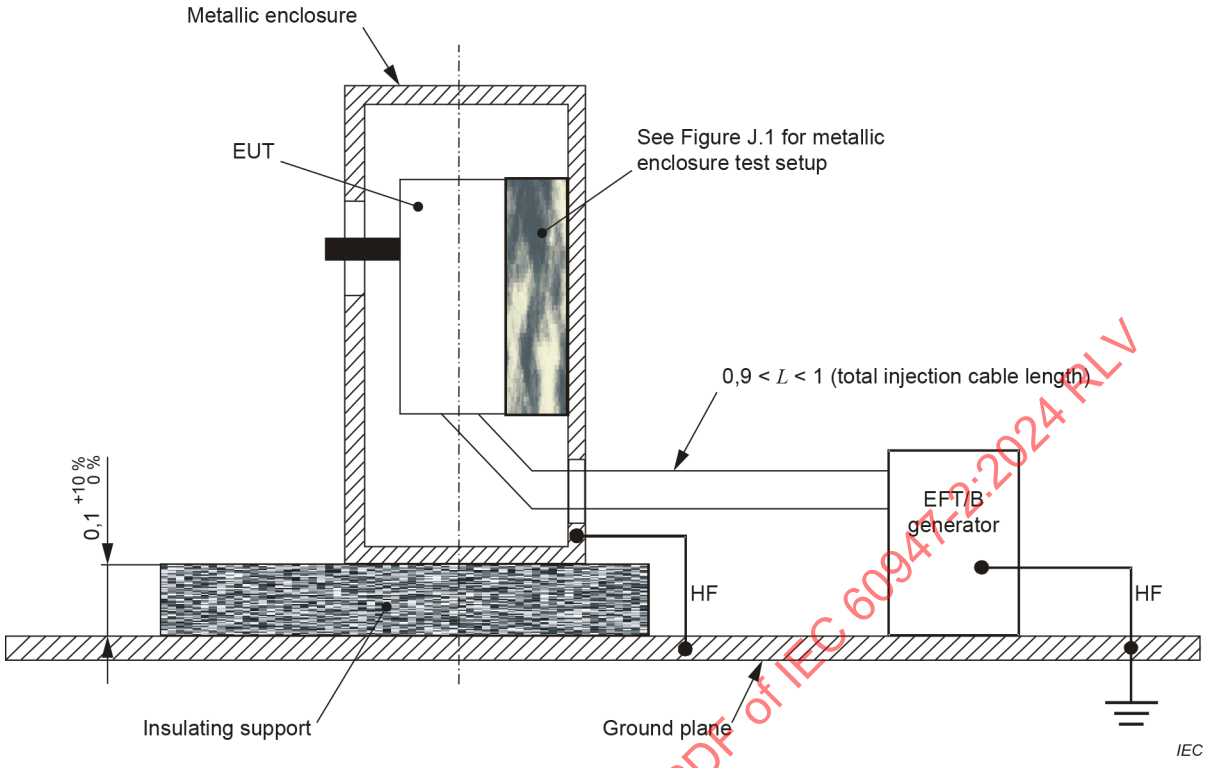


a See IEC 61000-4-3.

Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields

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Dimensions in metres



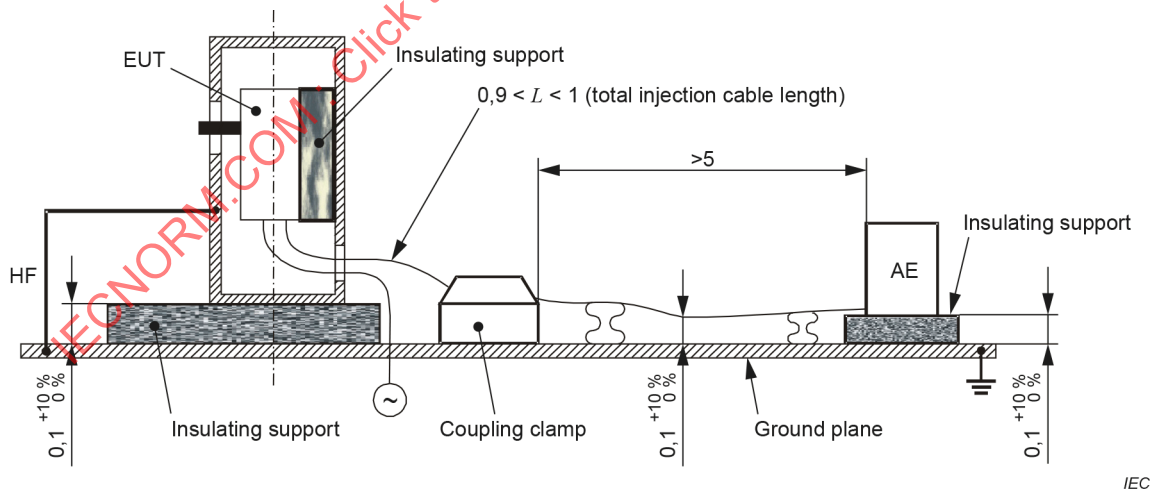
Key

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

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Dimensions in metres



Key

AE auxiliary equipment

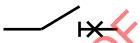
HF high frequency connection

Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines

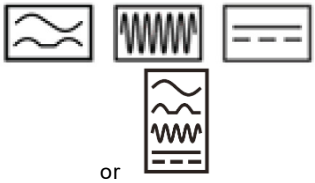
Annex K
(informative)

Glossary of symbols and graphical representation of characteristics

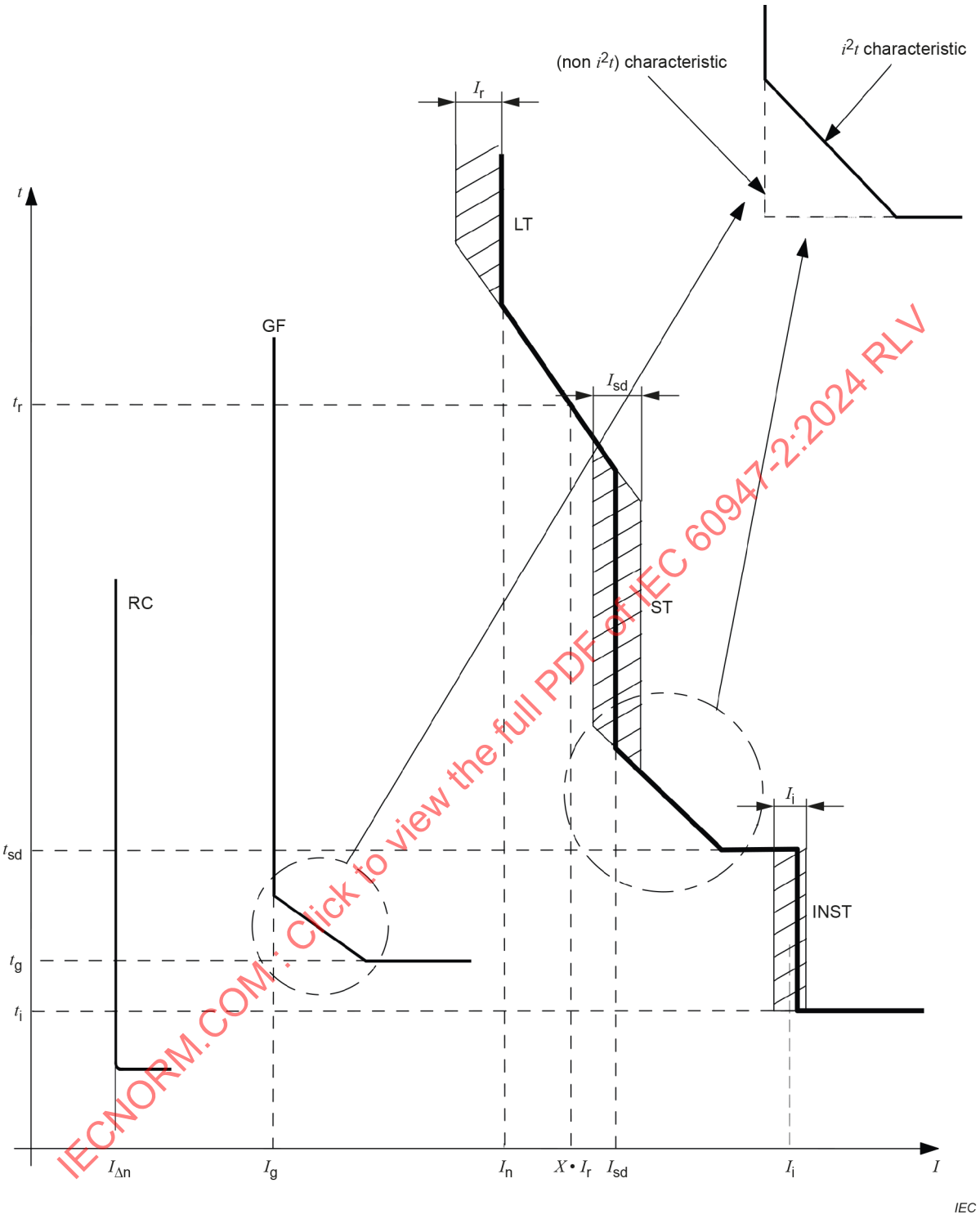
Table K.1 – Glossary of symbols and graphical representation of characteristics

Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Reference in this document
Circuit-breaker, closed position		IEC 60417-5007 (2002-10)	6.2
Circuit-breaker, open position		IEC 60417-5008 (2002-10)	6.2
Isolation suitability – circuit-breaker and ICB		IEC 60617-S00287 (2001-07) combined with IEC 60617-S00220 (2001-07)	6.2 O.4
Isolation suitability – CBI class W		IEC 60617-S00287:2001-07 combined with IEC 60617-S00220:2001-07	L.5
Isolation suitability – CBI classes X and Y		IEC 60617-S00288 (2007-01)	L.5
Neutral pole terminal	N		6.2
Protective earth terminal		IEC 60417-5019 (2006-08)	6.2
Rated control circuit voltage	U_c		5.7.2
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		5.3.3.3
Rated impulse withstand voltage	U_{imp}		5.3.2.3
Rated insulation voltage	U_i		5.3.2.2
Rated operational voltage	U_e		5.3.2.1
Rated service short-circuit breaking capacity	I_{cs}		5.3.6.2.4
Rated short-circuit making capacity	I_{cm}		5.3.6.1
Rated short time withstand current	I_{cw}		5.3.6.4
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}		5.3.6.2.2
Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	I_{cu1}		5.3.6.2.3
Selectivity limit current	I_s		
Take-over current	I_B		

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Characteristics list	Symbol	IEC 60417 or IEC 60617 reference	Reference in this document
Conventional enclosed thermal current	I_{the}		5.3.3.2
Conventional free air thermal current	I_{th}		5.3.3.1
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
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		3.16, 5.7.3, Figure K.1
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
Instantaneous short-circuit current setting	I_i		3.15, 5.7.3 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}		3.17 Figure K.1
Corresponding intentional time-delay	t_{sd}		Figure K.1
Suitability for phase-earthed systems	C		5.3.2.1
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)	Table B.3, item B2.3
Rated automatic re-closing operating residual current	$I_{\Delta ar}$		R.2.2

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Key

RC	residual current
GF	ground-fault
LT	long time
ST	short time
INST	instantaneous

Figure K.1 – Relationship between symbols and tripping characteristics

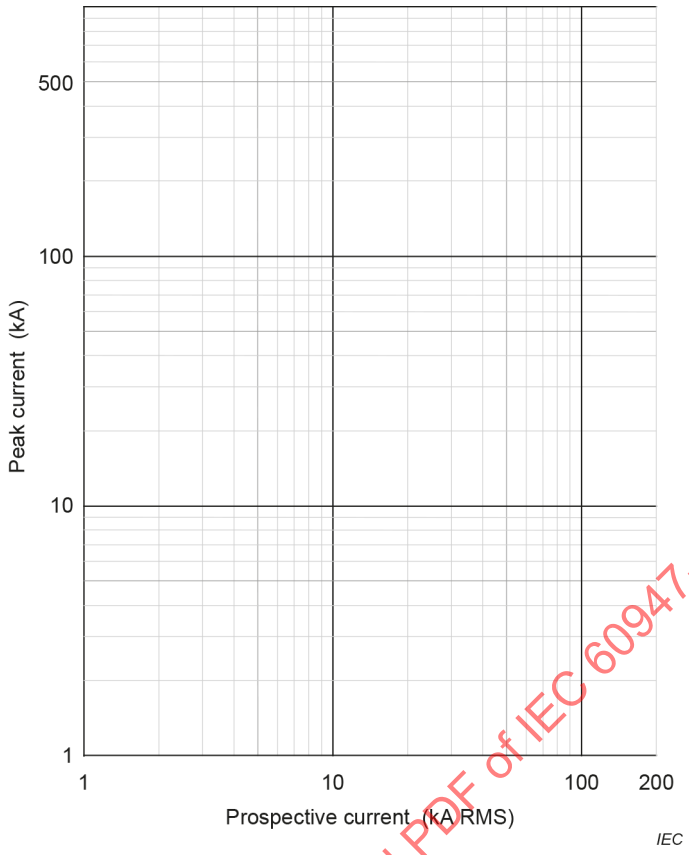


Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA

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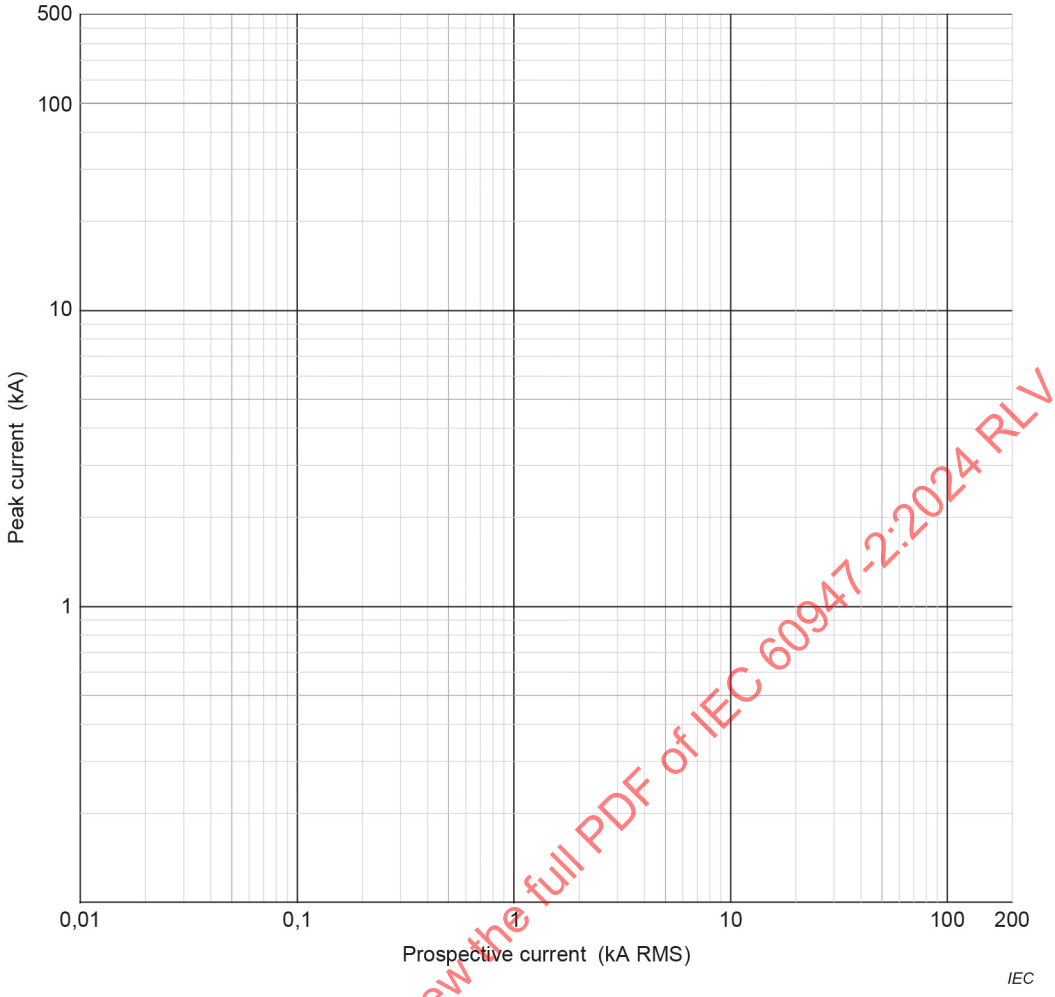


Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA

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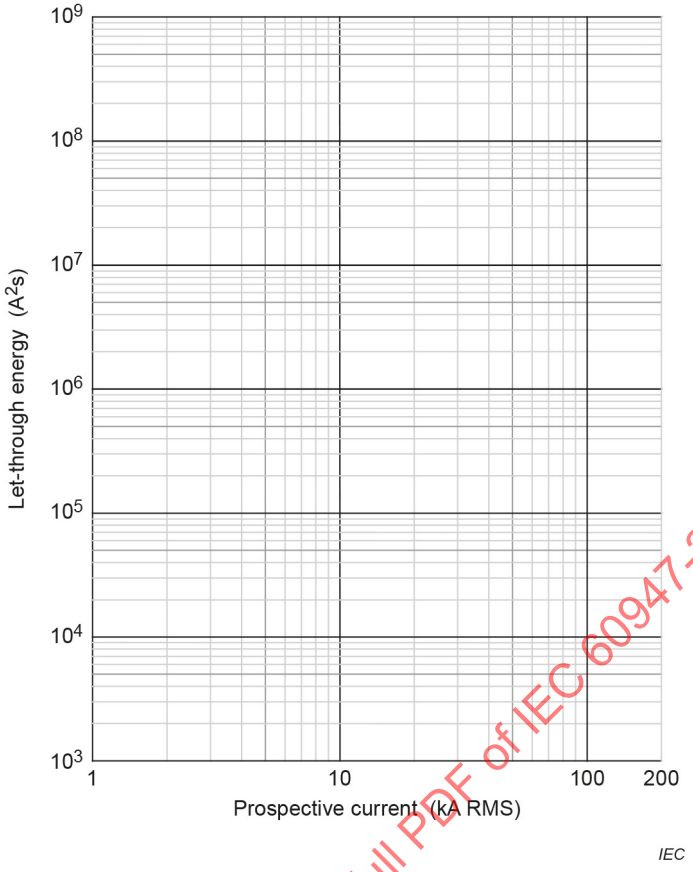


Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA

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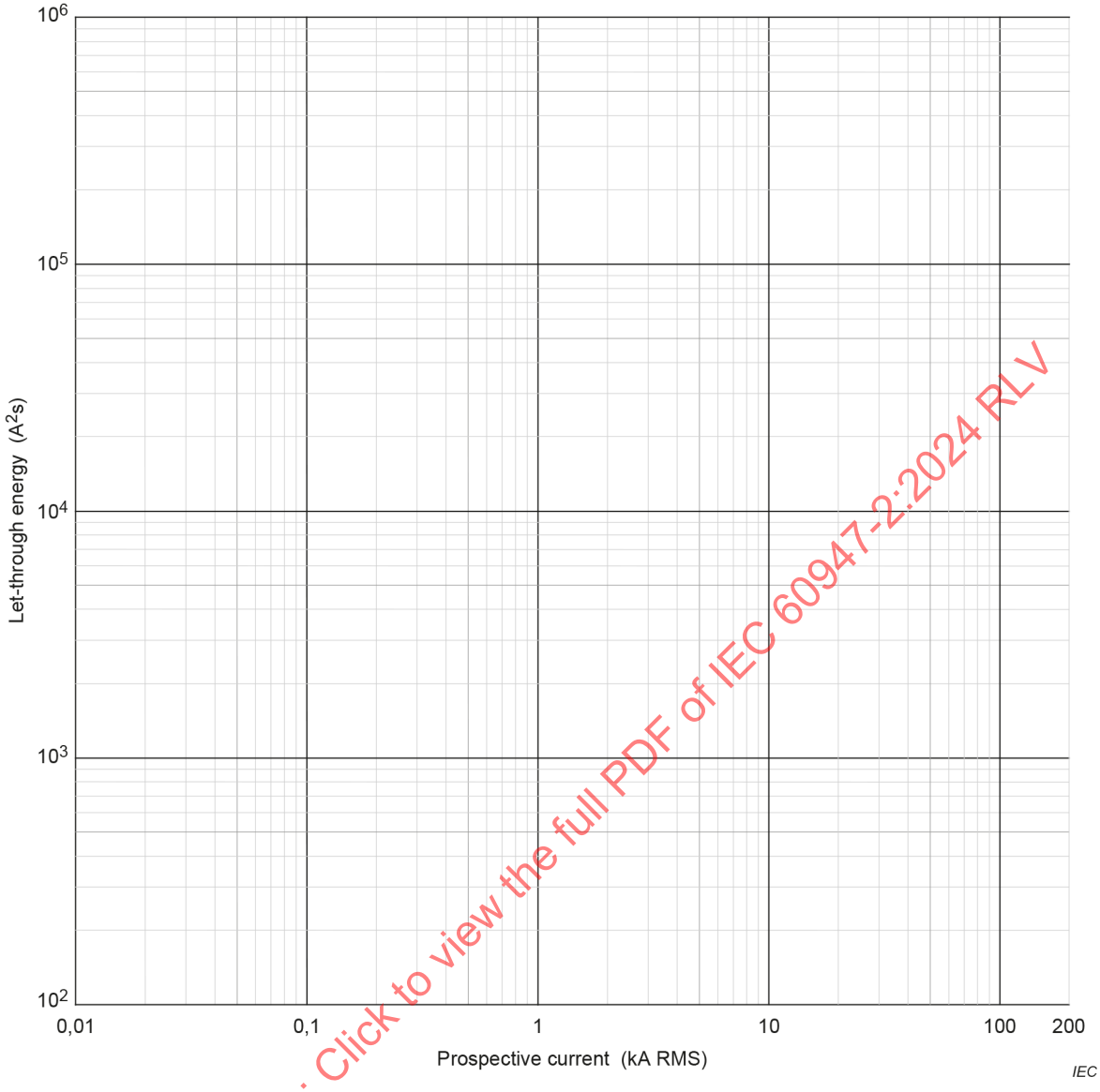
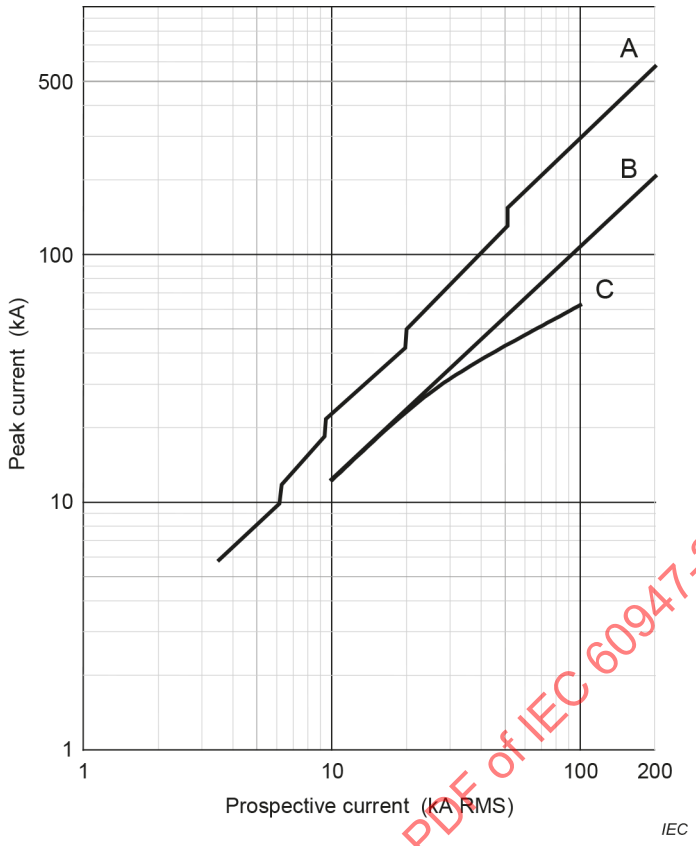


Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA

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Key

A Prospective asymmetric peak current under the test conditions of this document

B Prospective symmetrical peak current

C Typical cut-off current characteristic

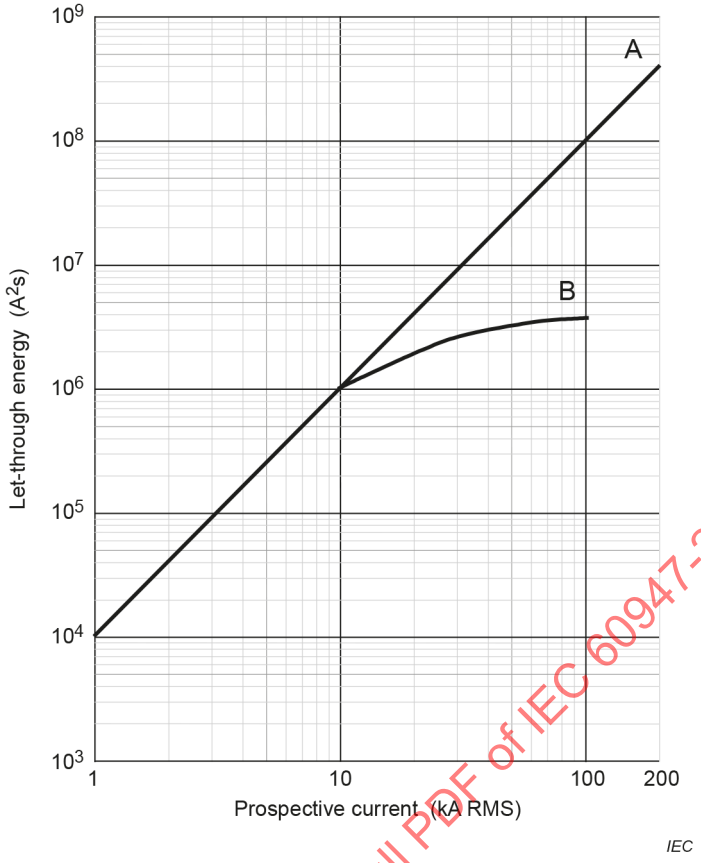
The use of the templates by manufacturers to plot the characteristics of circuit-breakers will provide common presentation, allowing easier interpretation by the user.

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 3.3 for the definition of current-limiting circuit-breakers).

The typical curve does not imply any requirement of this document 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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Key

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 3.3 for the definition of current-limiting circuit-breakers).

The typical curve for the 250 A MCCB does not imply any requirement of this document 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 (CBIs)

L.1 General

This annex covers circuit-breakers which do not fulfil all requirements for overcurrent protection specified in the main part of this document, hereinafter referred to as CBIs. They are capable of being tripped by an auxiliary device, e.g. shunt or undervoltage release. They do not provide circuit protection by themselves. They may be used for isolation. CBIs 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), or intended to be used with external protection relays to provide circuit protection (class W), see L.3.

L.2 Terms and definitions

In addition to the terms and definitions given in Clause 3, 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 document 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

In addition to the classifications given in Clause 4, CBIs are classified as follows:

– Class W: intended to be used with external protection relays to provide circuit protection.

  They are derived from an equivalent selectivity category B circuit-breaker (L.2.1). To ensure circuit protection, they shall be used with external protection relays. Such external protection relays generally use separate current sensors and trip the CBI via an auxiliary release.

  NOTE This solution is generally used when the embedded releases do not provide all the protection characteristics for a particular application, or when the user prefers to use a specific model of protection relay for standardisation purpose.

– Class X: with integral non-adjustable instantaneous short-circuit releases for self-protection. They are derived from an equivalent circuit-breaker (L.2.1) by omitting the overload release only. They have a rated conditional short-circuit current.

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– Class Y: without integral overcurrent releases. They are derived from an equivalent circuit-breaker (L.2.1) by omitting the overcurrent releases. They have a conditional short-circuit current rating.

L.4 Characteristics

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 60947-1:2020).

L.4.2 Rated conditional short-circuit current (I_{cc})

Subclause 5.3.6.4 of IEC 60947-1:2020 applies to CBIs class X and Y.

Both CBIs class X and Y do not have I_{cu} or I_{cs} ratings, but shall have at least one I_{cc} rating.

L.4.3 Other characteristics

Clause 5 applies, except:

– 5.7.1 item 2), 5.7.2 item 2), 5.7.3 and 5.7.4 for all CBIs.
– 5.3.6.2 and 5.3.6.3 for CBIs class X and Y.

The rated values of a CBI shall not exceed those of the equivalent circuit-breaker.

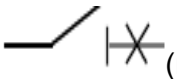
For a CBI class W, the marked I_{cu} value (see 5.3.6.2.2) shall be equal to I_{cw} (see 5.3.6.4).

L.5 Product information

Subclause 6.2 applies, as relevant, with modifications and additions as per Table L.1.

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Table L.1 – Product information

Item	Information	Marking location
L1.1	Suitability for isolation: For CBIs class X and Y with the symbol  (IEC 60617-S00288:2001-07) For CBIs class W with the symbol  (IEC 60617-S00287:2001-07 combined with IEC 60617-S00220:2001-07)	Visible [a]
L1.2	Classification with the marking: CBI-W or CBI-X I_i = … or CBI-Y or CBI-X/W I_i = … or CBI-Y/W as applicable, where I_i is the instantaneous short-circuit current setting (see 3.15)	Visible [b]
L3.1	For CBIs class X or Y only, rated conditional short-circuit current (I_{cc}) and, if specified, overcurrent protective device (OCPD)	Literature
L3.2	Statement that CBIs class X or Y do not provide overcurrent protection (coordination with the upstream SCPD shall be ensured)	Literature
L3.3	Statement that CBIs class W need an external relay to provide overcurrent protection, within the tripping limits and ratings of the equivalent circuit-breakers (in particular, the CBIs class W shall be used within their I_{cw} rating and their maximum short time delay)	Literature
L3.4	For CBIs class W, requirements to operate the auxiliary releases	Literature
L3.5	Presence of a making-current release for CBIs class W, when applicable	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		
[a] As applicable, these symbols replace the symbol used in Table 4, item 1.2 [b] CBIs may be classified as : class W and class X : class W and class Y		

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L.6 Constructional and performance requirements

CBIs, being derived from the equivalent circuit-breaker (see L.2.1), comply with all the applicable construction and performance requirements of Clause 8, except 8.2.1.2.4.

NOTE CBIs can additionally comply with IEC 60947-3 and be marked accordingly.

L.7 Tests

L.7.1 General

L.7.1.1 CBI class W

As the CBI class W is derived from an equivalent circuit-breaker having higher or equal short-circuit characteristics (see 5.3.6) and which has been subjected to the type tests of 9.3, the compliance of the CBI-W with the test requirements of 9.3 is met by carrying out the test of 9.3.6.3, on one sample of maximum current rating, tested at max kVA rating (I_{cu} × corresponding U_e), under the following conditions.

If a CBI class W does not utilize a making-current release, the sequence of operations in 9.3.6.3 is replaced with CO-*t*-CO, otherwise the sequence of operations shall be O-*t*-CO.

The CBI class W shall be opened by the activation of an auxiliary release, supplied with a voltage equal to the operational limit as given in 9.3.4.4.2.3 item ii) and 9.3.4.4.2.4, as appropriate.

For the first operation, the voltage, or the interruption of voltage in case of an undervoltage release, shall be applied to the auxiliary release after a time equal to the maximum time setting of the short-time delay short-circuit release of the equivalent circuit-breaker, according to the manufacturer's instructions.

For the second operation, the voltage, or the interruption of voltage in case of an undervoltage release, shall be applied to the auxiliary release between 0 and 10 ms after the initiation of the short-circuit.

NOTE The purpose of these tests is to verify the ability of the auxiliary release to trip the circuit-breaker under short-circuit conditions.

Following these tests, the dielectric withstand and the leakage current of the sample shall be verified in accordance with 9.3.6.4, and the auxiliary release shall be verified in accordance with 9.3.4.9.

For a CBI class W with both 3-pole and 4-pole variants, the tests shall be performed on the 4-pole variant, covering the 3-pole variant.

When the equivalent circuit-breaker, which the CBI class W is derived from, has been subjected to the type tests of Annex C, Annex H or Annex P, compliance of the CBI class W with the corresponding annexes is covered.

L.7.1.2 CBI class X

The OCPD is specified.

Case 1:

$I_{cc} \leq I_{cu}$ 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;

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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.

In both cases, the relationship between short-circuit making capacity and I_{cc} is given in Table 1.

L.7.1.3 CBI 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 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.

In both cases, the relationship between short-circuit making capacity and I_{cc} is given in Table 1.

L.7.2 Rated conditional short-circuit current tests

L.7.2.1 General

L.7.2.1.1 Applicability

These tests shall be made when required by L.7.1.2 (CBI-X) case 2, or by L.7.1.3 (CBI-Y) 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 9.3.3.6 applies.

The test circuit shall be in accordance with Figure X.4 of IEC 60947-1:2020, SCPD being replaced with 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 9.3.3.6.4 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 X.4 of IEC 60947-1:2020).

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L.7.2.1.3 Behaviour during tests

Subclause 9.3.3.6.5 applies.

L.7.2.2 OCPD specified

L.7.2.2.1 Test sequence

The test sequence comprises the tests in Table L.2.

Table L.2 – Rated conditional short-circuit tests when the OCPD is specified

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 9.3.6.3, 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 and leakage current

Following the test of L.7.2.2.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

L.7.2.3 OCPD not specified

L.7.2.3.1 Test sequence

The test sequence comprises the tests in Table L.3.

Table L.3 – Rated conditional short-circuit tests when the OCPD is not specified

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 9.3.6.3, 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 and leakage current

Following the test of L.7.2.3.2, the dielectric withstand and the leakage current shall be verified according to 9.3.4.6, except that the leakage current shall not exceed 6 mA.

L.7.3 Routine tests

Subclause 9.4 applies, except the verification of the calibration of overcurrent releases (9.4.3).

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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 processing device is 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 processing device is 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 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.

MRCDs may or may not be functionally dependent on a voltage source.

The object of this annex is to state the specific requirements that the MRCD shall comply with, in association with the specified current-breaking device(s).

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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

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 SCPD, can satisfactorily withstand for the total operating time of the SCPD, 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 M.2.1.1)

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 in the case of failure of the voltage source but able to operate as intended in M.8.13 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 DC 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 5.3.3.3 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 5.3.1.2 of IEC 60947-1:2020 applies.

M.4.1.2.4 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:2020 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 5.6 of IEC 60947-1:2020 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 $I_{\Delta n}$ ≤ 30 mA), 10 $I_{\Delta n}$ (or 0,5 A for $I_{\Delta n}$ ≤ 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 $I_{\Delta n}$ ≤ 30 mA shall be of the non-time-delay type.

M.4.2.2 Operating characteristic in the case of residual current with DC 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 5.3.6.4 of IEC 60947-1:2020 applies.

M.4.3.2 Rated conditional residual short-circuit current ($I_{\Delta c}$)

Subclause 5.3.6.4 of IEC 60947-1:2020 applies.

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M.4.3.3 Rated short-time withstand current (I_{cw})

Subclause 5.3.6.1 of IEC 60947-1:2020 applies.

M.4.3.4 Peak withstand current

Subclause 3.7.28 of IEC 60947-1:2020 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.4.2.2 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.4.2.3 applies.

M.4.4.4 Preferred values of rated voltage of the voltage source of MRCDs

Subclause 5.5.1 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 DC 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 for which an MRCD with separate sensing means will not trip at an overcurrent of 6 I_n, with a single-phase load (see M.8.6)	-	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 60947-1:2020)	Literature	Literature	Literature
M3.9	position of use and mounting precautions	Literature	Literature	Literature

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Item	Information	Marking location		
		on single device	on separate device	
			Sensing means	Proces-sing device
M3.10	wiring diagram	Literature	Literature	Literature
M3.11	connection of the sensing means to the processing device (cable type, length, etc.)	-	Literature	-
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 7 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.

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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 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 8.2.3 of IEC 60947-1:2020.

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 60947-1:2020 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.

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M.7.2.9 Behaviour of MRCDs of types A and B in the case of an earth fault current comprising a DC component

MRCDs of type A and type B shall meet the requirements of 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 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 in the case of 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 8.2.2 of IEC 60947-1:2020.

M.7.2.11.2 Ambient air temperature

The temperature-rise limits given in Table 2 of IEC 60947-1:2020 and in Table 3 of IEC 60947-1:2020 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 60947-1:2020 and in Table 3 of IEC 60947-1:2020.

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.

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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.

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.

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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 DC 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.

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 9.4.5 applies.

M.8.2 Compliance with constructional requirements

Subclause 9.2 of IEC 60947-1:2020 applies, except in so far as 8.1 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.

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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:

– 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.

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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.

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 9.3.3.4 of IEC 60947-1:2020 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 9.3.3.4.1 item 2), of IEC 60947-1:2020.

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 an uninsulated busbar is installed according to the manufacturer's instructions.

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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.

If the voltage source circuit is not supplied by the monitored circuit, the test voltage defined in Table 12 of IEC 60947-1:2020 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 DC 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.

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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.

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 DC 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

Subclause 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.

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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.

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.

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

Subclause 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.

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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.

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.

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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.

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 condition. 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 dependent on the line voltage. For the tripping tests the flow of rated current may be interrupted, provided that the total interruption duration does not exceed 30 s. As soon as the sum of interruption durations exceeds 30 s, the MRCD shall be loaded again with its rated current until the steady-state condition is reached, before the next tripping time measurement. The thermal steady-state condition, measured at one of the main terminals, shall be in accordance with 9.3.3.3.2 of IEC 60947-1:2020.

In the case of MRCDs having multiple settings of residual operating current, the tests are made at the minimum and maximum settings.

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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.

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 60947-1:2020, 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 9.3.3.3.1 of IEC 60947-1:2020 applies.

M.8.10.3 Test procedure

The test shall be carried out in accordance with 9.3.3.3.4 of IEC 60947-1:2020, at the rated current I_n.

During this test, temperature-rise shall not exceed the values listed in Table 2 of IEC 60947-1:2020 and Table 3 of IEC 60947-1:2020.

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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 applicable.

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.

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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 voltage source is then switched off by opening S_a; the MRCD shall not operate.

The switch S_a 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.

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 9.3.4.1.2 of IEC 60947-1:2020 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 18 of IEC 60947-1:2020 applies.

M.8.14.2.3 Power factor of test circuit

Table 16 applies.

M.8.14.2.4 Power frequency recovery voltage

Subclause 9.3.2.2.3, item a), of IEC 60947-1:2020 applies.

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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 9.3.4.6.

The MRCD shall perform satisfactorily the tests specified in B.8.11.4 b) 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.

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M.8.14.4 Verification of rated short-time withstand current (I_{cw})

Subclause 9.3.4.3 of IEC 60947-1:2020 applies to the primary circuit.

The test may be carried out at any suitable 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:

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).

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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.8.13.1 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.

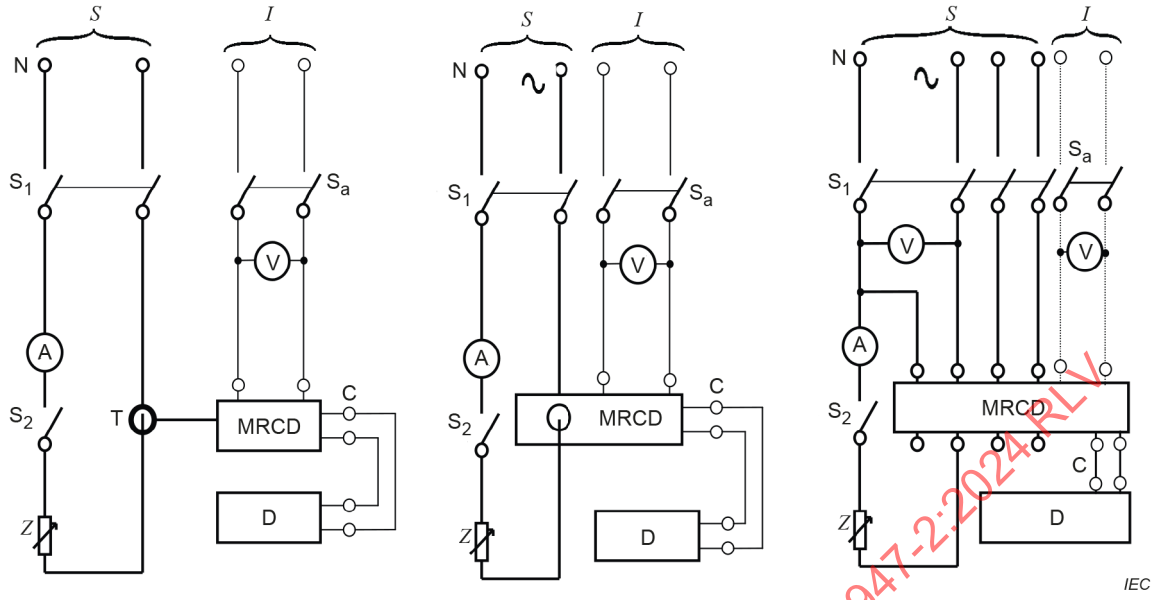
The test set-up shall be in accordance with Figure M.24 for MRCDs with separate sensing means.

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.

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a) **MRCD with separate sensing means**

b) **MRCD with integral sensing means**

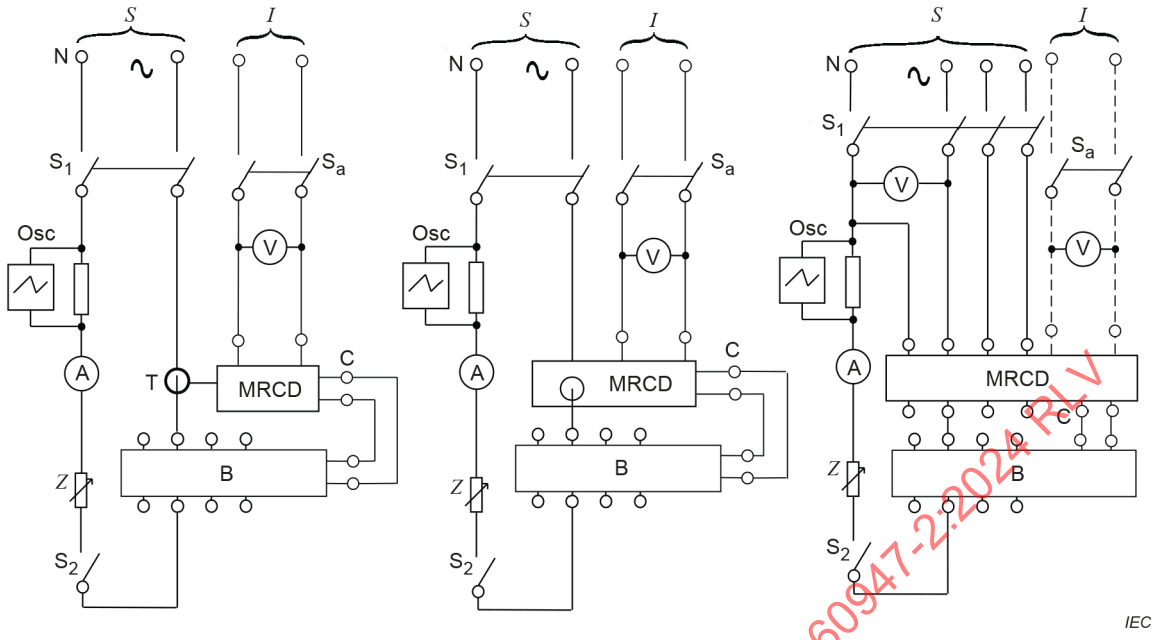
c) **Terminal-type MRCD**

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		

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**

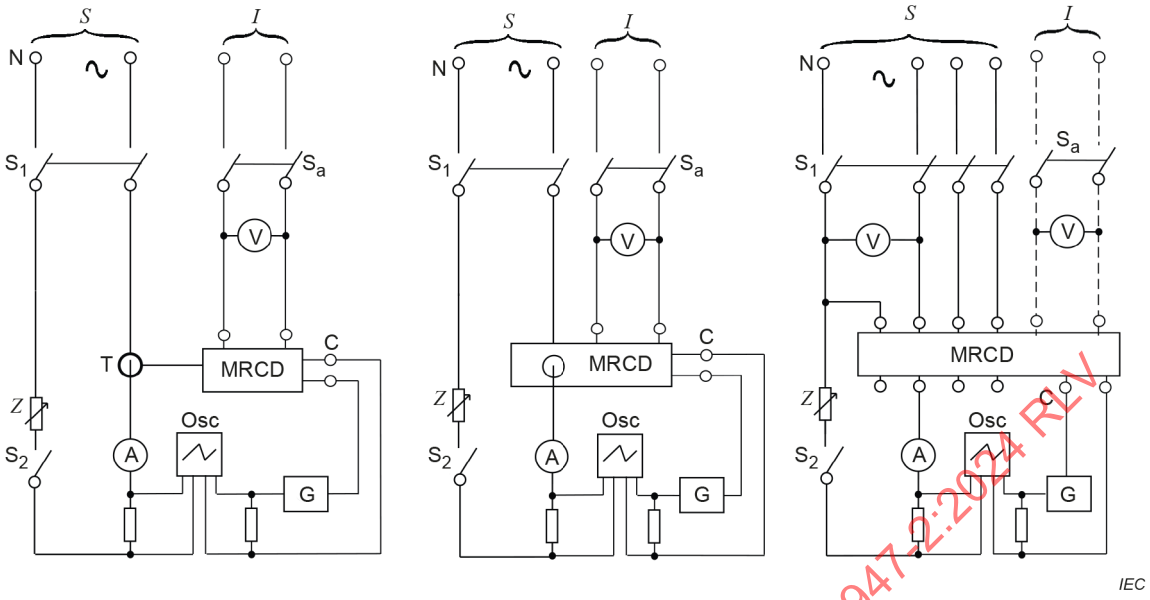
c) **Terminal-type MRCD**

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**

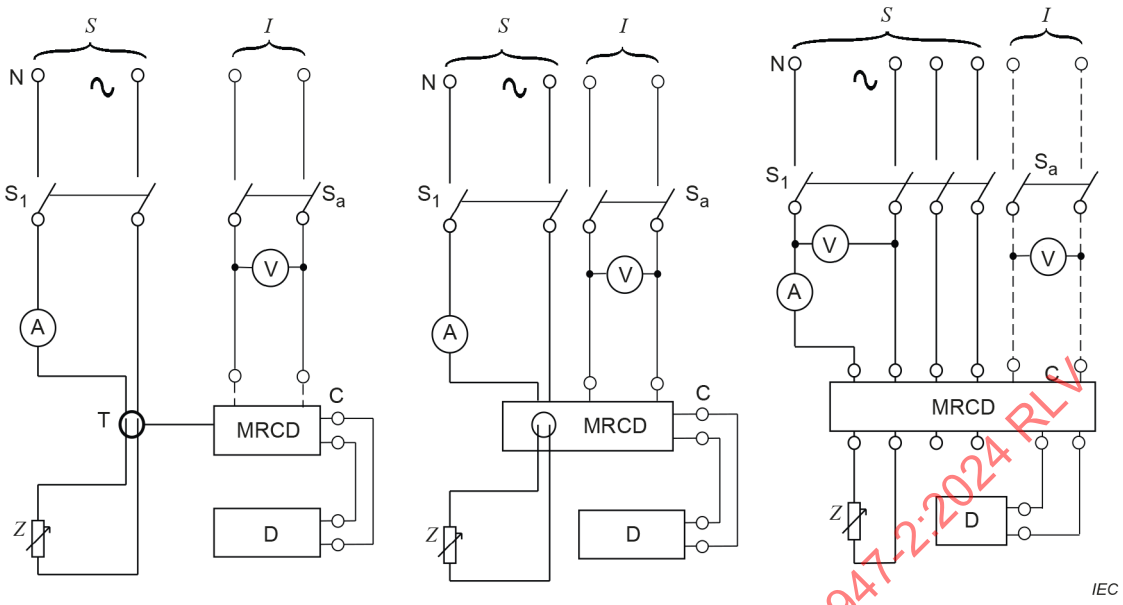
c) **Terminal-type MRCD**

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

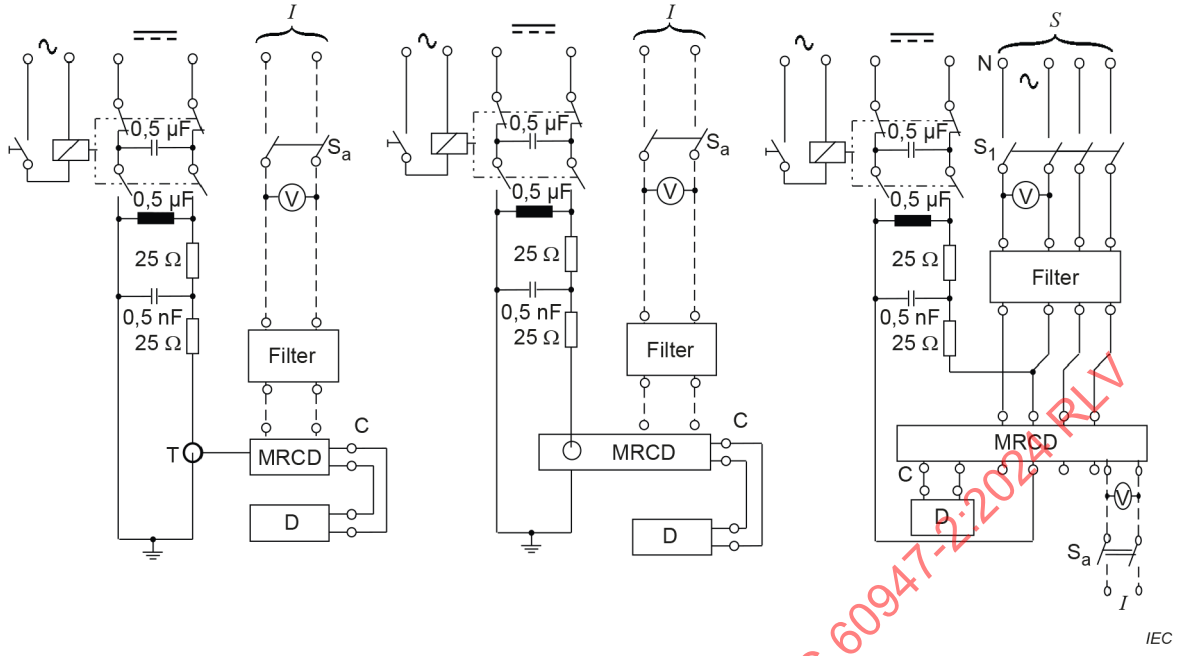
c) Terminal-type MRCD

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

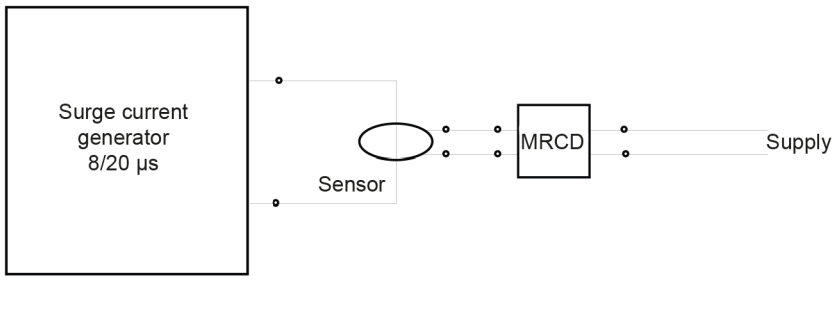
c) Terminal-type MRCD

Key

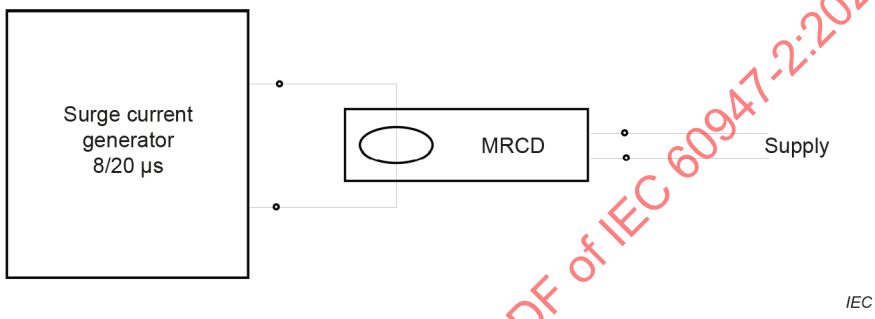
S	power supply	T	sensing means
V	voltmeter	C	output circuit
I	separate voltage source, if applicable	D	instrument indicating the change of status
S_1	multi-pole switch	S_a	auxiliary switch

Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance

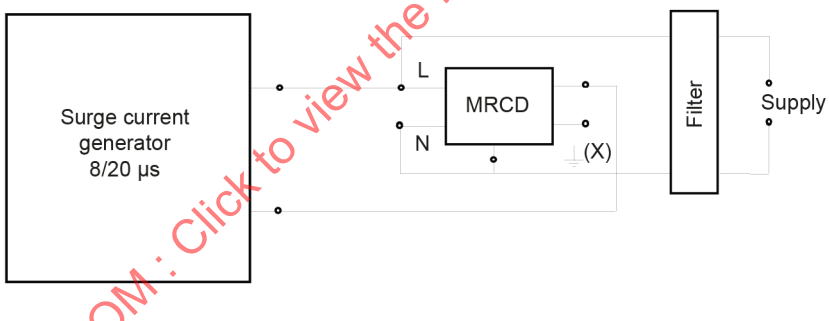
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(a) MRCD with separate sensing means



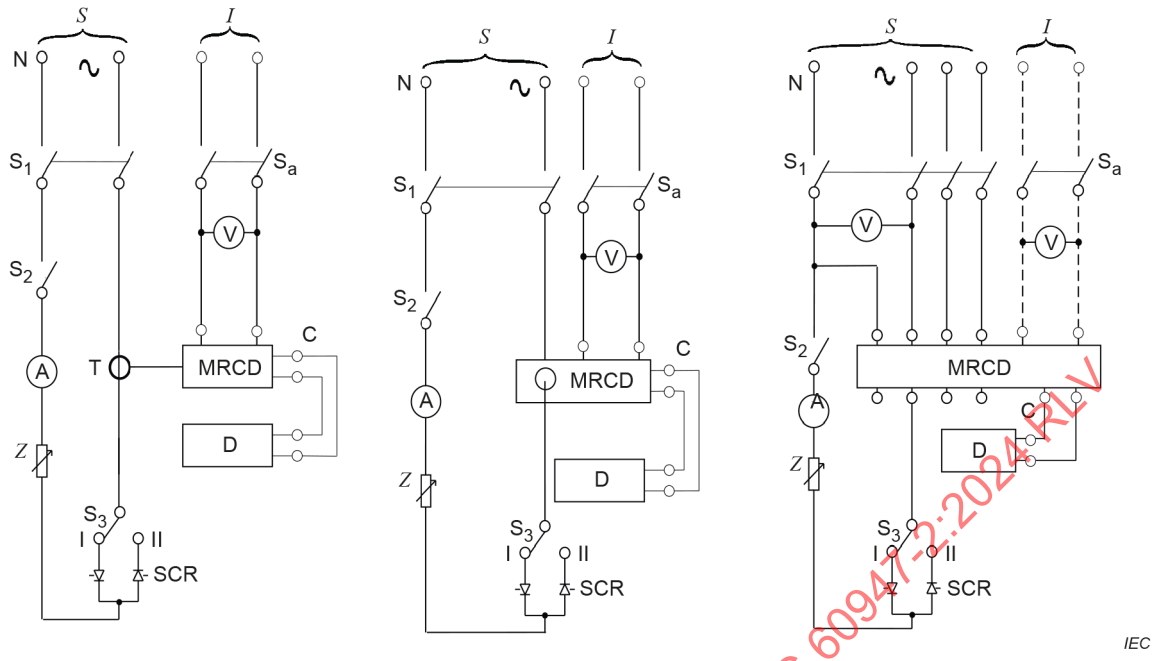
(b) MRCD with integral sensing means



(c) Terminals type MRCD

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

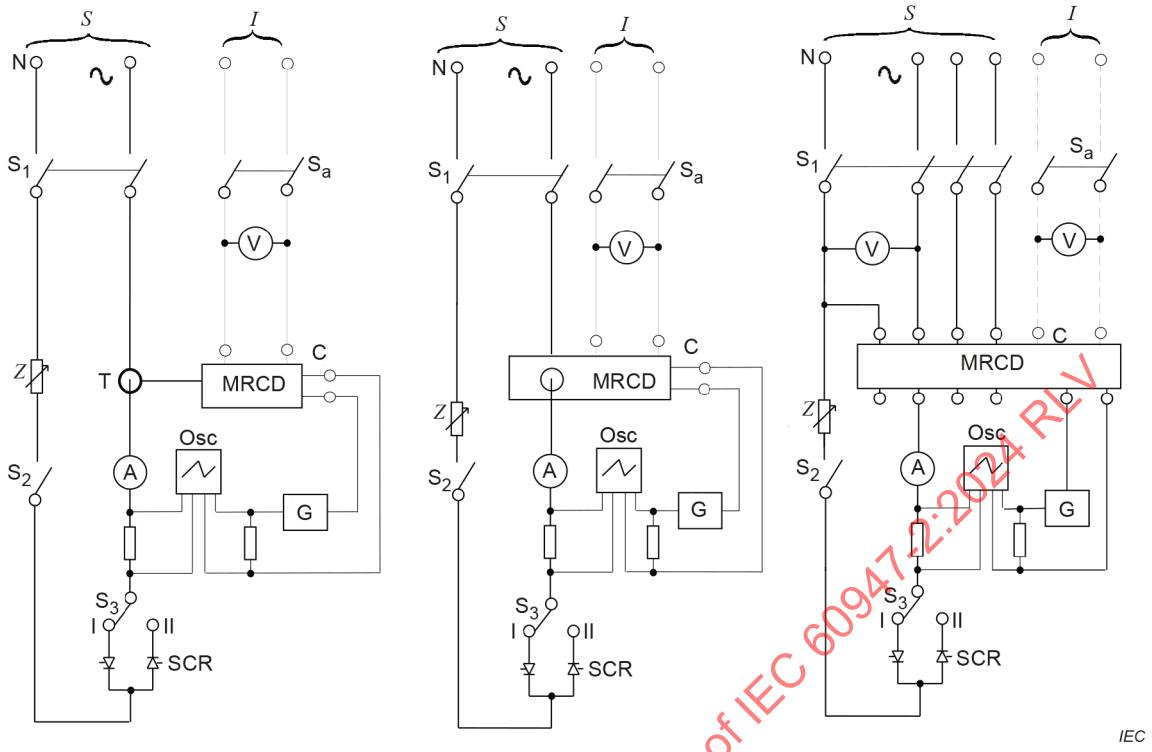
c) Terminal-type MRCD

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**

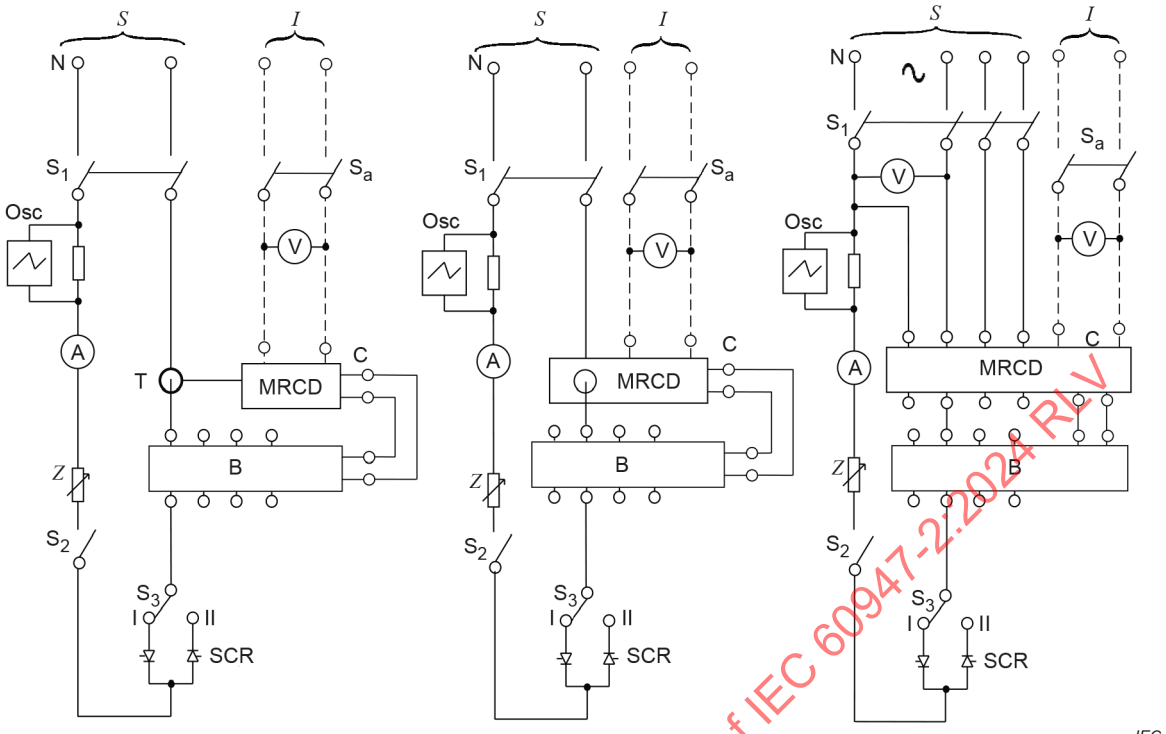
c) **Terminal-type MRCD**

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

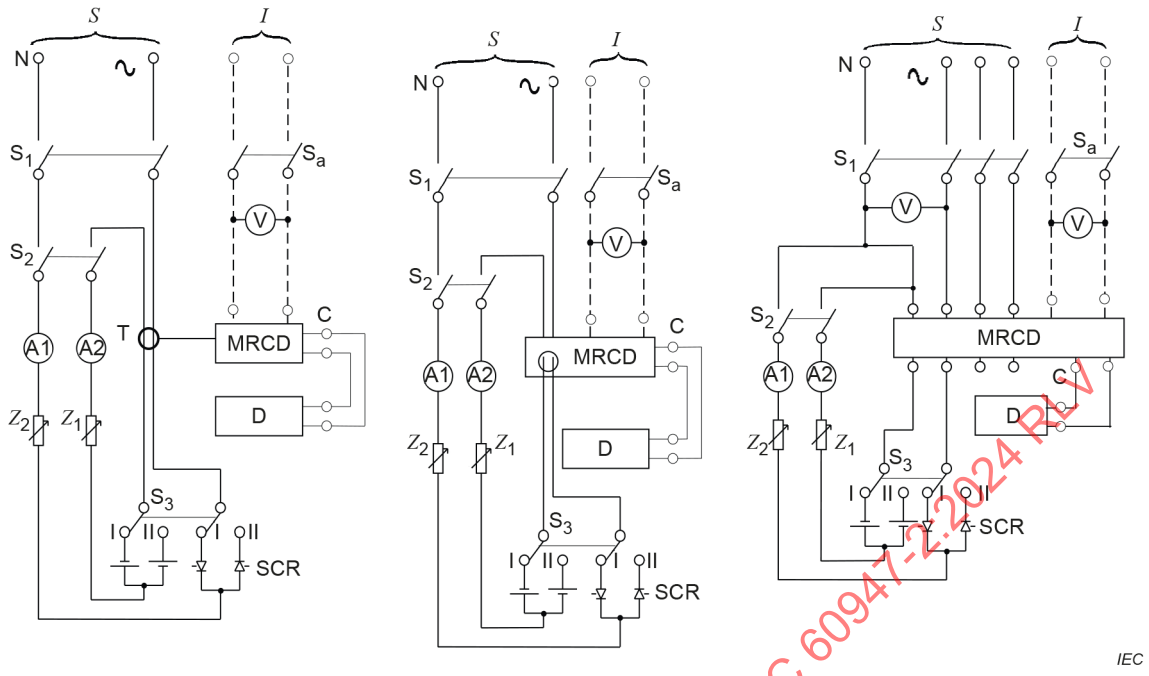
c) Terminal-type MRCD

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

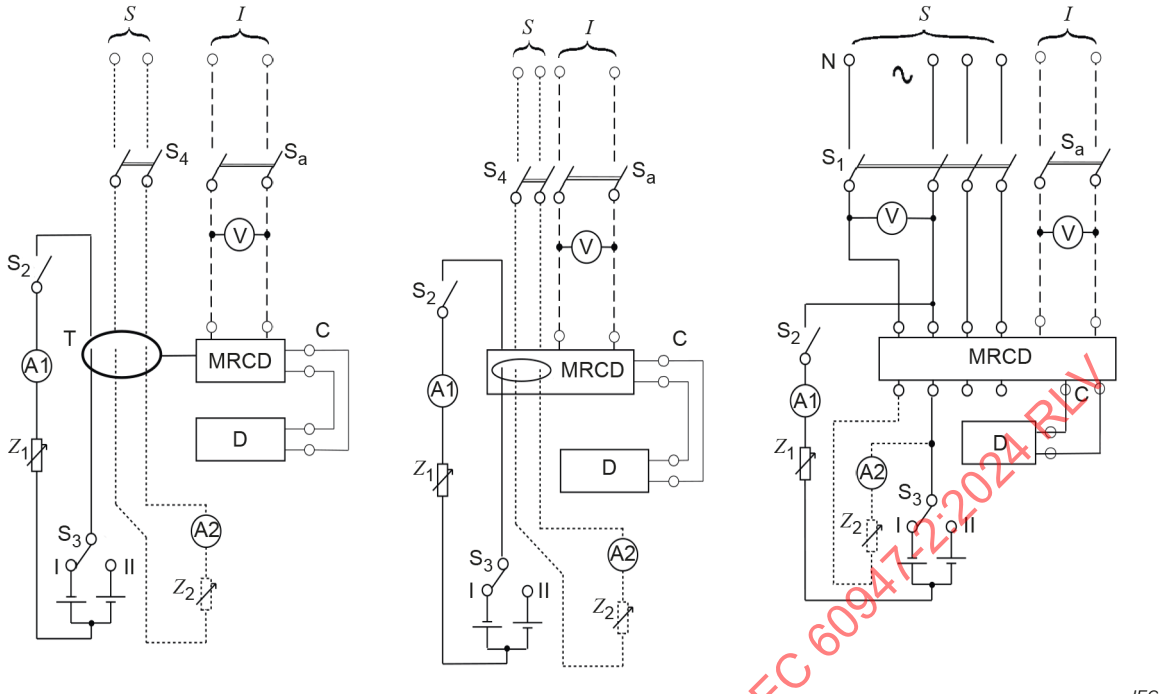
c) Terminal-type MRCD

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 DC current	T	sensing means
A2	ammeter measuring AC 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**

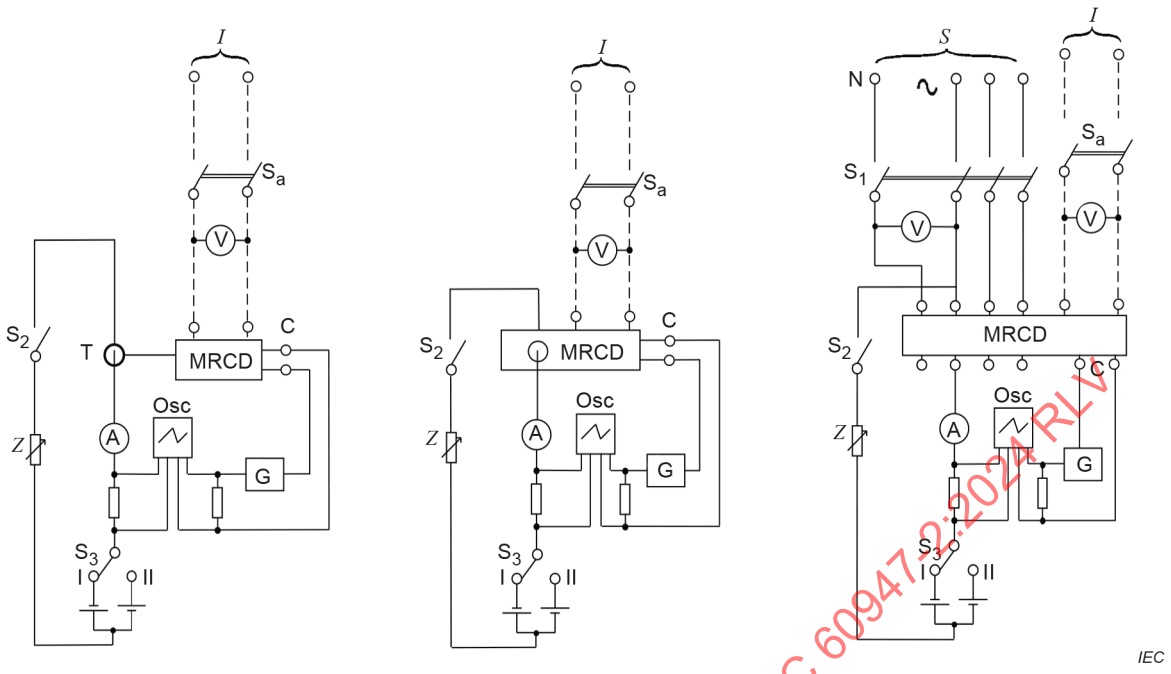
c) **Terminal-type MRCD**

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 DC current	Z_1, Z_2	adjustable impedances
A2	ammeter measuring AC 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**

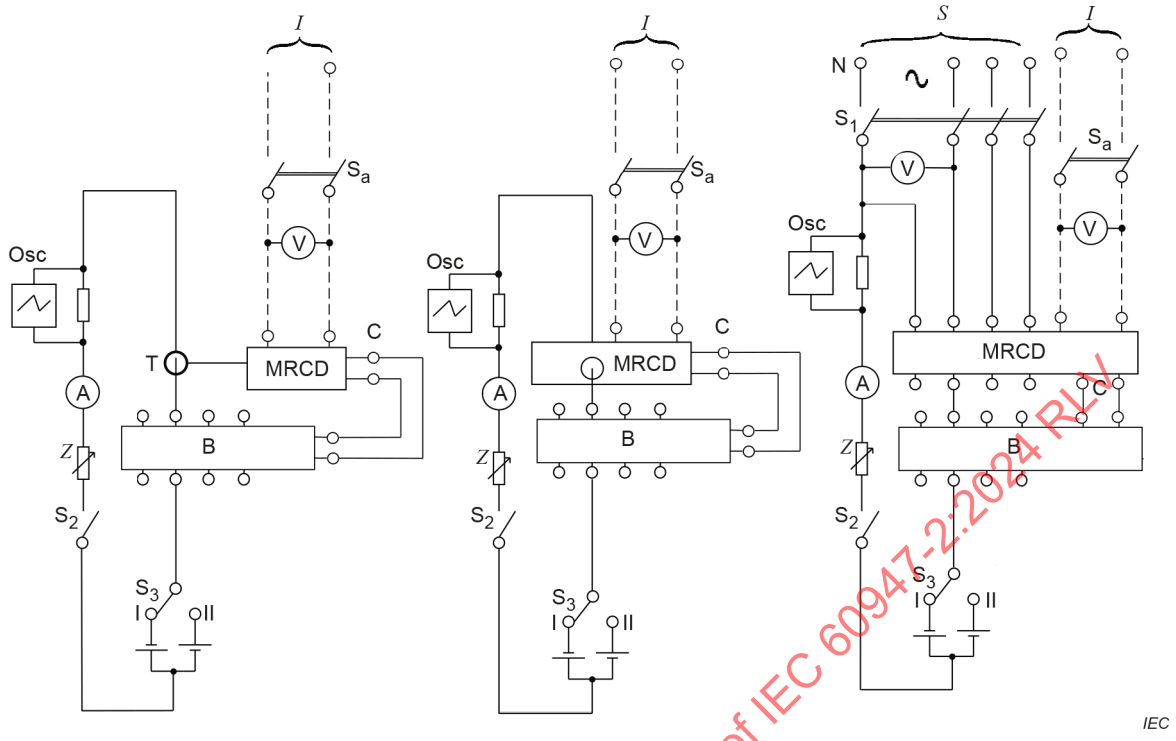
c) **Terminal-type MRCD**

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 DC 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

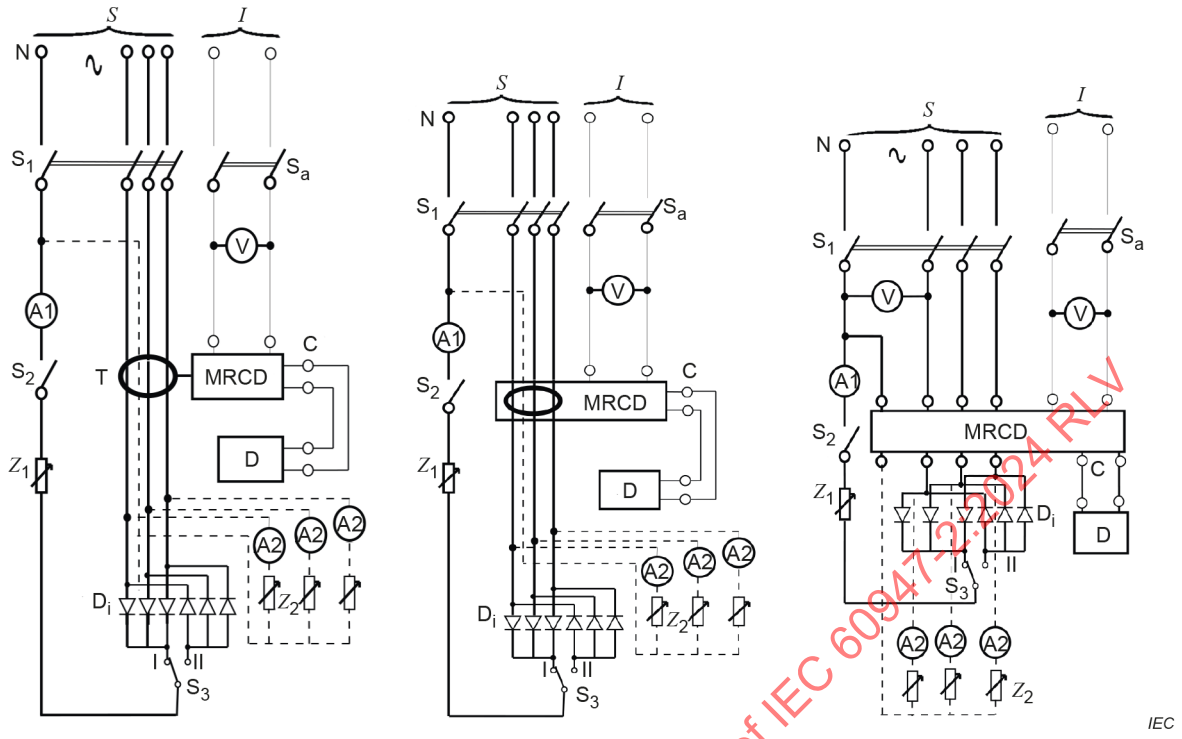
c) Terminal-type MRCD

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 DC 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

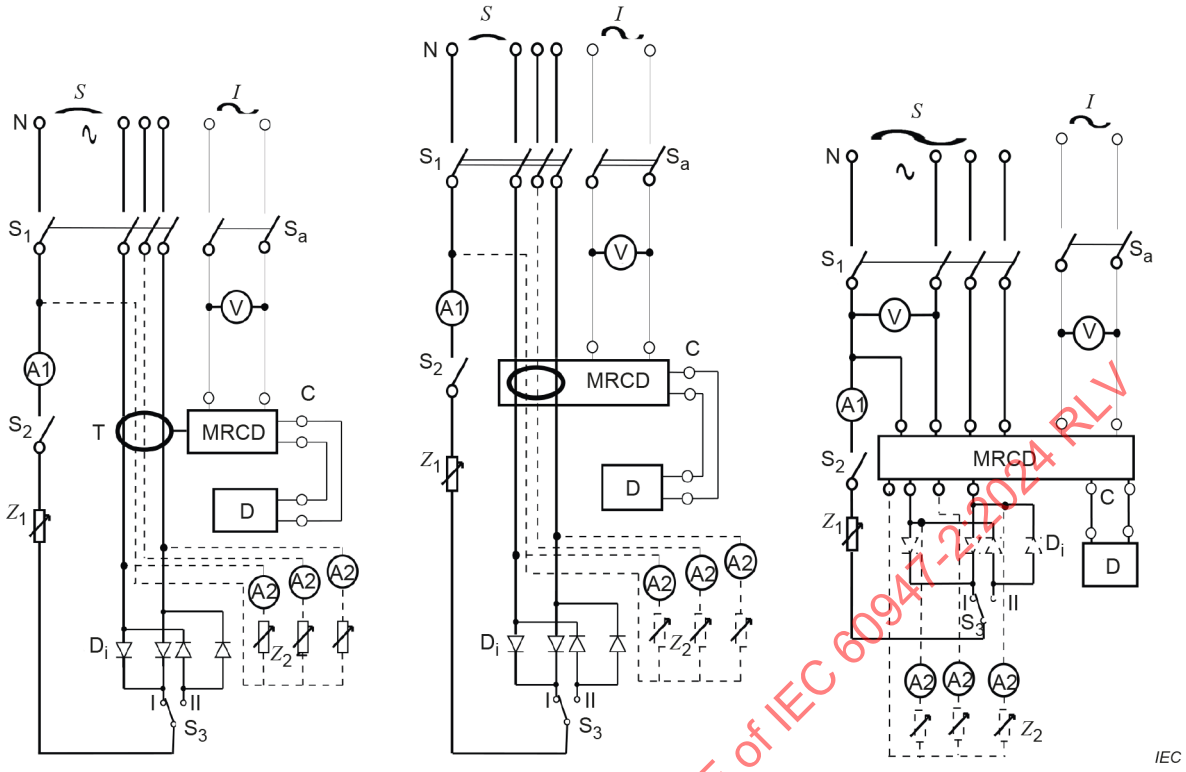
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	adjustable impedances
A1	ammeter measuring AC current	T	sensing means
A2	ammeter measuring AC current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
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

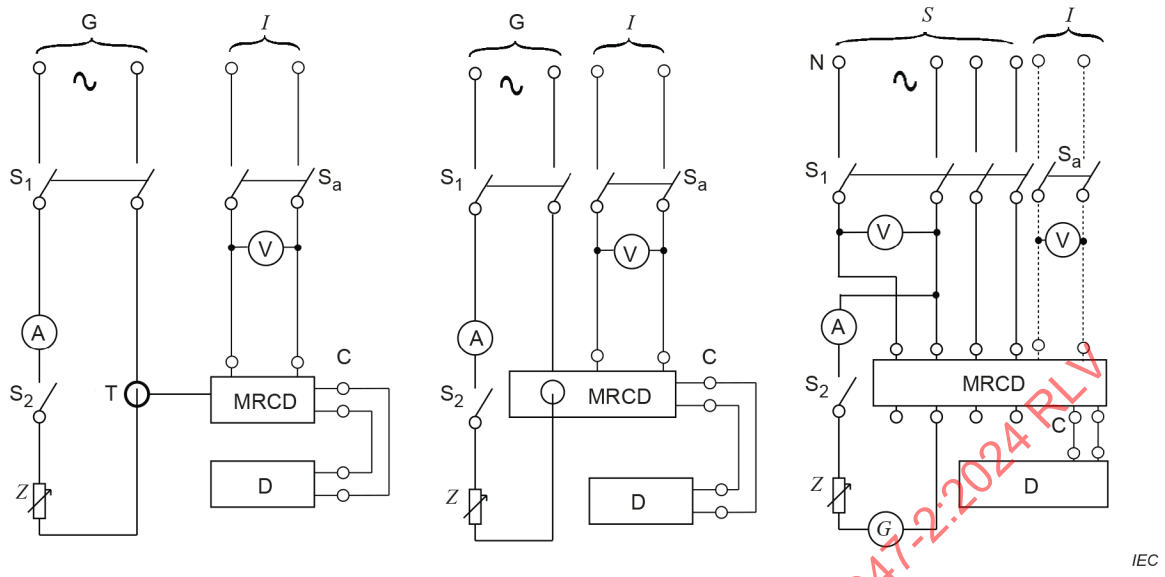
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z_1, Z_2	adjustable impedances
A1	ammeter measuring AC current	T	sensing means
A2	ammeter measuring AC current	C	output circuit
S_1	multi-pole switch	D	instrument indicating the change of status
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

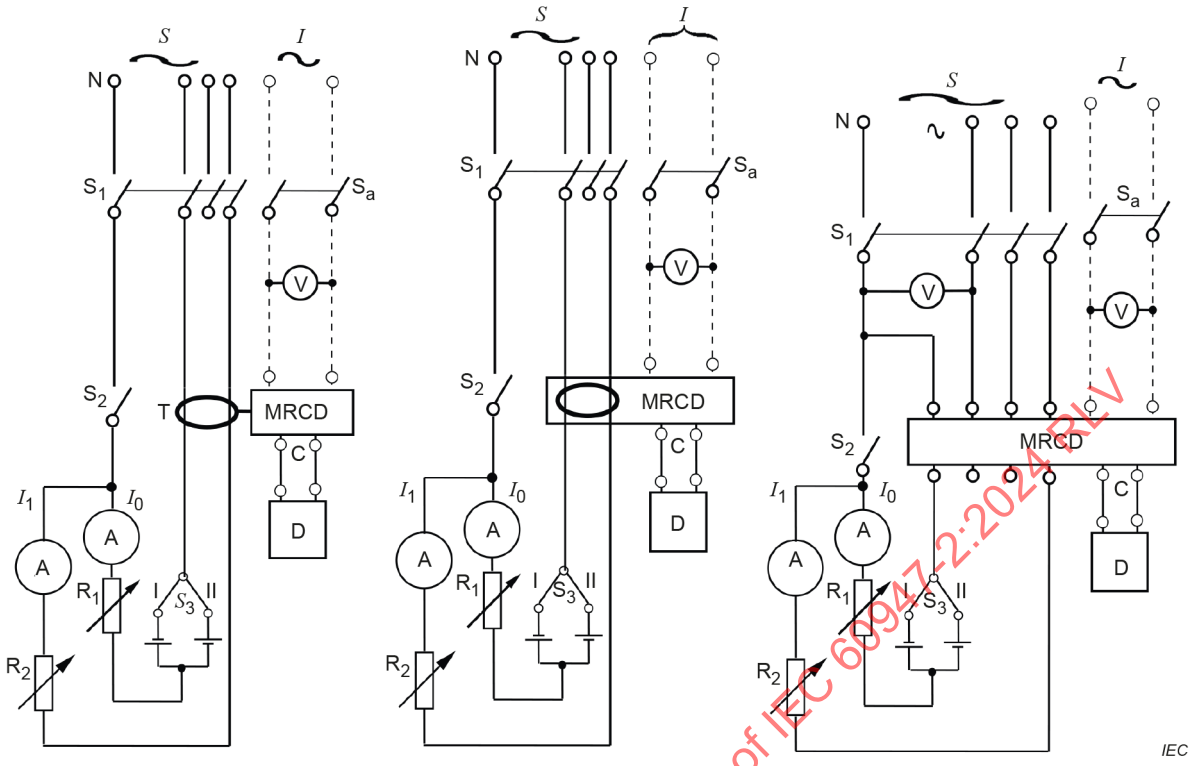
S	power supply	S_2	single-pole switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	Z	adjustable impedance
A	ammeter measuring AC current	T	sensing means
S_1	multi-pole switch	C	output circuit
G	generator	D	instrument indicating the change of status

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

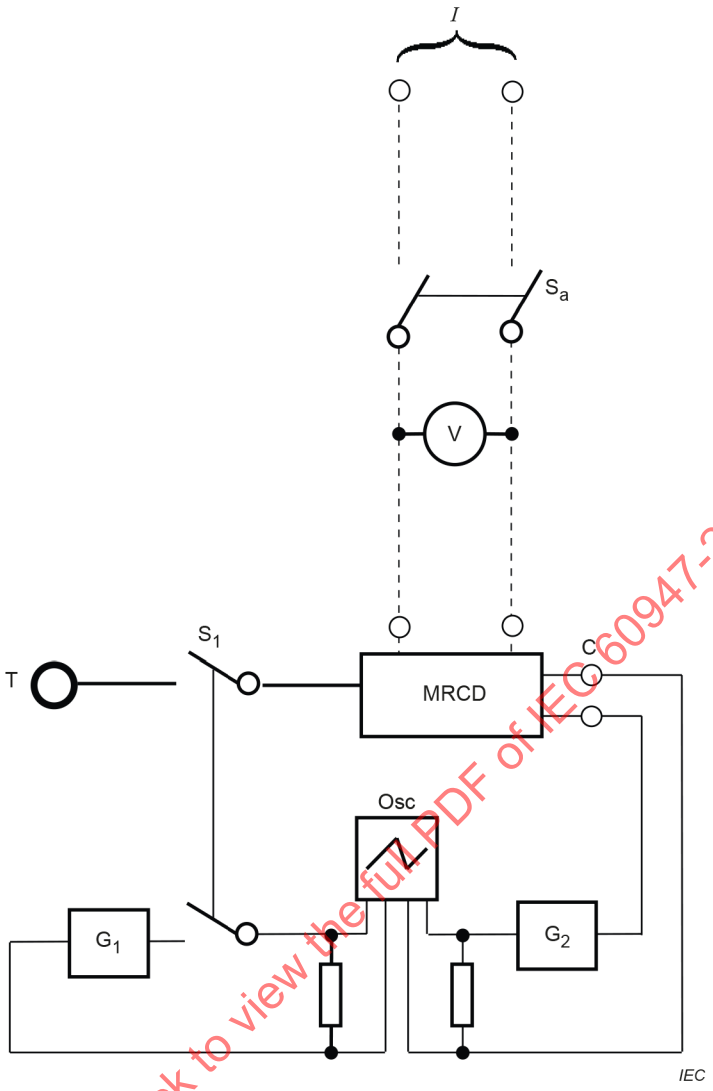
S	power supply	S_3	two-way switch
I	separate voltage source, if applicable	S_a	auxiliary switch
V	voltmeter	R_1, R_2	adjustable resistors
A	ammeter measuring AC current	T	sensing means
S_1	multi-pole switch	C	output circuit
S_2	single-pole switch	D	instrument indicating the change of status

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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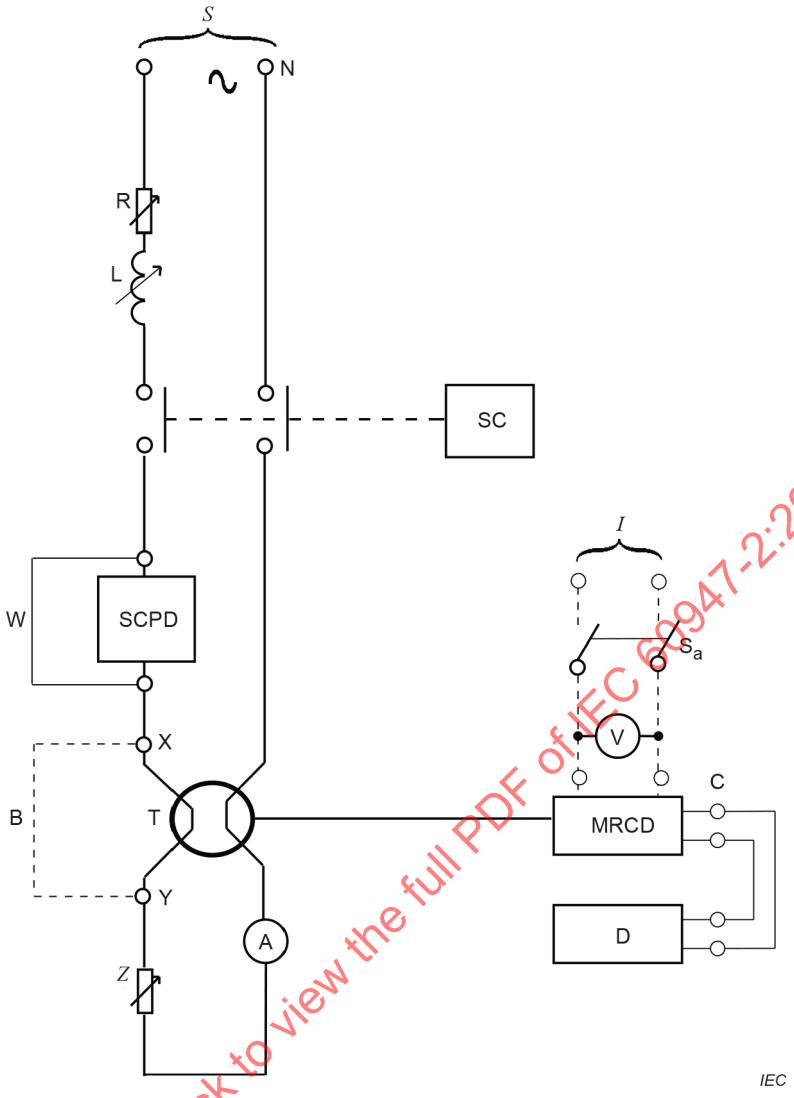


Key

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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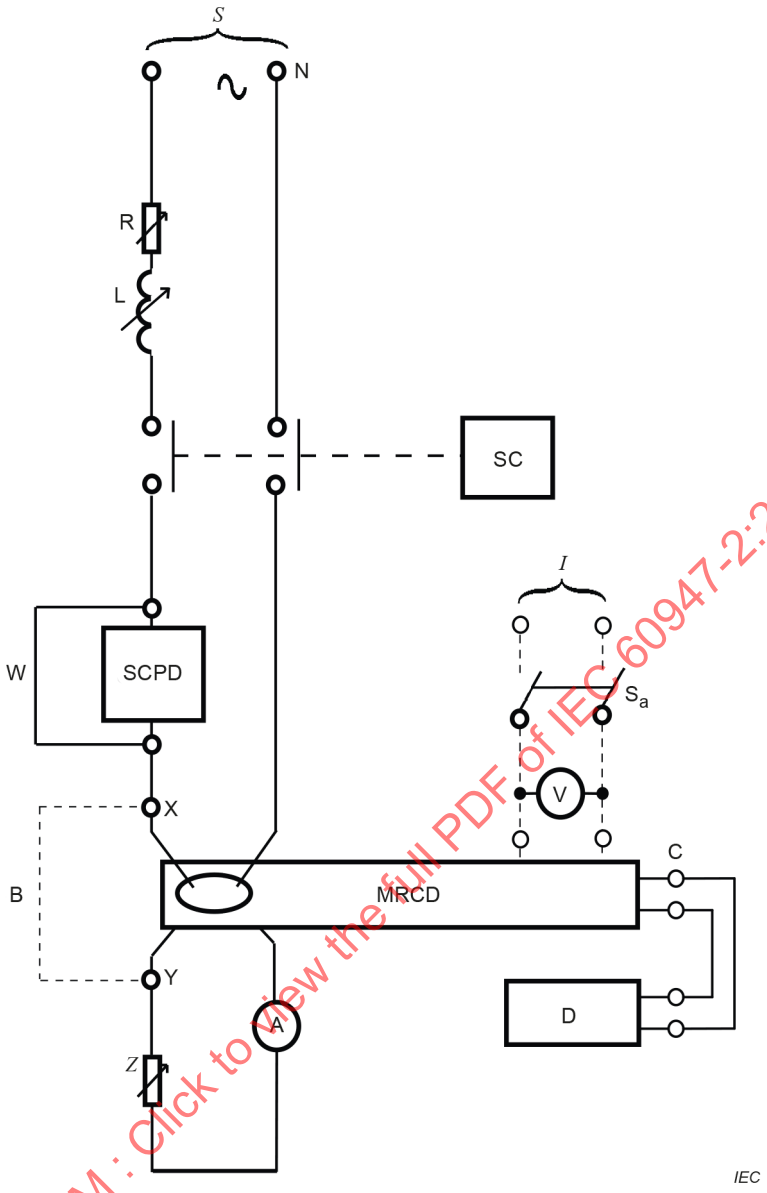


Key

S	power supply	L	adjustable reactor
I	separate voltage source, if applicable	R	adjustable resistor
V	voltmeter	*Z*	adjustable impedance
A	ammeter	T	sensing means
S_a	auxiliary switch	C	output circuit
SC	short-circuit switch	D	instrument indicating the change of status
W	temporary connection	SCPD	short-circuit protective device
B	connection for residual short-circuit test, replacing the connection through the sensing means		

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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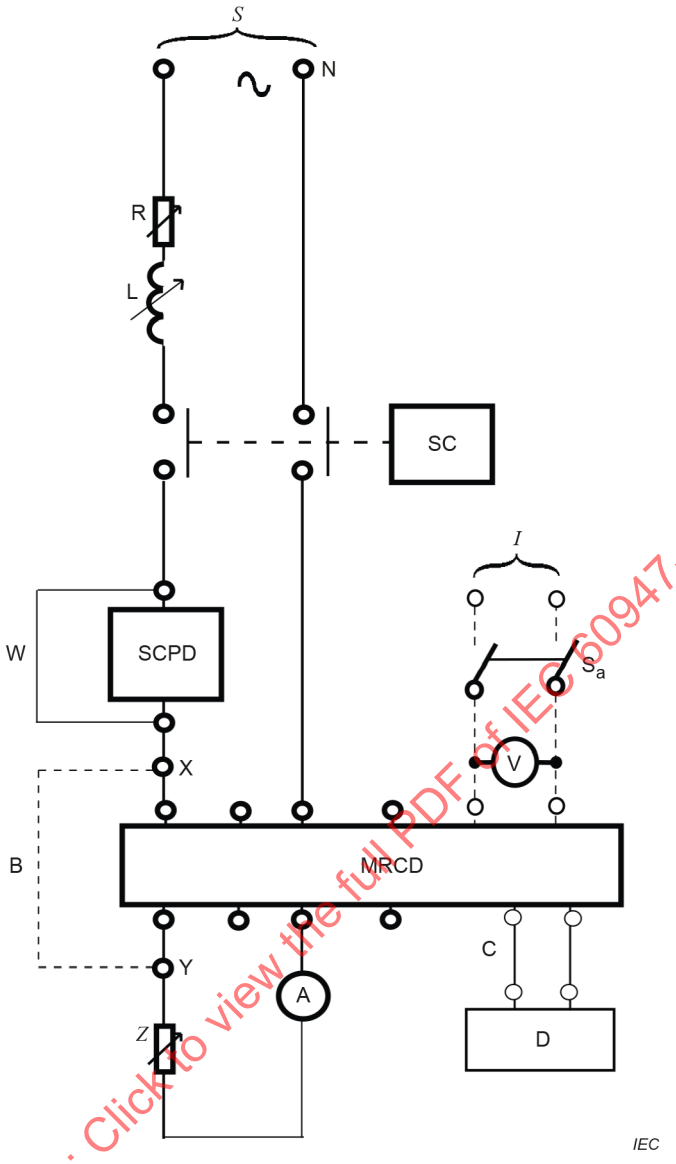


Key

S	power supply	B	connection for residual short-circuit test, replacing the connection through the sensing means
I	separate voltage source, if applicable	L	adjustable reactor
V	voltmeter	R	adjustable resistor
A	ammeter	*Z*	adjustable impedance
S_a	auxiliary switch	C	output circuit
SC	short-circuit switch	D	instrument indicating the change of status
W	temporary connection	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
Sa	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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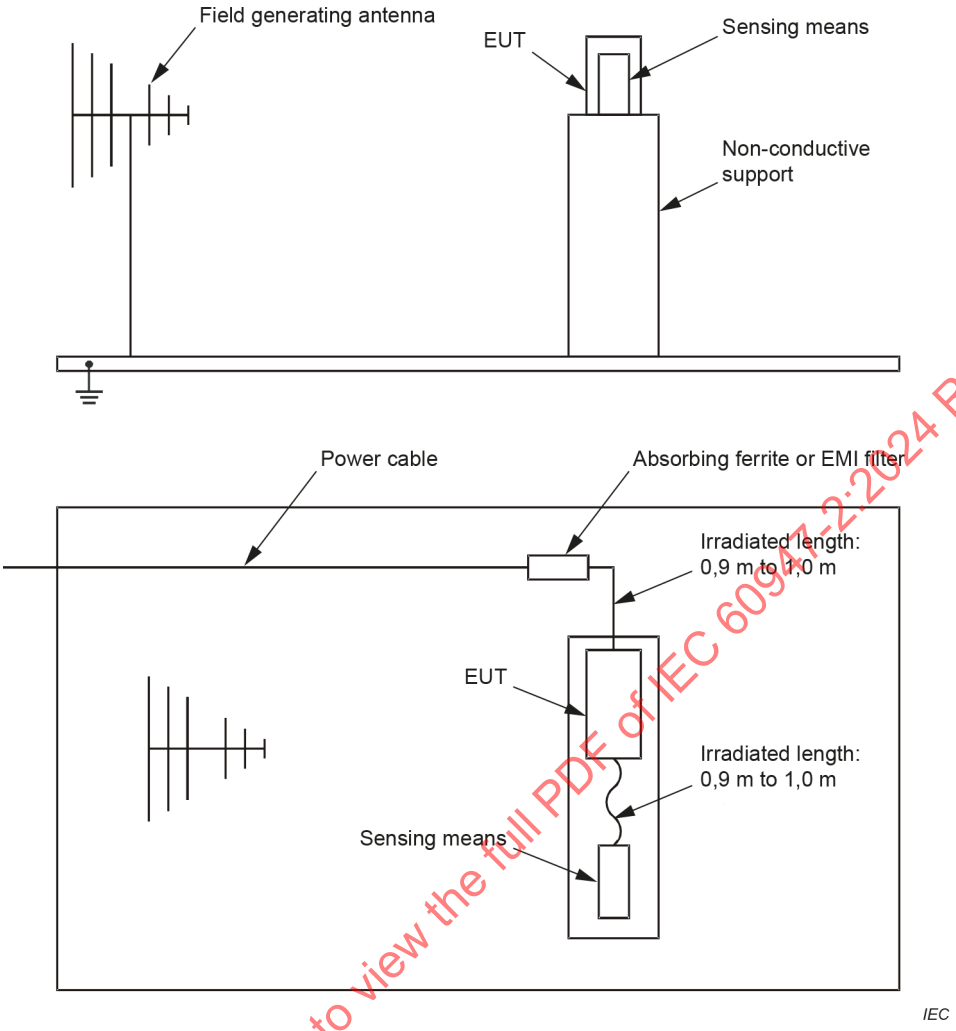


Figure M.22 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCDs with separate sensing means (in addition to the test of Annex B)

Dimensions in metres

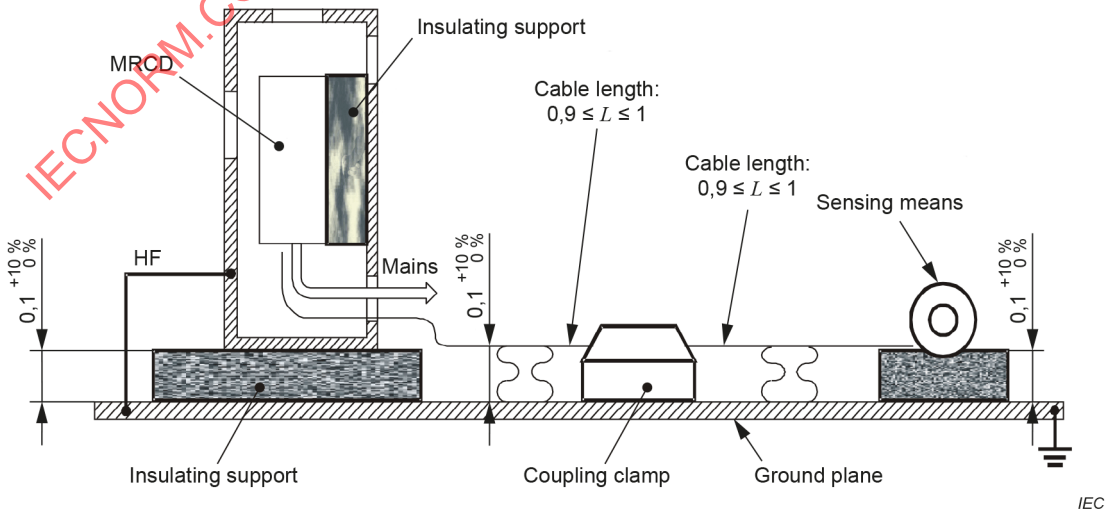
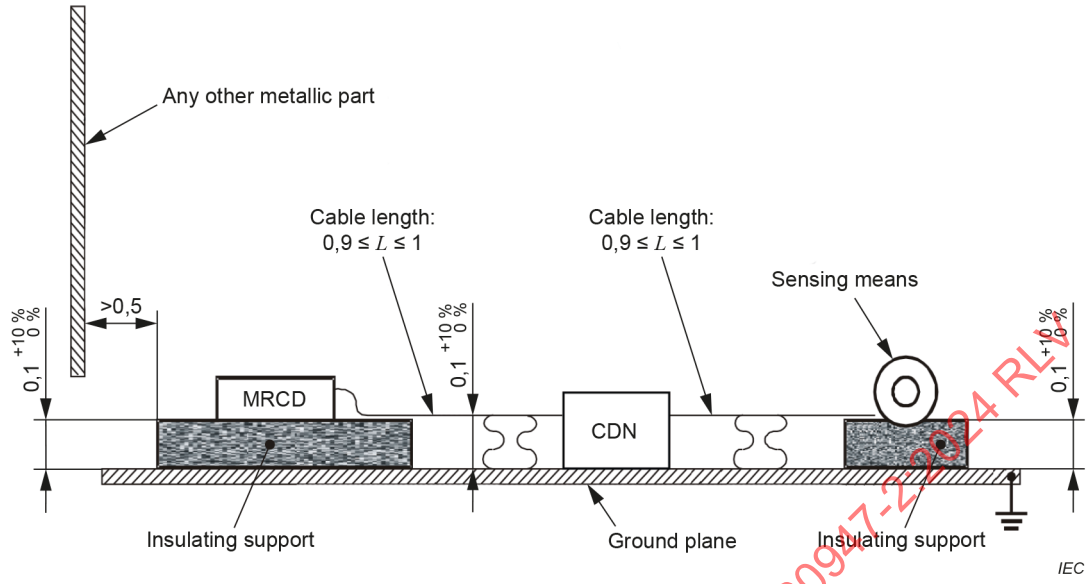


Figure M.23 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (in addition to the test of Annex B)

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Dimensions in metres



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 Overview

This annex applies to devices, mounted in or on the circuit-breaker, incorporating electronic circuits (see 8.3 of IEC 60947-1:2020), 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 9.

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 suitable 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 suitable 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 document.

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 Clause 7 of IEC 61000-4-3:2020, 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 AC power supply only.

Tests shall be performed in accordance with IEC 61000-4-11, at test levels of Table 23 of IEC 60947-1:2020.

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 8.3.3 of IEC 60947-1:2020), 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 6 000 MHz)

Annex J applies, in particular J.3.3.

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Annex O
(normative)

Instantaneous trip circuit-breakers (ICBs)

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 document, 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.

NOTE In some countries, there are circuit-breakers with the function of output of alarm signals without tripping in case of overload. In this case, the alarm signalling can be verified under the same conditions as tripping in the main part of this document. The final user will have to define the correct provisions for thermal protection.

O.2 Terms and definitions

In addition to the terms and definitions given in Clause 3, 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 document and which has the same frame size as the ICB

O.3 Rated values

O.3.1 General

The characteristics of Clause 5 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).

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O.3.4 Rated short-circuit breaking capacities

ICBs may be assigned rated short-circuit breaking capacities different to the equivalent circuit-breaker.

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 6.2 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	Instantaneous short-circuit current setting I_i (see 3.15) (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 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 8, except 8.2.1.2.4, item b).

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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.

In the case of one or more construction breaks (see 3.1.2 and 8.1.6) 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 document 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 9.3.4.2.2 on each phase pole in turn, at the maximum setting of the 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 DC circuit-breakers, rated up to 1 500 V DC, 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 document.

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 DC side of PV applications;
– the tests intended to verify product performance, and resistance to the PV service environmental conditions.

P.2 Terms and definitions

Clause 3 applies.

P.3 Classification

Clause 4 applies.

P.4 Characteristics of PV circuit-breakers

Clause 5 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
1 250	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 6 applies with the modifications and additions listed in Table P.2.

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.2 – Product information

Item	Information	Marking location
P2.1	IEC 60947-2:2024, 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 7 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 8.1 applies.

P.7.2 Performance requirements

Subclause 8.2 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 8.2.4.1, 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 subclause are required. Tests for short-circuit performance are given from P.8.3.4 to P.8.3.8.

With reference to 8.2.4.2 for operational performance capability, PV circuit-breakers shall be capable of meeting the requirements of Table P.3.

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Table P.3 – 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 document 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 8.3 applies.

P.8 Tests

P.8.1 Kind of tests

Subclause 9.1 applies.

P.8.2 Compliance with constructional requirements

Subclause 9.2 applies.

P.8.3 Type tests

Subclause 9.3 applies with the following modifications:

P.8.3.1 Test sequences

With reference to 9.3.2.2, 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 AC do not cover DC characteristics.

With reference to 9.3.2.4, 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 15.

With reference to 9.3.3.2.5, the time constant for operational performance capability, short-circuit tests and critical DC 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 9.3.4 applies with the following modifications:

With reference to 9.3.4.4.3, for operational performance capability without current, the number of operating cycles and the number of cycles per hour are given in Table P.3.

With reference to 9.3.4.4.4, for operational performance capability with current, the number of operating cycles and the number of cycles per hour are given in Table P.3, 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 9.3.4.5, the overload performance test is not applicable.

P.8.3.4 Test sequence II

Subclause 9.3.5 applies, with the modifications listed in P.8.3.2.

P.8.3.5 Test sequence III

Subclause 9.3.6 applies with the modifications listed in P.8.3.2.

P.8.3.6 Test sequence IV

Subclause 9.3.7 applies with the modifications listed in P.8.3.2.

P.8.3.7 Test sequence V

Subclause 9.3.8 applies with the modifications listed in P.8.3.2.

P.8.3.8 Test sequence VI

Subclause 9.3.9 applies with the modifications listed in P.8.3.2.

P.8.3.9 Test sequence VII

Subclause 9.3.10 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 9.3.4.2.3;
– a verification of temperature-rise at the main terminals in accordance with 9.3.3.5. The temperature-rise shall not exceed the values given in Table 6;
– a verification of dielectric withstand and leakage current according to 9.3.4.6.

The number of samples shall be in accordance with the requirements of Table 15 for Test sequence I.

P.8.3.11 Climatic test

PV circuit-breakers shall be subjected to the climatic tests of Annex Q, category B of IEC 60947-1:2020: 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 60947-1:2020 calls for verification of operational performance capability, this shall be made by carrying out the routine tests to 9.4 of this document, except for the dielectric tests of 9.4.6, which are covered by the tests of Table Q.1 of IEC 60947-1:2020.

With reference to footnote g) of Table Q.1 of IEC 60947-1:2020 during damp heat test, the functional test shall consist of the mechanical operations of 9.4.2 of this document. 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 15 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 9.4 applies.

P.8.5 Special tests

Subclause 9.5 applies.

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Annex Q

Vacant

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Annex R
(normative)

Circuit-breakers incorporating residual current protection with automatic reclosing functions (CBARs)

R.1 General

R.1.1 Preamble

CBRs according to Annex B of this document 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 document.

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 AC circuits.

The residual current function of CBARs according to this annex may or may not be functionally dependent on line voltage. CBARs dependent 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 3 and Clause B.2 of this document, 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 60050-441:2000, 441-16-10, modified – term “auto-reclosing” replaced with “automatic reclosing”, and “after a predetermined time” replaced with "depending on specific conditions" in the definition.]

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 4 and Clause B.3 of this document, 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 5 and Clause B.4 of this document 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 6 and Clause B.5 apply with the additions listed in Table R.1.

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Table R.1 – 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 7 applies.

R.7 Design and operating requirements

R.7.1 Design requirements

As a complement to 8.1 and B.7.1 of this document, 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 AC or 60 V DC; 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 AC or 2 mA DC.

R.7.2 Operating requirements

R.7.2.1 General

8.2 and B.7.2 apply.

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.

Compliance is checked by the tests of R.8.8.

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R.8 Tests

R.8.1 General conditions

As a complement to Clause 9 and Clause B.8 of this document, the following additional requirements apply.

Integral CBARs shall meet the test requirements from R.8.2 to R.8.8.

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 9.

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.8.13 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 overcurrent 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 9.3.4.2.2). 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.

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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.

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 × $I_{\Delta n}$ and the switch S_1 and the CBAR being in the closed position, the residual current is established by closing the switch S_2.

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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 × $I_{\Delta n}$, 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 × $I_{\Delta n}$. 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 7. 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 can be needed 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.8.1.2.1, replacing the operations performed by applying a residual current.

R.8.6 Verification of the isolation function

R.8.6.1 General

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.

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R.8.6.2 Leakage current between open contacts

The following requirements apply:

a) Following the test of 9.3.4.3 (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 9.3.4.6 (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 9.3.5.4 (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 9.3.6.4 (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 9.3.4.3 (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 60947-1:2020.

There shall be no unintentional disruptive discharge during the tests.

R.8.7 Verification of residual short-circuit making and breaking capacity

Subclause 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.8.1.2.2 (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

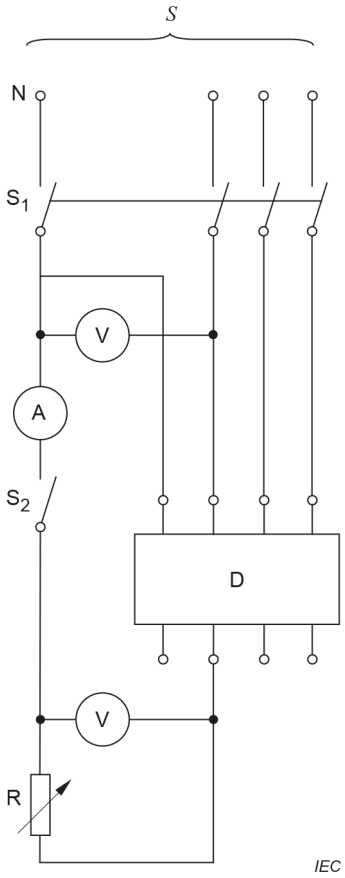
The following test sequences (see Table R.2) shall be performed on CBARs classified under R.3.1.2, in accordance with Figure R.1.

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.2 – Test sequences for external type automatic re-closing devices

Sequence (sample)	Test	Subclause
1	Verification of the non-reclosing after tripping under overcurrent 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	9.3.6
	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 = RMS 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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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

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Cette sixième édition annule et remplace la cinquième édition parue en 2016 et son Amendement 1:2019. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) aptitude au sectionnement (voir Article 1) ;

b) suppression de la classification selon le milieu de coupure, selon la conception et selon l'aptitude au sectionnement (voir Article 4);

c) ajustement du courant de réglage avec un dispositif externe connectable au déclencheur (voir 5.7.3) ;

d) exigences pour les circuits avec séparation de protection (voir 8.2.3.8);

e) essais supplémentaires pour les déclencheur à maximum de courant de défaut à la terre (voir 9.3.4.2.5);

f) essais supplémentaires concernant les propriétés diélectriques en position de déclenchement (voir 9.3.4.3) ;

g) utilisation de la tension continue pour les essais diélectriques (voir 9.3.4.6.2 et 9.4.6);

h) essais du pouvoir de coupure sur un pôle séparément à la tension phase-neutre alternative (voir 9.3.11);

i) amélioration du mesurage de la perte de puissance à l'Annexe G;

j) changements dans les essais CEM (voir Annexe J) ;

k) introduction des CBI de classe W à l'Annexe L.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
121A/608/FDIS	121A/621/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

La version française de la norme n'a pas été soumise au vote.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 60947, publiées sous le titre général *Appareillage à basse tension*, se trouve sur le site web de l'IEC.

La présente Norme internationale doit être utilisée conjointement avec l'IEC 60947-1:2020.

Les dispositions des règles générales traitées dans l'IEC 60947-1 s'appliquent au présent document lorsque celui-ci le précise. Les articles, paragraphes, tableaux, figures et annexes des règles générales qui sont ainsi applicables sont identifiés par référence à l'IEC 60947-1:2020.

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APPAREILLAGE À BASSE TENSION –

Partie 2: Disjoncteurs

1 Domaine d'application

Le présent document s'applique 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; il contient aussi des exigences supplémentaires pour les disjoncteurs à fusibles incorporés.

Le présent document s'applique également aux disjoncteurs dont les caractéristiques assignées sont inférieures ou égales à 1 000 V en courant alternatif, qui ont en outre une ou plusieurs caractéristiques assignées supérieures à 1 000 V en courant alternatif, sans toutefois dépasser 1 500 V en courant alternatif.

Il s'applique quels que puissent être les courants assignés, les méthodes de construction et l'emploi prévu des disjoncteurs.

Les disjoncteurs conformes au présent document sont aptes au sectionnement.

Les exigences pour les disjoncteurs qui sont également destinés à procurer une protection par courant différentiel résiduel font l'objet de l'Annexe B.

Les exigences supplémentaires pour les disjoncteurs destinés au raccordement de conducteurs en aluminium font l'objet de l'Annexe D.

Les exigences supplémentaires pour les disjoncteurs à protection électronique contre les surintensités font l'objet de l'Annexe F.

Les exigences supplémentaires pour les 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 qui ne satisfont pas aux exigences relatives aux 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 pour les disjoncteurs à déclenchement instantané font l'objet de l'Annexe O.

Les exigences et les méthodes d'essai pour les disjoncteurs à courant continu utilisés dans les applications photovoltaïques (PV) font l'objet de l'Annexe P.

Les exigences et les méthodes d'essai pour les disjoncteurs à protection incorporée par courant différentiel résiduel avec fonctions de refermeture automatique font l'objet de l'Annexe R.

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Les exigences supplémentaires pour les disjoncteurs utilisés comme démarreurs directs sont spécifiées dans l'IEC 60947-4-1, applicable aux contacteurs et aux démarreurs à basse tension.

Les exigences pour les disjoncteurs destinés à la protection contre les surintensités des installations domestiques et analogues et prévus pour être utilisés par des personnes non averties figurent dans la série 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 s'appliquer 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 1 Les disjoncteurs peuvent avoir des accessoires dédiés.

NOTE 2 Les disjoncteurs traités dans le présent document peuvent comporter des appareils destinés à déclencher une ouverture automatique dans des conditions prédéterminées autres que des conditions de surintensité et de chute de tension, telles que l'inversion de la puissance ou du courant, par exemple. Le présent document ne traite pas de la vérification du fonctionnement dans de telles conditions prédéterminées.

Le présent document a pour objet de spécifier:

a) les caractéristiques des disjoncteurs;

b) les exigences applicables aux disjoncteurs en ce qui concerne:

   1) leur fonctionnement et leur tenue en service normal;

   2) leur fonctionnement et leur tenue en cas de surcharge, le fonctionnement et le comportement en cas de court-circuit, y compris la coordination en service (sélectivité et protection d'accompagnement), ainsi que leur fonctionnement et leur tenue en cas de courant de défaut à la terre;

   3) leurs propriétés diélectriques;

   4) leurs exigences de compatibilité électromagnétique, le cas échéant;

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 disjoncteurs ou à fournir avec ceux-ci.

NOTE 3 Pour les exigences de cybersécurité, voir l'IEC TS 63208.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. 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, *Âmes des câbles isolés*

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

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IEC 60947-1:2020, *Appareillage à basse tension – Partie 1: Règles générales*

IEC 60947-4-1, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

IEC 61000-4-2:2008, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2020, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*

IEC 61000-4-4:2012, *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 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2023, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-11:2020, *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 pour les appareils à courant d'entrée inférieur ou égal à 16 A par phase*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61545:1996, *Dispositifs de connexion – Dispositifs pour la connexion des câbles en aluminium dans des organes 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 11:2015/AMD2:2019

CISPR 32:2015, *Compatibilité électromagnétique des équipements multimédia – Exigences d'émission*

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3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60947-1:2020, ainsi que les suivants s'appliquent.

NOTE Lorsque ces définitions sont identiques à celles du *Vocabulaire Électrotechnique International (IEV)*, IEC 60050-441, la référence à cette publication est donnée entre crochets.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
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]

3.1.1
taille
terme qui désigne 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 qui correspondent 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.

3.1.2
différence de construction
différence significative de construction entre des disjoncteurs d'une taille donnée, qui nécessite d'effectuer des essais de type supplémentaires

3.2
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 ligne

[SOURCE: IEC 60050-441:1984, 441-14-22, modifié – Remplacement du terme "phase" par le terme "ligne".]

3.3
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 de 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 de crête présumée symétrique ou asymétrique du courant coupé limité.

Note 2 à l'article: Le courant coupé limité est désigné par les termes anglais "let-through current" et "cut-off current" (voir l'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 représentés 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.

3.4
disjoncteur enfichable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts qui permet 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.

3.5
disjoncteur débrochable
disjoncteur qui, outre ses contacts d'interruption, possède un jeu de contacts de sectionnement qui lui permettent d'être retiré du circuit principal et, en position débrochée, de présenter une distance de sectionnement conforme à des exigences spécifiées

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3.6
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

3.7
déclencheur de court-circuit
déclencheur à maximum de courant destiné à la protection contre les courts-circuits

3.8
déclencheur de court-circuit à retard de courte durée
déclencheur à maximum de courant conçu pour fonctionner à l'issue d'un retard de courte durée

3.9
interrupteur de défaut
interrupteur auxiliaire qui ne fonctionne que lors du déclenchement du disjoncteur auquel il est associé

3.10
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

3.11
pouvoir de coupure (ou de fermeture) en court-circuit
pouvoir de coupure (ou de fermeture) pour lequel les conditions prévues comprennent un court-circuit

3.11.1
pouvoir de coupure ultime en court-circuit
pouvoir de coupure pour lequel les conditions prévues selon une séquence d'essai spécifiée ne comprennent pas l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

3.11.2
pouvoir de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative
pouvoir de coupure ultime en court-circuit déterminé pour un pôle séparément à la tension phase-neutre alternative

3.11.3
pouvoir de coupure de service en court-circuit
pouvoir de coupure pour lequel les conditions prévues selon une séquence d'essai spécifiée comprennent l'aptitude du disjoncteur à être parcouru en permanence par son courant assigné

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3.12
durée d'ouverture
<d'un appareil mécanique de connexion> intervalle de temps entre l'instant spécifié de début de la manœuvre 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", même si, à proprement parler, la durée de déclenchement comprend le délai entre l'instant où commence la durée d'ouverture et celui où la commande de l'ouverture devient irréversible.

[SOURCE: IEC 60947-1:2020, 3.7.39, modifié – Modification de la Note 1 à l'article et ajout de la Note 2 à l'article.]

3.13
caractéristique I^2t d'un disjoncteur
information (généralement une courbe) qui donne les valeurs maximales de I^2t liées 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 qui correspond au pouvoir assigné de coupure en court-circuit à la tension correspondante

3.14
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

3.15
courant instantané de réglage de court-circuit
I_i
courant de réglage d'un déclencheur de court-circuit, au-dessus duquel un courant provoque son fonctionnement sans retard intentionnel

Note 1 à l'article: I_i peut ne pas être réglable.

3.16
courant de réglage de surcharge
I_r
courant de réglage d'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.

3.17
courant de réglage de déclenchement à retard de courte durée
I_{sd}
courant de réglage d'un déclencheur de court-circuit, au-dessus duquel un courant provoque son fonctionnement avec un retard intentionnel (t_{sd})

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3.18
automate programmable
AP
système électronique à fonctionnement numérique, conçu pour être utilisé dans un environnement industriel, qui utilise une mémoire programmable pour le stockage interne d'instructions orientées utilisateur destinées à la mise en œuvre de fonctions spécifiques telles que la logique, le séquencement, le minutage, le comptage et le calcul arithmétique, afin de contrôler, grâce à des entrées et des sorties numériques ou analogiques, différents types de machines ou de processus

Note 1 à l'article: L'AP et ses périphériques associés sont tous conçus de manière à pouvoir s'intégrer facilement dans un système de commande industriel et à être utilisé simplement pour toutes les fonctions qui sont prévues.

[SOURCE: IEC 61131-1:2003, 3.5, modifié – Suppression de la note.]

3.19
déclencheur de fermeture
bobine de fermeture
déclencheur 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 sur 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.

4 Classification

4.1 Selon la catégorie de sélectivité, A ou B (voir 5.4)

4.2 Selon le mode de commande du mécanisme de manœuvre:

– manœuvre dépendante manuelle;
– manœuvre indépendante manuelle;
– manœuvre dépendante à source d'énergie extérieure;
– manœuvre indépendante à source d'énergie extérieure;
– manœuvre à accumulation d'énergie.

4.3 Selon les possibilités d'entretien:

– conçu pour être entretenu;
– non conçu pour être entretenu.

4.4 Selon la méthode d'installation:

– fixe;
– enfichable;
– débrochable.

4.5 Selon le degré de protection procuré par l'enveloppe (voir 8.1.12 de l'IEC 60947-1:2020)

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5 Caractéristiques des disjoncteurs

5.1 Énumération des caractéristiques

Les caractéristiques d'un disjoncteur doivent, selon le cas, être indiquées de la façon suivante:

– type du disjoncteur (5.2);
– valeurs assignées et valeurs limites du circuit principal (5.3);
– catégories de sélectivité (5.4);
– circuits de commande (5.5);
– circuits auxiliaires (5.6);
– déclencheurs (5.7);
– fusibles incorporés (disjoncteurs à fusibles incorporés) (5.8).

5.2 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.

5.3 Valeurs assignées et valeurs limites du circuit principal

5.3.1 Généralités

Les valeurs assignées établies pour un disjoncteur doivent être indiquées conformément aux 5.3.2 à 5.4, mais il n'est pas nécessaire d'établir la valeur I_{th} (5.3.3.1), la valeur I_{the} (5.3.3.2), la fréquence assignée (5.3.4) dans le cas d'un disjoncteur qui fonctionne exclusivement en courant continu et le service assigné (5.3.5).

5.3.2 Tensions assignées

5.3.2.1 Tension assignée d'emploi (U_e)

Le 5.3.1.1 de l'IEC 60947-1:2020 s'applique, avec le développement suivant:

– les disjoncteurs traités au point a) du 5.3.1.1 de l'IEC 60947-1:2020.

  U_e est généralement exprimée par la tension entre phases.

  NOTE 1 Au Canada et aux États-Unis, la tension assignée d'emploi U_e est exprimée par:

  a) la tension entre les phases et la terre, ainsi que par la tension entre les phases (par exemple, 277 V/480 V) pour des réseaux triphasés à quatre fils et neutre mis à la terre;

  b) la tension entre les 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 réseaux non reliés à la terre ou pour réseaux reliés à la terre par une impédance (IT) exigent des essais supplémentaires conformément à l'Annexe H.

– les disjoncteurs traités au point b) du 5.3.1.1 de l'IEC 60947-1:2020.

  Ces disjoncteurs exigent des essais supplémentaires conformément à l'Annexe C.

  U_e doit être exprimée par la tension entre phases, précédée de la lettre C.

  NOTE 2 Conformément à la pratique actuelle au Canada et aux États-Unis, les disjoncteurs traités au point b) du 5.3.1.1 de l'IEC 60947-1:2020 ne sont identifiés que par la tension entre phases.

5.3.2.2 Tension assignée d'isolement (U_i)

Le 5.3.1.2 de l'IEC 60947-1:2020 s'applique.

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5.3.2.3 Tension assignée de tenue aux chocs (U_{imp})

Le 5.3.1.3 de l'IEC 60947-1:2020 s'applique.

5.3.3 Courants

5.3.3.1 Courant thermique conventionnel à l'air libre (I_{th})

Le 5.3.2.1 de l'IEC 60947-1:2020 s'applique.

5.3.3.2 Courant thermique conventionnel sous enveloppe (I_{the})

Le 5.3.2.2 de l'IEC 60947-1:2020 s'applique.

5.3.3.3 Courant assigné (I_n)

Pour les disjoncteurs, le courant assigné est le courant assigné ininterrompu (I_u) (voir 5.3.2.4 de l'IEC 60947-1:2020) et a la même valeur que le courant thermique conventionnel à l'air libre (I_{th}).

5.3.4 Fréquence assignée

Le 5.3.3 de l'IEC 60947-1:2020 s'applique.

5.3.5 Service assigné

Les services assignés considérés comme normaux sont:

– le service de huit heures (voir 5.3.4.1 de l'IEC 60947-1:2020);
– le service ininterrompu (voir 5.3.4.2 de l'IEC 60947-1:2020).

5.3.6 Caractéristiques de court-circuit

5.3.6.1 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 assignée à ce disjoncteur par le fabricant pour la tension assignée d'emploi, à la fréquence assignée et avec un facteur de puissance spécifié en courant alternatif, ou une constante de temps spécifiée en courant continu. Il est exprimé par la valeur de crête maximale du courant présumé.

En courant alternatif, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur doit être au moins égal au produit de son pouvoir assigné de coupure ultime en court-circuit par le facteur n indiqué dans le Tableau 1 (voir 5.3.6.3).

En courant continu, le pouvoir assigné de fermeture en court-circuit d'un disjoncteur doit être au moins égal 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 qui correspond à ce pouvoir assigné pour une tension appliquée appropriée à la tension assignée d'emploi.

5.3.6.2 Pouvoirs assignés de coupure en court-circuit

5.3.6.2.1 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.

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NOTE Un disjoncteur conforme au présent document est capable d'interrompre des courts-circuits entre phases, entre phase et terre, entre phase et neutre (courant alternatif) et entre phase et point milieu (courant continu).

Un pouvoir assigné de coupure en court-circuit exige que le disjoncteur doit être capable de 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 qui correspond aux valeurs spécifiées pour la tension d'essai et:

– en courant alternatif, avec un facteur de puissance au moins égal à ceux exigés en 9.3.3.2.4;
– en courant continu, avec une constante de temps inférieure ou égale à celles exigées en 9.3.3.2.5.

Aucun pouvoir de coupure en court-circuit n'est assuré pour des tensions de rétablissement à fréquence industrielle supérieures aux valeurs spécifiées pour la tension d'essai (voir 9.3.3.2.6).

En courant alternatif, le disjoncteur doit être capable de couper un courant présumé qui correspond à son pouvoir assigné de coupure en court-circuit et au facteur de puissance correspondant indiqué en 9.3.3.2.4, quelle que soit la valeur de la composante continue inhérente, en prenant pour hypothèse que la valeur efficace de la composante alternative du courant présumé 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.

5.3.6.2.2 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 3.11.1) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi correspondante, dans les conditions spécifiées en 9.3.6. Il est exprimé par la valeur du courant de coupure présumé, en kA (valeur efficace de la composante alternative dans le cas du courant alternatif).

5.3.6.2.3 Pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative (I_{cu1})

Le pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative d'un disjoncteur est la valeur du pouvoir de coupure sur un pôle séparément à la tension phase-neutre assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi correspondante, dans les conditions spécifiées en 9.3.11. Il est exprimé par la valeur du courant de coupure présumé, en kA (valeur efficace de la composante alternative).

5.3.6.2.4 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 3.11.3) assignée par le fabricant à ce disjoncteur pour la tension assignée d'emploi correspondante, dans les conditions spécifiées en 9.3.5. Il est exprimé par la valeur du courant de coupure présumé, en kA, ou en 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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5.3.6.3 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 indiquée dans le Tableau 1.

Tableau 1 – Rapport n entre les pouvoirs de fermeture et de coupure en court-circuit et le facteur de puissance correspondant pour les disjoncteurs à courant alternatif

Pouvoir de coupure en court-circuit kA en valeur efficace I	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 spécifiées en 8.2.1.1 et en 8.2.1.2.

Pour des exigences particulières, le fabricant peut fixer une valeur de pouvoir assigné de fermeture en court-circuit supérieure à celle exigée dans le Tableau 1. Les essais de vérification de ces valeurs assignées doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

5.3.6.4 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 9.3.7.3.

NOTE 1 Le courant assigné de courte durée admissible n'est pas influencé par un changement de déclencheur.

NOTE 2 La sélectivité de temps atteignable dans une application dépend du courant de réglage de déclenchement à retard de courte durée (I_{sd}) réel et du retard intentionnel (t_{sd}) du déclencheur.

En courant alternatif, la valeur de ce courant est la valeur efficace de la composante alternative du courant présumé de court-circuit, qui est 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 doit avoir une valeur au moins égale aux valeurs indiquées dans le Tableau 2.

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Tableau 2 – 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 si cette valeur est plus élevée
$I_n > 2\ 500$	30 kA

5.4 Catégories de sélectivité

Les disjoncteurs conformes au présent document sont divisés en deux catégories de sélectivité:

– **catégorie de sélectivité B** qui comprend les disjoncteurs qui assurent la sélectivité en ayant un courant assigné de courte durée admissible et un retard de courte durée associé conformes au 5.3.6.4.

  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 dans le Tableau 2;

– **catégorie de sélectivité A** qui comprend 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 5.3.6.4. Dans ce cas, les essais doivent comprendre la séquence d'essai IV (voir 9.3.7) au courant assigné de courte durée admissible.

L'attention est attirée sur les différences entre les essais qui s'appliquent aux deux catégories de sélectivité (voir Tableau 10 et 9.3.5, 9.3.6, 9.3.7 et 9.3.9).

5.5 Circuits de commande

5.5.1 Circuits de commande électriques

Le 5.5.1 de l'IEC 60947-1:2020 s'applique, avec l'ajout suivant:

Si la tension assignée d'alimentation du circuit de commande est différente de celle du circuit principal, il est recommandé de choisir sa valeur parmi celles du Tableau 3.

Tableau 3 – Valeurs préférentielles de la tension assignée d'alimentation du circuit 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

5.5.2 Circuits de commande à air comprimé (pneumatiques ou électropneumatiques)

Le 5.5.2 de l'IEC 60947-1:2020 s'applique.

5.6 Circuits auxiliaires

Le 5.6 de l'IEC 60947-1:2020 s'applique.

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5.7 Déclencheurs

5.7.1 Types

Pour les besoins du présent document, les types de déclencheurs suivants sont étudiés:

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 (déclencheur du type thermique, par exemple);
   d) de défaut à la terre;

   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 3.6.31 de l'IEC 60947-1:2020). 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 3.7); il inclut les déclencheurs de court-circuit à retard de courte durée (voir 3.8).

   NOTE 2 Le terme "déclencheur réglable" utilisé dans le présent document comprend aussi les déclencheurs interchangeables.
3) déclencheur à minimum de tension (déclencheur d'ouverture);
4) déclencheur de fermeture;
5) autres déclencheurs.

5.7.2 Caractéristiques

Les caractéristiques suivantes doivent être prises en compte:

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 réglages);
   – temps de réglage (ou plage de réglages), 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) qui correspond au courant de réglage maximal qu'il doit être capable de supporter dans les conditions d'essai spécifiées en 9.3.3.5 sans que l'échauffement dépasse les valeurs spécifiées dans le Tableau 6.

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5.7.3 Courant de réglage des déclencheurs à maximum de courant

Pour les disjoncteurs équipés de déclencheurs réglables (voir Note 2 en 5.7.1, point 2), les courants de réglage doivent être marqués sur le déclencheur ou être affichés sur l'écran du déclencheur ou sur l'écran d'un dispositif externe connectable au déclencheur. Ces réglages peuvent être indiqués directement en ampères ou en multiples de la valeur du courant. Des moyens doivent être prévus par le fabricant pour lire l'affichage indépendamment de l'état du disjoncteur. Le cas échéant, le fabricant doit spécifier les caractéristiques du dispositif externe.

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 5, il suffit d'indiquer sur le disjoncteur son courant assigné (I_n).

Les courants de réglage peuvent être ajustés par l'intermédiaire d'un dispositif externe (local ou distant) connectable au déclencheur, auquel cas les indications locales du réglage ne doivent pas être dépassées, ou une indication locale doit montrer que les réglages sont commandés à distance. Le fabricant doit fournir au laboratoire d'essai des moyens de s'assurer que les réglages ne varient pas lors des essais de type.

Pour les déclencheurs indirects qui fonctionnent 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 préciser l'influence de la température ambiante dans la documentation (voir 8.2.1.2.4, point b)).

5.7.4 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 de les donner également pour chacune des valeurs extrêmes du temps de réglage.

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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 différents types de protections 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.

5.8 Fusibles incorporés (disjoncteurs à fusibles incorporés)

Le 5.8 de l'IEC 60947-1:2020 s'applique, en remplaçant "DPCC" par "fusible incorporé".

6 Informations sur le matériel

6.1 Nature des informations

Le 6.1 de l'IEC 60947-1:2020 s'applique, dans la mesure où il est approprié pour une conception particulière.

En outre, le fabricant doit fournir, à la demande, les informations relatives à la perte de puissance type pour les différentes tailles (voir 3.1.1). Voir Annexe G.

Pour le glossaire des symboles et la représentation graphique des caractéristiques, voir l'Annexe K.

6.2 Marquage

Chaque disjoncteur doit être marqué de façon indélébile; les données à fournir et les emplacements correspondants sont indiqués dans le Tableau 4.

Tableau 4 – Informations sur le matériel

Point	Information	Emplacement
1.1	courant assigné (I_n)	Visible
1.2	aptitude au sectionnement avec le symbole  (IEC 60617-S00287:2001-07 et IEC 60617-S00220:2001-07)	Visible
1.3	indications des positions d'ouverture et de fermeture, respectivement par O (IEC 60417-5008:2002-10) et par I (IEC 60417-5007:2002-10) si des symboles sont utilisés (voir 8.1.6.1 de l'IEC 60947-1:2020)	Visible
2.1	nom du fabricant ou marque commerciale	Marqué
2.2	désignation du type ou référence du catalogue	Marqué
2.3	IEC 60947-2, si le fabricant déclare la conformité au présent document	Marqué
2.4	catégorie de sélectivité A ou B	Marqué
2.5	tension(s) assignée(s) d'emploi U_e (voir 5.3.2.1 et, le cas échéant, Annexe H)	Marqué
2.6	indication que le disjoncteur n'est pas adapté aux réseaux IT à toutes les tensions assignées par le symbole  (IEC 60417-6363:2016-07). Pour les exceptions applicables à des tensions assignées spécifiques, voir l'Article H.5.	Marqué
2.7	tension assignée de tenue aux chocs (U_{imp})	Marqué
2.8	valeur (ou plage de valeurs) 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

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Point	Information	Emplacement
2.11	pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative (I_{cu1}), à la tension assignée correspondante (U_e), s'il est différent de I_{cu}	Marqué
2.12	courant assigné de courte durée admissible (I_{cw}) et retard de courte durée correspondant pour la catégorie de sélectivité B	Marqué
2.13	plage de courants de réglage (I_r) du déclencheur de surcharge réglable	Marqué [a]
2.14	valeur ou plage (lorsqu'il est réglable) du courant de réglage de déclenchement à retard de courte durée (I_{sd}) du déclencheur et son retard intentionnel (t_{sd}), le cas échéant	Marqué [a]
2.15	plage du courant de défaut à la terre (I_g) du déclencheur réglable, le cas échéant	Marqué [a]
2.16	plage du courant de réglage de court-circuit instantané (I_i), pour les déclencheurs réglables	Marqué [a]
2.17	température de référence pour les déclencheurs thermiques non compensés, si elle est différente de 30 °C	Marqué
2.18	identification des bornes, conformément au 8.1.8.4 de l'IEC 60947-1:2020	Marqué
2.19	identification des bornes d'alimentation et de charge, le cas échéant	Marqué
2.20	bornes du pôle neutre, le cas échéant, par la lettre N	Marqué
2.21	borne de terre de protection, le cas échéant, par le symbole  (IEC 60417-5019:2006-08) (voir 8.1.10.3 de l'IEC 60947-1:2020)	Marqué
3.1	pouvoir assigné de fermeture en court-circuit (I_{cm}) à la tension assignée correspondante (U_e), s'il est supérieur aux valeurs minimales spécifiées en 5.3.6.1	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 (voir 7.1.3.2 de l'IEC 60947-1:2020)	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 60947-1:2020)	Documentation
3.6	le cas échéant, taille minimale de l'enveloppe et, s'il y a lieu, données relatives à 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 une utilisation dans l'environnement A ou B conformément à l'Annexe J, selon le cas	Documentation
3.9	détection sensible à la valeur efficace, le cas échéant, conformément au F.4.1.1	Documentation
3.10	section minimale du câble, si différente de la valeur indiquée dans le Tableau 9 de l'IEC 60947-1:2020, 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, le cas échéant, pour des températures supérieures à la température de référence	Documentation
3.13	influence de la température ambiante, le cas échéant, sur les performances de déclenchement du déclencheur à maximum de courant (voir 5.7.3)	Documentation
3.14	déclassement du courant pour les bornes et les connexions, le cas échéant	Documentation
3.15	méthode et schéma de connexion en série des pôles (si nécessaire pour chaque caractéristique assignée) pour les disjoncteurs à courant continu	Documentation
3.16	type de fonction de détection de défaut à la terre (voir Article T.4 de l'IEC 60947-1:2020)	Documentation
3.17	valeur du courant de réglage de court-circuit instantané (I_i), pour les déclencheurs non réglables	Documentation
3.18	nombre de pôles	Documentation

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Point	Information	Emplacement
3.19	informations complémentaires relatives aux conducteurs en aluminium (voir D.5.2)	Documentation
4.1	pour les déclencheurs de fermeture (voir 3.19) 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 (voir 5.7.3)	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 réglages de I_r, I_i, I_{sd} et I_g peuvent être affichés sur l'écran du déclencheur ou d'un dispositif externe au lieu d'être marqués (voir 5.7.3).

6.3 Instructions d'installation, de fonctionnement et d'entretien

Le 6.3 de l'IEC 60947-1:2020 s'applique, avec l'ajout 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, qui résulte par exemple de l'énergie emmagasinée ou de substances dangereuses.

7 Conditions normales de service, de montage et de transport

L'Article 7 de l'IEC 60947-1:2020 s'applique, avec l'ajout suivant:

Degré de pollution (voir 7.1.3.2 de l'IEC 60947-1:2020).

Sauf indication contraire du fabricant, un disjoncteur est prévu pour être installé dans les conditions d'environnement du degré de pollution 3.

8 Exigences relatives à la construction et au fonctionnement

8.1 Exigences relatives à la construction

8.1.1 Généralités

Le 8.1 de l'IEC 60947-1:2020 s'applique, avec les modifications suivantes:

a) lorsque, selon le 8.1.2.2 de l'IEC 60947-1:2020, la température d'essai doit être spécifiée, la valeur exigée par le présent document pour les pièces nécessaires au maintien en position des parties qui transportent le courant est de 960 °C pour le circuit principal et de 850 °C pour les autres circuits;

NOTE 1 Les "autres circuits" englobent les circuits de commande (voir 5.5), les circuits auxiliaires (voir 5.6) et les déclencheurs (voir 5.7).

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b) les exigences spécifiées en 8.1.2 de l'IEC 60947-1:2020 ne s'appliquent pas aux pièces dont la masse est inférieure à 2 g (masse négligeable, conformément au 3.14 de l'IEC 60695-2-11:2021). Pour les matériels qui comportent plusieurs pièces de faibles dimensions, la masse totale des pièces non soumises à l'essai situées à 3 mm au maximum les unes des autres ne doit pas dépasser 10 g.

NOTE 2 Cette distance de 3 mm est définie en 30.2 de l'IEC 60335-1:2020.

Lorsque des conducteurs en aluminium doivent être utilisés, l'Annexe D s'applique.

NOTE 3 Des recommandations pour l'élaboration des logiciels embarqués sont données dans l'IEC TR 63201.

8.1.2 Disjoncteurs 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 conformes 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 appareil indicateur fiable et robuste, qui indique sans équivoque les positions des contacts de sectionnement.

Le mécanisme de débrochage doit être équipé de dispositifs de verrouillage qui ne permettent 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 qui ne permettent 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 qui permettent de s'assurer que les distances de sectionnement spécifiées entre les contacts de sectionnement ne puissent pas être réduites par inadvertance.

8.1.3 Sectionnement

Le 8.1.7 de l'IEC 60947-1:2020 s'applique.

Pour les exigences supplémentaires concernant le fonctionnement, voir le 8.2.6.

NOTE Au Royaume-Uni, pour les disjoncteurs équipés de connexions de ligne et de charge enfichables, le sectionnement est obtenu en retirant complètement le disjoncteur des contacts de connexion fixes.

8.1.4 Distances d'isolement et lignes de fuite

Les valeurs minimales sont indiquées dans le Tableau 13 de l'IEC 60947-1:2020 et dans le Tableau 15 de l'IEC 60947-1:2020.

Pour les valeurs de U_{imp} qui dépassent les valeurs indiquées dans le Tableau 13 de l'IEC 60947-1:2020, les distances d'isolement doivent être prises dans le Tableau F.2 de l'IEC 60664-1:2020.

8.1.5 Exigences pour la sécurité de l'opérateur

Aucun chemin ni aucune ouverture ne doit permettre à des particules incandescentes de quitter la zone des organes de manœuvre manuels.

La conformité est vérifiée selon les dispositions du 9.3.3.6.1, point b).

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8.1.6 Liste des différences de construction

Des disjoncteurs d'une taille donnée sont considérés comme présentant une différence de construction (voir 3.1.2) si l'une des caractéristiques suivantes n'est pas identique:

– matériau, revêtement et dimensions des parties internes qui transportent le courant, en admettant cependant les variations énumérées 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 décrites en a), b) et c) ci-après.

Les variations 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 secondaires des déclencheurs avec transformateurs de courant;

d) les moyens de manœuvre externes qui s'ajoutent aux moyens de manœuvre intégrés;

e) la désignation du type et/ou les particularités purement esthétiques (les étiquettes, par exemple);

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 le chemin de courant central ou en rendant le pôle central inaccessible;

h) une différence dans le logiciel embarqué (micrologiciel) dans les déclencheurs électroniques, qui n'a aucune incidence sur les caractéristiques de fonctionnement exigées, notamment la fonction de déclenchement;

i) le matériel des déclencheurs électroniques, en cas d'omission de composants sur des circuits imprimés de configuration identique (par exemple, bouton tournant, affichage, etc.).

8.1.7 Exigences supplémentaires pour les disjoncteurs dotés d'un pôle neutre

Le 8.1.9 de l'IEC 60947-1:2020 s'applique.

8.1.8 Entrées et sorties numériques à l'usage des automates programmables (AP)

L'Annexe S de l'IEC 60947-1:2020 s'applique. Pour les besoins du présent document, cette exigence ne s'applique pas aux entrées et sorties numériques dédiées à des appareils autres que les automates programmables.

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8.2 Exigences relatives au fonctionnement

8.2.1 Conditions de fonctionnement

8.2.1.1 Fermeture

8.2.1.1.1 Généralités

Pour qu'un disjoncteur soit fermé de façon sûre lorsqu'il établit un courant qui correspond 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.

8.2.1.1.2 Fermeture dépendante manuelle

Pour un disjoncteur équipé 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 avec mécanisme de fermeture dépendante manuelle et déclencheur d'ouverture incorporé à action rapide qui provoque la coupure en toute sécurité du disjoncteur, quelles que soient la vitesse et la force avec lesquelles il est fermé, à des valeurs de crête du courant présumé supérieures à 10 kA; dans ce cas, un pouvoir assigné de fermeture en court-circuit peut être fixé.

8.2.1.1.3 Fermeture indépendante manuelle

Dans le cas d'un disjoncteur équipé 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.

8.2.1.1.4 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 en toute condition, du fonctionnement à vide jusqu'à son pouvoir assigné de fermeture, quand la valeur de la tension d'alimentation, mesurée pendant la manœuvre de fermeture, reste dans les limites de 110 % et 85 % de la tension assignée d'alimentation du circuit de commande et, dans le cas du courant alternatif, à la fréquence assignée.

À 110 % de la tension assignée d'alimentation du circuit de commande, la manœuvre de fermeture, lorsqu'elle est effectuée à vide, ne doit causer aucune détérioration du disjoncteur.

À 85 % de la tension assignée d'alimentation du circuit de commande, la manœuvre de fermeture doit être assurée pour établir à travers le disjoncteur un courant égal à son pouvoir assigné de fermeture dans les limites admises par le fonctionnement de ses relais ou déclencheurs et, si une valeur maximale est indiquée pour la durée de fermeture, en un temps qui n'excède pas cette valeur maximale.

8.2.1.1.5 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.

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8.2.1.1.6 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 qui indique 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 du circuit 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 qui ont une manœuvre de fermeture indépendante manuelle.

8.2.1.2 Ouverture

8.2.1.2.1 Généralités

Les disjoncteurs dont l'ouverture est automatique doivent être à déclenchement libre (voir 3.6.24 de l'IEC 60947-1:2020) et l'énergie nécessaire à leur déclenchement doit être emmagasinée automatiquement avant l'achèvement de la manœuvre de fermeture.

8.2.1.2.2 Ouverture par déclencheurs à minimum de tension

Le 8.2.1.3 de l'IEC 60947-1:2020 s'applique.

8.2.1.2.3 Ouverture par déclencheurs shunt

Le 8.2.1.4 de l'IEC 60947-1:2020 s'applique.

8.2.1.2.4 Ouverture par déclencheurs à maximum de tension

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, le fabricant doit fournir des informations (habituellement des courbes) qui indiquent:

– la valeur de crête maximale du courant coupé limité (voir 3.7.21 de l'IEC 60947-1:2020) en fonction du courant présumé (valeur efficace périodique pour les courants alternatifs);

– les caractéristiques I^2t (voir 3.13) pour les disjoncteurs de catégorie de sélectivité A et, le cas échéant, de catégorie B pour les disjoncteurs à commande instantanée (voir note en 9.3.6.1).

Le cas échéant, la conformité à ces informations doit être vérifiée au cours des essais de type pertinents des séquences d'essai II et III (voir 9.3.5 et 9.3.6).

NOTE 1 Il est possible de fournir d'autres types de données pour vérifier les caractéristiques de coordination des disjoncteurs, par exemple, des essais qui portent sur des combinaisons de dispositifs de protection contre les courts-circuits.

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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 sont indiquées dans le Tableau 5.

À la température de référence (voir 5.7.3) et à 1,05 fois le courant de réglage (voir 3.6.38 de l'IEC 60947-1:2020), c'est-à-dire au courant conventionnel de non-déclenchement (voir 3.7.30 de l'IEC 60947-1:2020), le déclencheur de surcharge 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 3.7.30 de l'IEC 60947-1:2020) à partir de l'état froid, c'est-à-dire avec le disjoncteur à la température de référence.

En outre, 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 3.7.31 de l'IEC 60947-1:2020), 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 5 – 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 5 doivent s'appliquer à l'intérieur du domaine de températures annoncé par le fabricant, avec une tolérance qui ne dépasse 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.

c) Ouverture dans des conditions de défaut à la terre

Le déclencheur à maximum de courant de défaut à la terre doit entraîner le déclenchement du disjoncteur dans la plage de tolérance qui correspond au type de la fonction de détection (CI-A ou CI-B), selon l'Article T.4 de l'IEC 60947-1:2020, pour toutes les valeurs du courant de réglage du déclencheur à maximum de courant de défaut à la terre.

Les déclencheurs à maximum de courant de défaut à la terre peuvent avoir un retard intentionnel, mais la durée de coupure ne doit pas dépasser les valeurs de durée de déclenchement indiquées dans le Tableau T.1 de l'IEC 60947-1:2020.

NOTE 3 Les déclencheurs à maximum de courant de défaut à la terre peuvent comporter des capteurs internes ou externes au disjoncteur.

8.2.2 Échauffement

8.2.2.1 Limites d'échauffement

Les échauffements des différents organes d'un disjoncteur, mesurés dans les conditions spécifiées en 9.3.3.5, ne doivent pas dépasser les valeurs limites indiquées dans le Tableau 6 au cours des essais effectués conformément au 9.3.4.7. Les échauffements des bornes ne doivent pas dépasser les valeurs limites indiquées dans le Tableau 6 au cours des essais effectués conformément au 9.3.5.5 et au 9.3.7.4.

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8.2.2.2 Température de l'air ambiant

Les limites d'échauffement spécifiées dans le Tableau 6 ne sont valables que si la température de l'air ambiant reste dans les limites indiquées en 7.1.1 de l'IEC 60947-1:2020.

8.2.2.3 Circuit principal

Le circuit principal d'un disjoncteur, y compris les déclencheurs à maximum de courant qui peuvent lui être associés, doit pouvoir supporter son courant assigné I_n, dans les conditions de l'Article 9, sans que les échauffements ne dépassent les limites spécifiées dans le Tableau 6.

8.2.2.4 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 5.3.5 ainsi que d'effectuer les essais d'échauffement dans les conditions spécifiées en 9.3.3.5 sans que les échauffements dépassent les limites spécifiées dans le Tableau 6.

Les exigences du présent paragraphe doivent être vérifiées sur un échantillon neuf. En variante, à la discrétion du fabricant, la vérification peut être effectuée pendant l'essai d'échauffement du 9.3.4.7.

8.2.2.5 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 dans le Tableau 6 lorsqu'ils sont soumis à l'essai conformément au 9.3.3.5.

Tableau 6 – 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 qui ne doivent pas être touchées en service normal:	
métalliques	50
non métalliques	60

[a] Aucune valeur n'est précisée pour les pièces autres que celles énumérées, 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 neuf, mais celles qui s'appliquent aux vérifications de l'échauffement au cours des séquences d'essai appropriées spécifiées à l'Article 9.

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8.2.3 Propriétés diélectriques

8.2.3.1 Généralités

Les 8.2.3.1 a) et 8.2.3.1 b) de l'IEC 60947-1:2020 s'appliquent.

Les essais de type doivent être effectués conformément au 9.3.4.3.

La vérification de la tenue diélectrique au cours de toutes les séquences d'essai doit être effectuée conformément au 9.3.4.6.

Les essais individuels de série doivent être effectués conformément au 9.4.6.

8.2.3.2 Tension de tenue aux chocs

Le 8.2.3.2 de l'IEC 60947-1:2020 s'applique.

Pour les disjoncteurs de caractéristiques assignées supérieures à 1 000 V en courant alternatif, la tension de tenue aux chocs doit être fixée par accord entre le fabricant et l'utilisateur, mais ne doit pas être inférieure aux valeurs qui correspondent à 1 000 V en courant alternatif.

NOTE Le Tableau 1 de l'IEC TS 62993:2017 fournit des valeurs de tension de choc assignées supérieures à 1 000 V en courant alternatif.

8.2.3.3 Tension de tenue à fréquence industrielle ou en courant continu 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.

8.2.3.4 Distance d'isolement

Le 8.2.3.4 de l'IEC 60947-1:2020 s'applique.

8.2.3.5 Lignes de fuite

Le 8.2.3.5 de l'IEC 60947-1:2020 s'applique.

8.2.3.6 Isolation solide

L'isolation solide doit être vérifiée soit par des essais à fréquence industrielle, conformément au 9.3.3.4.1, point 3) de l'IEC 60947-1:2020, soit par des essais en courant continu (les tensions d'essai pour les essais en courant continu sont à l'étude).

Pour les besoins du présent document, les circuits qui comprennent des appareils à semiconducteurs doivent être déconnectés pour les essais.

8.2.3.7 Espacements entre circuits distincts

Le 8.2.3.7 de l'IEC 60947-1:2020 s'applique.

8.2.3.8 Exigences pour les circuits avec séparation de protection

L'Annexe N de l'IEC 60947-1:2020 s'applique.

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8.2.4 Aptitude à l'établissement et à la coupure à vide, en charge normale et en surcharge

8.2.4.1 Fonctionnement en surcharge

Cette exigence s'applique aux disjoncteurs dont le courant assigné est inférieur ou égal à 630 A.

Le disjoncteur doit être capable d'effectuer le nombre de cycles de manœuvres dans les conditions d'essai du 9.3.4.5, 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.

8.2.4.2 Aptitude au fonctionnement en service

Le 8.2.4.2 de l'IEC 60947-1:2020 s'applique, avec les ajouts suivants:

Le disjoncteur doit être capable de satisfaire aux exigences du Tableau 7:

– pour l'essai de fonctionnement en service sans courant dans le circuit principal, dans les conditions d'essai spécifiées en 9.3.4.4.3;
– pour l'essai de fonctionnement en service avec courant dans le circuit principal, dans les conditions d'essai spécifiées en 9.3.4.4.4.

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).

Tableau 7 – 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 sans dépasser 2 s.

8.2.5 Aptitude à l'établissement et à la coupure en condition de court-circuit

Le 8.2.5 de l'EC 60947-1:2020 s'applique, avec les développements suivants:

Le pouvoir assigné de fermeture en court-circuit doit être conforme au 5.3.6.1 et au 5.3.6.3.

Le pouvoir assigné de coupure en court-circuit doit être conforme au 5.3.6.2.

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Le courant assigné de courte durée admissible doit être conforme au 5.3.6.4.

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.

8.2.6 Exigences de sectionnement

Le 8.2.7 de l'IEC 60947-1:2020 s'applique et les essais doivent être effectués conformément au 9.3.4.3, au 9.3.4.6, au 9.3.4.10, au 9.3.5.4, au 9.3.6.4 et au 9.3.8.8, selon le cas.

8.2.7 Exigences particulières pour les disjoncteurs à fusibles incorporés

NOTE Pour la coordination des disjoncteurs et des fusibles séparés associés dans un même circuit, voir le 8.2.8.

Un disjoncteur à fusibles incorporés doit être conforme au présent document à tout égard jusqu'au pouvoir assigné de coupure ultime en court-circuit. En particulier, il doit satisfaire aux exigences de la séquence d'essai V (voir 9.3.8).

Le disjoncteur doit fonctionner, sans provoquer le fonctionnement des fusibles, en présence de surintensités qui ne dépassent pas le courant limite de sélectivité I_s déclaré par le fabricant.

Pour toutes les surintensités inférieures ou égales au 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 3.10), il ne doit pas être possible de refermer le disjoncteur tant que les éléments de remplacement fondus ou les éléments de remplacement manquants n'ont pas été remplacés, ou bien que les dispositifs de verrouillage n'ont pas été réarmés.

8.2.8 Coordination entre un disjoncteur et un autre dispositif de protection contre les courts-circuits

Pour la coordination entre un disjoncteur et un autre dispositif de protection contre les courts-circuits, voir l'Annexe A.

8.3 Compatibilité électromagnétique (CEM)

Les exigences et les méthodes d'essai sont données à l'Annexe J.

9 Essais

9.1 Nature des essais

9.1.1 Généralités

Le 9.1 de l'IEC 60947-1:2020 s'applique, avec les ajouts suivants:

Les essais destinés à vérifier les caractéristiques des disjoncteurs sont:

– les essais de type (voir 9.3);
– les essais individuels de série (voir 9.4);
– les essais spéciaux (voir 9.5).

Pour les points qui font l'objet d'un accord entre le fabricant et l'utilisateur, voir l'Annexe E.

9.1.2 Essais de type

Les essais de type comprennent les essais énumérés dans le Tableau 8.

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Tableau 8 – Essais de type

Essai	Paragraphe
Échauffement	9.3.3.5
Limites et caractéristiques de déclenchement	9.3.4.2
Propriétés diélectriques	9.3.4.3
Aptitude au fonctionnement en service	9.3.4.4
Fonctionnement en surcharge (le cas échéant)	9.3.4.5
Pouvoirs de coupure en court-circuit	9.3.5 et 9.3.6
Courant de courte durée admissible (le cas échéant)	9.3.7
Fonctionnement des disjoncteurs à fusibles incorporés	9.3.8
Courant continu critique de charge	9.3.10
Pouvoir de coupure en court-circuit sur un pôle séparément à la tension phase-neutre alternative (le cas échéant)	9.3.11

Les essais de type doivent être effectués par le fabricant, dans ses ateliers ou dans un laboratoire approprié de son choix.

9.1.3 Essais individuels de série

Les essais individuels de série comprennent les essais énumérés en 9.4.

9.1.4 Essais spéciaux

Les essais spéciaux comprennent les essais énumérés en 9.5.

9.2 Conformité aux exigences de construction

Le 9.2 de l'IEC 60947-1:2020 s'applique.

9.3 Essais de type

9.3.1 Généralités

Pour éviter la répétition de textes identiques concernant les différentes séquences d'essai, les conditions générales d'essai ont été regroupées au début du présent paragraphe sous trois titres:

– conditions d'essai applicables à toutes les séquences (9.3.4 à 9.3.9);
– conditions d'essai applicables aux essais d'échauffement (9.3.3.5);
– conditions d'essai applicables aux essais de court-circuit (9.3.3.6).

Le cas échéant, 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 exige l'emploi de références croisées, mais permet de présenter chaque séquence d'essai sous une forme très simplifiée.

Le terme "essai" est utilisé dans l'ensemble du présent paragraphe 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 peut avoir été endommagé.

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Un index alphabétique est donné dans le Tableau 9 pour repérer plus facilement une condition d'essai ou un essai. Cet index comprend les termes qui sont le plus susceptibles d'être employés (et pas nécessairement les termes exacts qui figurent dans le titre des paragraphes correspondants).

Tableau 9 – Index alphabétique des essais

Conditions générales d'essai	**Paragraphe**
Disposition des disjoncteurs, généralités	9.3.3.1
Disposition des disjoncteurs pour les essais de court-circuit	9.3.3.6.1
Fréquence	9.3.3.2.3
Facteur de puissance	9.3.3.2.4
Enregistrements (interprétation)	9.3.3.6.6
Tension de rétablissement	9.3.3.2.6
Court-circuit: circuits d'essai	9.3.3.6.2
Court-circuit: mode opératoire d'essai	9.3.3.6.4
Essai d'échauffement	9.3.3.5
Constante de temps	9.3.3.2.5
Tolérances	9.3.3.2.2
Essais (voir le Tableau 10 pour le schéma d'ensemble des séquences d'essai)	**Paragraphe**
Courant continu critique de charge	9.3.10
Propriétés diélectriques	9.3.4.3
Tenue diélectrique (vérification)	9.3.4.6 – 9.3.5.4 – 9.3.6.4 – 9.3.7.6 – 9.3.8.4 – 9.3.8.8 – 9.3.9.6
Essai en court-circuit sur un pôle séparément (pour réseaux avec une phase reliée à la terre)	Annexe C
Essai en court-circuit sur un pôle séparément (pour réseaux IT)	Annexe H – voir Article H.2
Indication de la position des contacts principaux	9.3.4.10
Disjoncteurs à fusibles incorporés (essais de court-circuit)	9.3.8.2 – 9.3.8.6 – 9.3.8.7
Aptitude au fonctionnement en service	9.3.4.4 – 9.3.5.3 – 9.3.5.5
Fonctionnement en surcharge	9.3.4.5
Déclencheurs de surcharge (vérification)	9.3.4.8 – 9.3.5.6 – 9.3.6.2 – 9.3.6.5 – 9.3.7.2 – 9.3.7.7 – 9.3.8.5 – 9.3.8.9 – 9.3.9.2 – 9.3.9.8
Pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative	9.3.11
Pouvoir de coupure de service en court-circuit	9.3.5.2 – 9.3.9.4
Essai de pouvoir de coupure en court-circuit au courant maximal de courte durée admissible	9.3.7.5
Courant de courte durée admissible	9.3.7.3 – 9.3.9.3
Échauffement (vérification)	9.3.4.7 – 9.3.5.5 – 9.3.7.4 – 9.3.8.3 – 9.3.9.7
Limites et caractéristiques de déclenchement	9.3.4.2
Pouvoir de coupure ultime en court-circuit	9.3.6.3
Disjoncteurs débrochables (essais supplémentaires)	9.3.4.4.5

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9.3.2 Séquences d'essai

9.3.2.1 Généralités

Les essais de type sont regroupés dans plusieurs séquences, comme cela est indiqué dans le Tableau 10.

Pour chaque séquence, les essais doivent être réalisés dans l'ordre indiqué, sauf spécification contraire dans le présent document.

9.3.2.2 Essais omis de la séquence I et réalisés séparément

En référence au 9.1.1 de l'IEC 60947-1:2020, les essais suivants de la séquence d'essai I (voir 9.3.4) peuvent être omis de la séquence et réalisés sur des échantillons séparés:

– limites et caractéristiques de déclenchement (9.3.4.2); dans ce cas, l'échantillon ou les échantillons en essai dans la séquence doivent être soumis aux essais du 9.3.4.2.3 uniquement sur les pôles des phases et au réglage maximal, à la température ambiante et sans l'essai supplémentaire du point b) destiné à vérifier la caractéristique temps-courant;

– essai des propriétés diélectriques (9.3.4.3);

– essai des déclencheurs à minimum de tension du 9.3.4.4.2.3 et du 9.3.4.4.3, afin de vérifier les exigences du 8.2.1.3 de l'IEC 60947-1:2020, et essais des déclencheurs à minimum de tension aux fréquences alternatives (voir 9.3.3.1);

– essai des déclencheurs shunt du 9.3.4.4.2.4 et du 9.3.4.4.3, afin de vérifier les exigences du 8.2.1.4 de l'IEC 60947-1:2020, et essais des déclencheurs shunt aux fréquences alternatives (voir 9.3.3.1);

– essais supplémentaires d'aptitude au fonctionnement en service sans courant pour les disjoncteurs débrochables (9.3.4.4.5).

9.3.2.3 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 indiquée dans le Tableau 11.

Tableau 10 – Schéma d'ensemble des séquences d'essai[a]

Séquence d'essai	Validité	Essais
I Caractéristiques générales de fonctionnement (9.3.4)	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
II Pouvoir assigné de coupure de service en court-circuit (9.3.5)	Tous les disjoncteurs [b]	Pouvoir assigné de coupure de service en court-circuit Vérification de l'aptitude au fonctionnement en service Vérification de la tenue diélectrique Vérification de l'échauffement Vérification des déclencheurs de surcharge

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Séquence d'essai	Validité	Essais
III Pouvoir assigné de coupure ultime en court-circuit (9.3.6)	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 (9.3.7)	Disjoncteurs de catégorie de sélectivité B [b] et disjoncteurs de catégorie de sélectivité A avec un courant assigné de courte durée admissible (voir 5.4)	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 (9.3.8)	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 (9.3.9)	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
VII Courant continu critique de charge (9.3.10)	Disjoncteurs à caractéristiques assignées à courant continu	Essais de courant continu critique de charge
VIII Pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative (9.3.11)	Disjoncteurs à courant alternatif, le cas échéant (voir 9.3.11.1)	Vérification des déclencheurs de surcharge Pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative (I_{cu1}) Vérification de la tenue diélectrique Vérification des déclencheurs de surcharge
Séquence d'essai en court-circuit sur un pôle séparément (Annexe C)	Disjoncteur pour emploi sur des réseaux avec une phase reliée à la 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 11.

[b] Sauf lorsque la séquence VI est appliquée.

[c] Sauf
- lorsque $I_{cs} = I_{cu}$ (voir cependant 9.3.6),
- lorsque la séquence VI est appliquée,
- pour les disjoncteurs à fusibles incorporés.

[d] Voir la note en 9.3.6.1

Tableau 11 – 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]	

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[a] Le présent tableau s'applique à chacune des valeurs de U_e. Dans le cas de plusieurs valeurs assignées de U_e, le tableau s'applique à chaque valeur assignée de U_e. L'applicabilité d'une séquence d'essai est indiquée par un X dans la case correspondante.

[b] Essai applicable seulement si $I_{cu} > I_{cw}$.

[c] À 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 5.4).

9.3.2.4 Programmes d'essais alternatifs pour disjoncteurs à courant alternatif qui comportent différents nombres de pôles

Ces programmes d'essai alternatifs peuvent être appliqués uniquement aux caractéristiques assignées en courant alternatif et lorsque toutes les caractéristiques assignées sont inférieures ou égales à celles de la variante soumise au programme complet du Tableau 10 et que 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 10. Il n'est pas nécessaire de soumettre à l'essai un disjoncteur bipolaire obtenu en supprimant le chemin de courant central d'un disjoncteur tripolaire soumis à l'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 remplie en réalisant l'un des programmes alternatifs 1 ou 2 suivants:

– programme 1: Les séquences d'essai applicables selon le Tableau 10 doivent être effectuées sur la variante tripolaire. De plus, le cas échéant, les essais ou séquences d'essai énumérés dans le Tableau 13 doivent être effectués sur les autres variantes;

– programme 2: Les séquences d'essai applicables selon le Tableau 10 doivent être effectuées sur la variante tétrapolaire. De plus, le cas échéant, les essais ou séquences d'essai énumérés dans le Tableau 14 doivent être effectués sur les autres variantes.

Le principe d'application des programmes d'essais alternatifs est indiqué dans le Tableau 12:

Tableau 12 – Programmes d'essais alternatifs pour les disjoncteurs à courant alternatif

	Programme 1				Programme 2			
	unipolaire	bipolaire	tripolaire	tétrapolaire	unipolaire	bipolaire	tripolaire	tétrapolaire
Construction 1[a]	□	□	■	□	○	○	○	■
Construction 2	–	–	■	□	–	–	–	■
Construction 3	–	–	■	□	–	–	–	■
…	–	–	■	□	–	–	–	■
Construction *n*	–	–	■	□	–	–	–	■
Légende	■ intégralement soumis à l'essai selon le Tableau 10 □ soumis à l'essai selon le Tableau 13 ○ soumis à l'essai selon le Tableau 14 – aucun essai exigé							

[a] La construction 1 est celle qui couvre la caractéristique assignée maximale.

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Tableau 13 – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tétrapolaires selon le programme alternatif 1 du 9.3.2.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tétrapolaire[f, h]	Applicabilité aux variantes unipolaires ou bipolaires[g]
I	9.3.4.2	Essai des limites et des caractéristiques de déclenchement		
	9.3.4.2.1	Généralités	X	X
	9.3.4.2.2	Déclencheurs de court-circuit	X[a]	X[e]
	9.3.4.2.3 a)[i] ou 9.3.4.2.3 b)[i] (suivant le cas)	Déclencheurs de surcharge: – instantanés/à retard indépendant – à temps inverse	X	X[e]
	9.3.4.2.4	Essai supplémentaire pour les déclencheurs à retard indépendant:		
	9.3.4.3	Propriétés diélectriques	X	X
	9.3.4.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	9.3.4.4.1	Généralités	X	X
	9.3.4.4.2	Dispositions de construction et fonctionnement mécanique	X[d]	X[d, e]
	9.3.4.4.3	Aptitude au fonctionnement en service sans courant	X	X
	9.3.4.4.4	Aptitude au fonctionnement en service avec courant	X	X
	9.3.4.4.5	Disjoncteurs débrochables	X	
	9.3.4.5	Fonctionnement en surcharge	X	X
	9.3.4.6	Vérification de la tenue diélectrique	X	X
	9.3.4.7	Vérification de l'échauffement	X	X
	9.3.4.8	Vérification des déclencheurs de surcharge		
	9.3.4.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	9.3.4.10	Vérification de la position des contacts principaux	X	X
II	9.3.5	Pouvoir assigné de coupure de service en court-circuit		
III	9.3.6[b, c]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	9.3.7	Courant assigné de courte durée admissible	X 4[e] pôle et pôle adjacent uniquement (voir 9.3.3.6.4)	
V	9.3.8	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	9.3.9	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		

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NOTE L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case correspondante.

[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 Tableau 10).

[c] Essai à la valeur maximale en kVA (I_{cu} × U_e correspondante).

[d] Sans les essais de vérification des déclencheurs à minimum de tension (9.3.4.4.2.3) et des déclencheurs shunt (9.3.4.4.2.4).

[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 qui comporte le niveau le plus élevé doit être soumise à l'essai selon le Tableau 13.

[g] Un seul échantillon, de courant assigné maximal uniquement, pour chaque séquence d'essai.

[h] Un échantillon de courant assigné maximal pour chaque séquence d'essai; en cas d'une ou de plusieurs différences de construction (voir 3.1.2 et 8.1.6) pour une taille donnée, un échantillon supplémentaire est soumis à l'essai au courant assigné maximal qui correspond à chaque construction.

[i] Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

Tableau 14 – Applicabilité des essais ou des séquences d'essai aux disjoncteurs unipolaires, bipolaires et tripolaires selon le programme alternatif 2 du 9.3.2.4

Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[e]	Applicabilité aux variantes unipolaires ou bipolaires[e]
I	9.3.4.2	Essai des limites et des caractéristiques de déclenchement		
	9.3.4.2.1	Généralités		X
	9.3.4.2.2	Déclencheurs de court-circuit		X [d]
	9.3.4.2.3 a)[f] ou ou 9.3.4.2.3 b)[f] (suivant le cas)	Déclencheurs de surcharge: – instantanés/à retard indépendant – à temps inverse		X[d]
	9.3.4.2.4	Essai supplémentaire des déclencheurs à retard indépendant		
	9.3.4.3	Propriétés diélectriques	X	X
	9.3.4.4	Fonctionnement mécanique et aptitude au fonctionnement en service		
	9.3.4.4.1	Généralités	X	X
	9.3.4.4.2	Dispositions de construction et fonctionnement mécanique		X[c, d]
	9.3.4.4.3	Aptitude au fonctionnement en service sans courant	X	X
	9.3.4.4.4	Aptitude au fonctionnement en service avec courant	X	X
	9.3.4.4.5	Disjoncteurs débrochables		
	9.3.4.5	Fonctionnement en surcharge	X	X
	9.3.4.6	Vérification de la tenue diélectrique	X	X
	9.3.4.7	Vérification de l'échauffement	X	X
	9.3.4.8	Vérification des déclencheurs de surcharge		
	9.3.4.9	Vérification des déclencheurs à minimum de tension et des déclencheurs shunt	X	X
	9.3.4.10	Vérification de la position des contacts principaux	X	X

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Séquence d'essai	Paragraphe de l'essai	Essai	Applicabilité à la variante tripolaire[e]	Applicabilité aux variantes unipolaires ou bipolaires[e]
II	9.3.5	Pouvoir assigné de coupure de service en court-circuit		
III	9.3.6[a, b]	Pouvoir assigné de coupure ultime en court-circuit	X	X
IV	9.3.7	Courant assigné de courte durée admissible		
V	9.3.8	Fonctionnement des disjoncteurs à fusibles incorporés	X	X
VI	9.3.9	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 correspondante.

[a] 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 Tableau 10).

[b] Essai à la valeur maximale en kVA (I_{cu} × U_e correspondante).

[c] Sans les essais de vérification des déclencheurs à minimum de tension (9.3.4.4.2.3) et des déclencheurs shunt (9.3.4.4.2.4).

[d] Applicable uniquement à la variante unipolaire; non exigé pour les variantes bipolaires.

[e] Un seul échantillon, de courant assigné maximal uniquement, pour chaque séquence d'essai.

[f] Cet essai n'est pas exigé pour les unités de déclenchement électroniques.

9.3.3 Conditions générales d'essai

9.3.3.1 Exigences générales

Sauf accord contraire du fabricant, chaque séquence d'essai doit être effectuée sur un échantillon de disjoncteur (ou sur un jeu d'échantillons) à l'état neuf et propre.

Le nombre d'échantillons à soumettre à l'essai pour chaque séquence d'essai ainsi que les conditions d'essai (par exemple, réglage des déclencheurs de surcharge, raccordement des bornes) sont indiqués dans le Tableau 15 et, le cas échéant, pour les programmes d'essais alternatifs, dans le Tableau 13 et le Tableau 14 (voir 9.3.2.4).

Lorsque cela est nécessaire, des informations complémentaires sont données aux paragraphes correspondants.

Sauf spécification contraire, les essais doivent être effectués sur un disjoncteur qui présente le courant maximal assigné pour une taille donnée et sont considérés comme couvrant tous les courants assignés de cette taille.

En cas d'une ou de plusieurs différences de construction (voir 3.1.2 et 8.1.6) pour une taille donnée, des échantillons supplémentaires doivent être soumis à l'essai conformément au Tableau 13 et/ou au Tableau 15, selon le cas.

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 l'essai doivent être conformes dans tous leurs détails essentiels au plan du type qu'ils représentent.

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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 prévu. Les essais réalisés à la fréquence de 50 Hz couvrent les applications à 60 Hz et inversement, à l'exception du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (voir 8.2.1 et 8.2.2.7 de l'IEC 60947-1:2020).

Si le mécanisme est à commande électrique, il doit être alimenté à la tension minimale spécifiée en 8.2.1.1.4. En outre, les mécanismes à commande électrique doivent être alimentés par les circuits de commande appropriés du disjoncteur complet, avec les 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 3.6.12 de l'IEC 60947-1:2020), 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'appareillage d'essai touche l'organe de manœuvre du disjoncteur soumis à l'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 en essai doit être monté complet sur son propre support ou sur un support équivalent.

Sauf indication contraire, les connexions du déclencheur complet et du déclencheur séparé (le cas échéant, voir 9.3.4.2.1) doivent être réalisées de la même façon que pour le service normal avec des conducteurs d'une section qui correspond au courant assigné (I_n) (voir le Tableau 9 de l'IEC 60947-1:2020 avec une section minimale de 1 mm^2, le Tableau 10 de l'IEC 60947-1:2020 et le Tableau 11 de l'IEC 60947-1:2020) et d'une longueur conforme au 9.3.3.3.4 de l'IEC 60947-1:2020. Dans le cas de conducteurs en aluminium, leur section doit être conforme au Tableau D.7 ou au Tableau D.8, selon le cas.

Les disjoncteurs doivent être soumis à l'essai à l'air libre.

Lorsqu'un disjoncteur peut être utilisé dans des enveloppes individuelles spécifiées et qu'il a été soumis à l'essai à l'air libre, il doit en plus être soumis à l'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 le 9.3.6, à U_e max et à la valeur correspondante de I_{cu}, avec les réglages du déclencheur au maximum (voir note [a] du Tableau 15);
b) un essai d'échauffement selon les conditions générales du 9.3.3.5 réalisé sur un disjoncteur qui a une valeur maximale de I_{th} au courant thermique assigné conventionnel sous enveloppe I_{the} (voir 5.3.3.2). Les échauffements doivent satisfaire aux exigences du 8.2.2, excepté 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 indiqués 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 l'essai dans la plus petite des enveloppes déclarées par le fabricant, il n'est pas nécessaire d'effectuer les essais à l'air libre à condition que l'enveloppe soit en métal nu, sans isolation. Les détails, y compris les dimensions de l'enveloppe doivent être indiqués dans le rapport d'essai.

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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 indiqués 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: inférieure ou égale à 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 9.3.4.1.2, point d) de l'IEC 60947-1:2020) 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 à appliquer aux vis des bornes doivent être conformes aux instructions du fabricant (voir Tableau 4, point 3.11).

Sauf indication contraire, tous les essais doivent être réalisés avec des connexions directes.

L'entretien ou le remplacement de pièces n'est pas admis.

Si, pour faciliter un essai, il apparaît utile d'en augmenter la sévérité (par exemple d'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 15 – Nombre d'échantillons pour les essais

Séquence d'essai	Nombre de caractéristiques assignées U_e ou I_{cw} [p] marquées			Bornes repérées alimentation/ charge		Nombre d'échantillons	Échantillon 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 9.3.4		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}) et VIII (I_{cu1})	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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Séquence d'essai	Nombre de caractéristiques assignées U_e ou I_{cw} [p] marquées			Bornes repérées alimenta-tion/ charge		Nombre d'échan-tillons	Échan-tillon N°	Courant de réglage [a]		Tension d'essai	Courant d'essai		Retard		Vérifica-tion de l'échauf-fement	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
							1		X	U_e max		X	X		X	g
			X	X	X	3	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
VI (combinée)	Voir séquence d'essai II															
VII (I_{crit})	X	X	X	X	X	1	1		X	U_e max DC	X					g
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; Corr. = correspondant; Interméd. = intermédiaire

NOTE 1 Le Tableau 15 s'applique aux programmes d'essai du Tableau 10. Dans le cas des programmes d'essais alternatifs (voir 9.3.2.4), le Tableau 13 et le Tableau 14 s'appliquent.
NOTE 2 L'applicabilité d'un essai ou d'une séquence d'essai est indiquée par un X dans la case correspondante.

[a] Min désigne la valeur minimale de I_n pour une taille donnée; dans le cas de déclencheurs de surcharge réglables, cela signifie le réglage minimal de la valeur minimale de I_n. Max désigne la valeur maximale de I_n pour une taille donnée.

[b] Cet échantillon est omis dans les cas suivants:
- un disjoncteur qui a 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 à maximum de courant intégré);
- un disjoncteur à protection électronique contre les surintensités, d'une taille donnée, qui a 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] Essai à la valeur maximale en kVA (I_{cu} ou I_{cs}, selon le cas, multipliée par la valeur U_e intermédiaire correspondante). Cet échantillon est omis si un autre échantillon a déjà été soumis à l'essai dans les mêmes conditions.

[f] Si les bornes ne sont pas repérées, un échantillon supplémentaire doit être soumis à l'essai avec les connexions inversées.

[g] En cas d'une ou de plusieurs différences de construction (voir 3.1.2 et 8.1.6) pour une taille donnée, un échantillon supplémentaire est soumis à l'essai au courant assigné maximal qui correspond à chaque construction dans les conditions applicables à l'échantillon 1.

[h] L'exigence de la note g s'applique à la séquence VI (combinée) ainsi qu'à la séquence II lorsque $I_{cs} = I_{cu}$.

[i] Cet échantillon est choisi d'après la valeur la plus élevée de l'énergie thermique ($I_{cw}^2 t$; où "t" est le retard de courte durée correspondant, voir 5.3.6.4). 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 9.3.6).

[k] Connexions inversées, si bornes non repérées, lorsque la séquence III est remplacée par la séquence II ($I_{cu} = I_{cs}$, voir 9.3.6) ou si la séquence VI remplace les séquences II, III et IV ($I_{cu} = I_{cs} = I_{cw}$, voir 9.3.9), autrement cet échantillon est soumis à l'essai avec une connexion dans le sens direct.

[l] S'applique uniquement aux disjoncteurs à courant assigné de courte durée admissible (voir 5.4).

[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 9.3.6).

[n] Cet échantillon est uniquement exigé lorsque la séquence III est remplacée par la séquence IV ($I_{cu} = I_{cw}$, voir 9.3.6).

[p] Lire "U_e" pour toutes les séquences d'essai, à l'exception de la séquence d'essai IV. Lire "I_{cw}" pour la séquence d'essai IV.

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9.3.3.2 Grandeurs d'essai

9.3.3.2.1 Valeurs des grandeurs d'essai

Le 9.3.2.2.1 de l'IEC 60947-1:2020 s'applique.

9.3.3.2.2 Tolérances sur les grandeurs d'essai

Le 9.3.2.2.2 de l'IEC 60947-1:2020 s'applique.

9.3.3.2.3 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 %.

9.3.3.2.4 Facteur de puissance du circuit d'essai

Le 9.3.4.1.3 de l'IEC 60947-1:2020 s'applique, avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2020 est remplacé par le Tableau 16 du présent document.

Tableau 16 – 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		

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9.3.3.2.5 Constante de temps du circuit d'essai

Le 9.3.4.1.4 de l'IEC 60947-1:2020 s'applique, avec la modification suivante:

Le Tableau 16 de l'IEC 60947-1:2020 est remplacé par le Tableau 16 du présent document.

9.3.3.2.6 Tension de rétablissement à fréquence industrielle

Le 9.3.2.2.3, point a) de l'IEC 60947-1:2020 s'applique.

9.3.3.2.7 Ondulation du courant d'essai en courant continu

Le courant d'essai doit satisfaire aux exigences du 6.3.1 de l'IEC 62475:2010.

9.3.3.3 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 du présent document 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.

9.3.3.4 Rapports d'essai

Le 9.3.2.4 de l'IEC 60947-1:2020 s'applique.

9.3.3.5 Conditions d'essai pour les essais d'échauffement

Le disjoncteur doit satisfaire aux exigences du 8.2.2.

Le 9.3.3.3 de l'IEC 60947-1:2020 s'applique, à l'exception du 9.3.3.3.6, avec l'ajout suivant:

Le disjoncteur doit être monté conformément au 9.3.3.1.

Pendant l'essai d'échauffement de la séquence I (voir 9.3.4.7), 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 à courant alternatif, un essai doit d'abord être réalisé sur les 3 pôles de phase; pour le pôle neutre, l'essai supplémentaire en courant monophasé du 9.3.3.3.4 de l'IEC 60947-1:2020 s'applique uniquement lorsqu'il y a une différence de construction entre le pôle neutre et les pôles de phase (voir 8.1.6), auquel cas le courant d'essai est le courant assigné du pôle neutre.

Les disjoncteurs à courant continu doivent être connectés conformément aux instructions du fabricant. Les détails relatifs aux connexions doivent être indiqués dans le rapport d'essai.

9.3.3.6 Conditions d'essai pour les essais de court-circuit

9.3.3.6.1 Exigences générales

Le 9.3.4.1.1 de l'IEC 60947-1:2020 est complété comme suit:

a) le disjoncteur doit être monté conformément au 9.3.3.1;

b) à moins qu'il puisse être démontré que, quelle que soit la position des moyens de manœuvre manuelle, il n'existe aucune 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.

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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 100 mm × 100 mm, positionnée comme cela est 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 qu'il est reconnu que les manœuvres O ne sont pas moins sévères que les manœuvres CO (voir 9.3.3.6.4).

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 équipé de déclencheurs réglables à maximum de courant, le réglage de ces déclencheurs doit être celui 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 du circuit de commande du déclencheur (voir 8.2.1.2.3), 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, repérées par le fabricant. En l'absence de tels repères, les connexions d'essai doivent être celles spécifiées dans le Tableau 15.

9.3.3.6.2 Circuit d'essai

Le 9.3.4.1.2 de l'IEC 60947-1:2020 s'applique.

9.3.3.6.3 Étalonnage du circuit d'essai

Le 9.3.4.1.5 de l'IEC 60947-1:2020 s'applique.

9.3.3.6.4 Mode opératoire d'essai

9.3.3.6.4.1 Généralités

Le 9.3.4.1.6 de l'IEC 60947-1:2020 s'applique, avec l'ajout suivant.

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9.3.3.6.4.2 Essais communs aux disjoncteurs unipolaires, bipolaires, tripolaires et tétrapolaires

Après étalonnage du circuit d'essai, conformément au 9.3.3.6.3, 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 10 (voir 9.3.2).

Pour les disjoncteurs dont le courant assigné est inférieur ou égal à 630 A, un câble d'une longueur maximale de 75 cm et d'une section qui correspond au courant thermique conventionnel (voir 9.3.3.3.4, Tableaux 9 et 10 de l'IEC 60947-1:2020) doit être inséré comme suit:

– environ 50 cm côté source;
– environ 25 cm côté charge.

Pour les caractéristiques assignées ≤ 20 A, le fabricant peut spécifier une section plus importante, 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 le 9.3.4.2.3 b) doit être réalisée avec ladite section.

La séquence de manœuvres doit être celle applicable à chaque séquence d'essai, comme cela est spécifié en 9.3.5.2, en 9.3.6.3, en 9.3.7.5 et en 9.3.8.7.

Des programmes d'essais alternatifs pour les disjoncteurs qui disposent de variantes à trois pôles et quatre pôles sont indiqués en 9.3.2.4.

9.3.3.6.4.3 Essais supplémentaires sur les disjoncteurs tétrapolaires

Des séquences de manœuvres supplémentaires doivent être effectuées sur un ou plusieurs échantillons neufs, conformément au Tableau 15, sur le quatrième pôle et le pôle adjacent, conformément à la séquence d'essai III ou V, selon 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 selon la séquence d'essai III ou V, et 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 du 9.3.3.6.4.2 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 60947-1:2020 avec les connexions C1 et C2 retirées. Le courant d'essai doit être fixé par accord entre le fabricant et l'utilisateur, mais ne doit pas être inférieur à 60 % de I_{cu} ou de I_{cw}, selon le cas.

Des programmes d'essais alternatifs pour les disjoncteurs qui disposent de variantes à trois pôles et quatre pôles sont indiqués en 9.3.2.4. Lorsque le programme 1 est choisi, ce paragraphe s'applique aux échantillons tétrapolaires énumérés dans le Tableau 13.

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9.3.3.6.4.4 Manœuvres d'essai

Les symboles suivants sont utilisés pour définir la séquence de manœuvres:

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 successives en court-circuit, qui doit être aussi court que possible, en tenant compte de la durée de réarmement du disjoncteur (voir 3.14), mais pas inférieur à 3 min. La valeur réelle de t doit être spécifiée dans le rapport d'essai.

La durée de réarmement maximale, au cours de laquelle le disjoncteur ne doit pas être déplacé, doit être de 15 min ou une durée plus longue qui peut être déclarée par le fabricant, sans toutefois dépasser 1 h. 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 3.7.18 de l'IEC 60947-1:2020) lors de ces essais peut être consignée dans le rapport d'essai (voir 8.2.1.2.4, point a)).

9.3.3.6.5 Comportement du disjoncteur pendant les essais de fermeture et de coupure en court-circuit

Le 9.3.4.1.7 de l'IEC 60947-1:2020 s'applique.

9.3.3.6.6 Interprétation des enregistrements

Le 9.3.4.1.8 de l'IEC 60947-1:2020 s'applique.

9.3.3.6.7 Vérification après les essais de court-circuit

Après les manœuvres d'ouverture des essais de pouvoir de coupure et de fermeture en court-circuit du 9.3.5.2, du 9.3.6.3, du 9.3.7.5, du 9.3.8.2, du 9.3.8.7 et du 9.3.9.4, selon le cas, les conditions suivantes doivent être remplies:

– l'isolant des conducteurs 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 de diamètre inférieur à 0,26 mm peuvent être ignorés;

Ensuite, après les essais de court-circuit, le disjoncteur doit satisfaire aux vérifications spécifiées pour chaque séquence d'essai, le cas échéant.

9.3.4 Séquence d'essai I: caractéristiques générales de fonctionnement

9.3.4.1 Généralités

Cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais indiqués dans le Tableau 17.

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Tableau 17 – Essais de la séquence d'essai I

Essai	Paragraphe
Limites et caractéristiques de déclenchement	9.3.4.2
Propriétés diélectriques	9.3.4.3
Fonctionnement mécanique et aptitude au fonctionnement en service	9.3.4.4
Fonctionnement en surcharge (le cas échéant)	9.3.4.5
Vérification de la tenue diélectrique et du courant de fuite	9.3.4.6
Vérification de l'échauffement	9.3.4.7
Vérification des déclencheurs de surcharge	9.3.4.8
Vérification des déclencheurs à minimum de tension et des déclencheurs shunt (le cas échéant)	9.3.4.9
Vérification de la position des contacts principaux	9.3.4.10

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

Voir le 9.3.2 pour les essais qui peuvent être omis de la séquence et effectués sur des échantillons séparés.

9.3.4.2 Essai des limites et des caractéristiques de déclenchement

9.3.4.2.1 Généralités

Le 9.3.3.2 de l'IEC 60947-1:2020 est complété comme suit:

La température de l'air ambiant doit être mesurée de la même manière que lors des essais d'échauffement (voir 9.3.3.5).

Quand le déclencheur d'ouverture à maximum de courant fait normalement 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 conformément au 9.3.3.1. Le matériel à l'essai doit être protégé tout échauffement ou refroidissement extérieur excessif.

Pour les disjoncteurs équipés de déclencheurs à maximum de courant réglables, les essais doivent être effectués:

a) au courant de réglage minimal et au réglage minimal de la temporisation, suivant le cas; et

b) au courant de réglage maximal et au réglage maximal de la temporisation, suivant le cas,

dans chaque cas avec des conducteurs qui correspondent au courant assigné I_n (voir 5.7.2).

En ce qui concerne 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 9.3.3.3.4 de l'IEC 60947-1:2020. Il convient que les raccordements soient compatibles avec le courant d'essai et les contraintes thermiques induites.

Pour les disjoncteurs qui ont 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.

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9.3.4.2.2 Déclencheurs de court-circuit

Le fonctionnement des déclencheurs de court-circuit (voir 5.7.1, point 2) 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 3.6.25 de l'IEC 60947-1:2020). En variante, dans le cas d'un disjoncteur qui comporte également un déclencheur de court-circuit à retard de courte durée (voir 3.8), le courant doit être maintenu pendant la durée de non-déclenchement indiquée par le fabricant au lieu de la durée de 0,2 s (si le déclencheur de court-circuit à retard de courte durée est réglable, le retard doit être réglé sur sa valeur maximale pour cet essai);

  NOTE La proposition alternative a pour objet d'éviter le déclenchement intempestif du déclencheur de court-circuit à retard de courte durée pendant l'essai du déclencheur instantané.

– 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:

– dans un délai de 0,2 s dans le cas de déclencheurs instantanés (voir 3.15);

– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs équipés d'un déclencheur à maximum de courant électronique, le fonctionnement des déclencheurs de court-circuit doit être vérifié par seulement un essai sur chaque pôle individuellement.

Pour les disjoncteurs équipés de déclencheurs à maximum de courant 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 qui possèdent un pôle neutre identifié équipé d'un déclencheur de court-circuit, le pôle neutre doit être soumis à l'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:

– dans un délai de 0,2 s dans le cas de déclencheurs instantanés (voir 3.15);

– 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 du 9.3.4.2.4.

9.3.4.2.3 Déclencheurs de surcharge

a) Déclencheurs instantanés ou à retard indépendant

   Le fonctionnement des déclencheurs de surcharge instantanés ou à retard indépendant (voir Note 1 du 5.7.1) 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 du 9.3.4.2.4.

À 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 3.15);
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

À un courant d'essai d'une valeur égale à 110 % du courant de réglage, le déclencheur doit fonctionner:

– dans un délai de 0,2 s dans le cas de déclencheurs instantanés (voir 3.15);
– pendant un temps égal à deux fois le retard fixé par le fabricant dans le cas de déclencheurs à retard indépendant.

Pour les disjoncteurs qui ont un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 9.3.4.2.1), 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 du 8.2.1.2.4, point b), 2).

Pour les disjoncteurs qui ont un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 9.3.4.2.1), les courants d'essai pour ce déclencheur doivent être ceux indiqués dans le Tableau 5, 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 5.7.3 et Tableau 4, point 2.17), le déclencheur étant alimenté sur tous les pôles de phase.

Si l'essai est effectué à une température différente 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 7.1.1 de l'IEC 60947-1:2020), le déclencheur étant alimenté sur tous les pôles de phase.

Un essai supplémentaire, à une valeur de courant supérieure ou égale à deux fois le courant de réglage, 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 le présent paragraphe, les déclencheurs des disjoncteurs sont également vérifiés sur chaque pôle séparément au cours des séquences d'essai III, IV, V et VI (voir 9.3.6.2, 9.3.6.5, 9.3.7.2, 9.3.7.7, 9.3.8.5, 9.3.8.9, 9.3.9.2 et 9.3.9.8).

9.3.4.2.4 Essais supplémentaires des déclencheurs à retard indépendant

Les déclencheurs à retard indépendant doivent être soumis à l'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 qui ont un pôle neutre identifié équipé d'un déclencheur de surcharge (voir 9.3.4.2.1), le courant d'essai pour ce déclencheur doit être égal à 1,5 fois le courant de réglage;

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– 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 équipés d'un déclencheur de court-circuit;

– dans le cas de déclencheurs de court-circuit électroniques, sur un pôle choisi au hasard;

– dans le cas de déclencheurs à maximum de courant de défaut à la terre, sur un pôle choisi au hasard et avec le montage d'essai décrit en 9.3.4.2.5.

Le retard mesuré doit être compris dans 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, les déclencheurs de court-circuit et les déclencheurs à maximum de courant de défaut à la terre.

Le 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 indiquée par le fabricant; ensuite,

– dans le cas de déclencheurs de court-circuit ou de déclencheurs de surcharge, le courant est réduit à la valeur qui correspond au courant de réglage de surcharge (I_r);

– dans le cas de déclencheurs à maximum de courant de défaut à la terre, le courant est réduit à 75 % du courant de réglage de déclenchement par défaut à la terre (I_g);

et il est maintenu à cette valeur pendant une durée égale au double du retard indiqué par le fabricant. Le disjoncteur ne doit pas se déclencher.

9.3.4.2.5 Essais supplémentaires pour les déclencheurs à maximum de courant de défaut à la terre

L'Annexe T de l'IEC 60947-1:2020 s'applique, en remplaçant le terme "relais" par le terme "déclencheur", le cas échéant, et avec les ajouts suivants.

Les déclencheurs à retard indépendant doivent satisfaire aux exigences du 9.3.4.2.4.

Tous les essais doivent être réalisés sur un pôle choisi au hasard.

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.

Si le disjoncteur possède une caractéristique I^2t de défaut à la terre (voir Figure K.1), cette caractéristique I^2t doit être désactivée pour les essais.

9.3.4.3 Essai des propriétés diélectriques

Le 9.3.3.4.1 de l'IEC 60947-1:2020 s'applique, avec les ajouts suivants:

(i) en référence au 9.3.3.4.1, points 2) c) i) et ii) de l'IEC 60947-1:2020: les positions normales de service comprennent la position de déclenchement, le cas échéant;

(ii) en référence au 9.3.3.4.1, point 3 c) de l'IEC 60947-1:2020: pour les besoins du présent document, les circuits qui comprennent des appareils à semiconducteurs reliés au circuit principal doivent être déconnectés pour l'essai;

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(iii) pour les disjoncteurs qui ont une tension d'emploi supérieure à 50 V, le courant de fuite, mesuré à travers chaque pôle avec les contacts en position d'ouverture et en position de déclenchement (le cas échéant), à une tension d'essai égale à 1,1 U_e, ne doit pas dépasser 0,5 mA;

(iv) les disjoncteurs qui ont une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à l'essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou de 2 U_i si cette valeur est plus élevée;

(v) les disjoncteurs débrochables (voir 8.1.2) doivent faire l'objet d'une vérification de la tension de tenue aux chocs, conformément au 9.3.3.4.1, point 2) b) de l'IEC 60947-1:2020. La tension d'essai doit être choisie dans le Tableau 14 de l'IEC 60947-1:2020, et elle doit être appliquée entre les contacts de sectionnement des unités débrochables, en position déconnectée. Les critères d'acceptation sont ceux du 9.3.3.4.1, point 2) d) de l'IEC 60947-1:2020.

9.3.4.4 Essais de fonctionnement mécanique et d'aptitude au fonctionnement en service

9.3.4.4.1 Conditions générales d'essai

Le disjoncteur doit être monté comme cela est indiqué en 9.3.3.1, 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.

Les essais doivent être effectués à la température ambiante du local d'essai.

La tension d'alimentation de chaque circuit de commande doit être mesurée à ses bornes sous le courant assigné.

Toutes les résistances ou impédances qui font 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 du 9.3.4.4.2, du 9.3.4.4.3 et du 9.3.4.4.4 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 du 9.3.4.4.2 et du 9.3.4.4.3 peuvent être effectués, en variante, sur un échantillon neuf.

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.

9.3.4.4.2 Dispositions de construction et fonctionnement mécanique

9.3.4.4.2.1 Construction

Un disjoncteur débrochable doit être vérifié par rapport aux exigences indiquées en 8.1.2.

La conformité au 8.2.1.1.6 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.

9.3.4.4.2.2 Fonctionnement mécanique

Les essais doivent être effectués comme cela est spécifié en 9.3.4.4.1 afin de:

– vérifier le déclenchement satisfaisant du disjoncteur, 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;

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– 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 du 8.2.1.1.4.

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 du 8.2.1.1.6 avec une tension d'alimentation auxiliaire égale à 85 % et à 110 % de la tension assignée d'alimentation du circuit de commande. Il doit être aussi vérifié que les contacts mobiles ne 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.

9.3.4.4.2.3 Déclencheurs à minimum de tension

Les déclencheurs à minimum de tension doivent satisfaire aux exigences du 8.2.1.3 de l'IEC 60947-1:2020. Pour cela, le déclencheur doit être adapté à un disjoncteur qui présente le courant maximal assigné pour lequel le déclencheur convient.

i) Tension de retombée

Il doit être 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 du circuit 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 de la bobine du déclencheur.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation du circuit 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 qui correspond à l'application de la tension assignée d'alimentation du circuit de commande au déclencheur et au courant assigné dans les pôles principaux du disjoncteur. Cet essai peut être combiné avec l'essai d'échauffement du 9.3.4.7.

Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation du circuit de commande, cet essai est effectué aux deux tensions assignées minimale et maximale d'alimentation du circuit de commande.

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ii) Essai pour les limites de fonctionnement

En commençant 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 du circuit 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 du circuit 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 du circuit de commande pendant 4 h, sans altération de ses performances.

9.3.4.4.2.4 Déclencheurs shunt

Les déclencheurs shunt doivent satisfaire aux exigences du 8.2.1.4 de l'IEC 60947-1:2020. Pour cela, le déclencheur doit être adapté à un disjoncteur qui présente le courant maximal assigné pour lequel le déclencheur convient.

Il doit être vérifié que le déclencheur fonctionne de manière à ouvrir le disjoncteur à 70 % de la tension assignée d'alimentation du circuit de commande lors d'un essai à une température ambiante de +55 °C ± 2 °C sans courant dans les pôles principaux du disjoncteur. Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation du circuit de commande, la tension d'essai doit correspondre à 70 % de la tension minimale assignée d'alimentation du circuit de commande.

9.3.4.4.3 Aptitude au fonctionnement en service sans courant

Ces essais doivent être effectués dans les conditions spécifiées en 9.3.3.1. Le nombre de cycles de manœuvres à effectuer sur le disjoncteur est indiqué dans la colonne 3 du Tableau 7; 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 (colonne 3 du Tableau 7) doivent être des manœuvres de fermeture/déclenchement, c'est-à-dire avec le déclencheur shunt alimenté à la tension maximale assignée d'alimentation du circuit de commande.

Pour les disjoncteurs qui peuvent être équipés de déclencheurs à minimum de tension, 10 % du nombre total de cycles de manœuvres (colonne 3 du Tableau 7) doivent être des manœuvres de fermeture/déclenchement à la tension minimale assignée d'alimentation du circuit 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 correspondant 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 étant 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 équipé de son propre mécanisme de fermeture. Dans le cas de disjoncteurs équipés d'un déclencheur électrique ou pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation du circuit de commande ou à sa pression assignée. Des précautions doivent être prises pour s'assurer que les échauffements des organes électriques ne dépassent pas les limites indiquées dans le Tableau 6.

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Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

9.3.4.4.4 Aptitude au fonctionnement en service avec courant

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 9.3.3.1, le circuit d'essai étant conforme au 9.3.3.5.2 de l'IEC 60947-1:2020.

Le nombre et la fréquence des cycles de manœuvres à effectuer sont indiqués dans les colonnes 2 et 4 du Tableau 7.

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, selon le cas, conforme au Tableau 16, les tolérances étant celles indiquées en 9.3.3.2.2.

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 équipés 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 équipé de son propre mécanisme de fermeture. Dans le cas de disjoncteurs équipés d'un déclencheur électrique ou pneumatique de fermeture, cet appareil doit être alimenté à sa tension assignée d'alimentation du circuit de commande ou à sa pression assignée. Des précautions doivent être prises pour s'assurer que les échauffements des organes électriques ne dépassent pas les valeurs indiquées dans le Tableau 6.

Les disjoncteurs manœuvrés à la main doivent être manœuvrés comme en usage normal.

9.3.4.4.5 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 de 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 examen.

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9.3.4.5 Fonctionnement en surcharge

Cet essai s'applique aux disjoncteurs dont le courant assigné est 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 9.3.3.1, et le circuit d'essai doit être conforme au 9.3.3.5.2 de l'IEC 60947-1:2020.

L'essai doit être effectué à une tension qui correspond 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 18 (voir également 9.3.2.2.3 a) de l'IEC 60947-1:2020).

Pour les disjoncteurs équipés 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 qui ont un déclencheur de court-circuit dont le réglage maximal est inférieur au courant d'essai, pour lesquels les 12 manœuvres doivent toutes être automatiques.

Si le moyen d'essai ne résiste pas à l'énergie limitée qui apparaît 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 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 sans dépasser 2 s.

Le nombre de cycles de manœuvres par heure doit être celui spécifié dans la colonne 2 du Tableau 7. Si le disjoncteur ne se verrouille pas à la fréquence spécifiée, cette fréquence peut être réduite pour permettre au disjoncteur de se fermer après l'établissement complet du courant.

Les valeurs du courant et de la tension de rétablissement d'essai doivent être conformes à celles du Tableau 18, avec le facteur de puissance ou la constante de temps, le cas échéant, conforme au Tableau 16, les tolérances étant celles indiquées en 9.3.3.2.2.

Tableau 18 – 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 égal à au moins 10 fois la valeur du courant d'essai, ou à au moins 50 kA si cette valeur est plus faible.

NOTE 2 Avec l'accord du fabricant, cet essai peut être effectué dans des conditions plus sévères que celles spécifiées.

Le nombre de manœuvres manuelles et automatiques, les durées à l'état passant et, si elle diffère de celle indiquée dans le Tableau 7, la fréquence de manœuvre doivent être indiqués dans le rapport d'essai.

9.3.4.6 Vérification de la tenue diélectrique et du courant de fuite

9.3.4.6.1 Généralités

L'essai doit être effectué sur le disjoncteur qui reste monté comme 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 des mesures doivent alors être prises pour s'assurer que cela n'influence pas les résultats de l'essai.

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9.3.4.6.2 Tension d'essai pour la tenue diélectrique

Le 9.3.3.4.1, point 4) b), de l'IEC 60947-1:2020 s'applique, avec la modification suivante:

La tension d'essai doit être en courant alternatif dans le cas d'un disjoncteur à courant alternatif et en courant continu dans le cas d'un disjoncteur à courant continu.

La tension d'essai d'un disjoncteur à courant alternatif doit être égale à 2 U_e avec une tension efficace minimale de 1 000 V. Seulement si une tension d'essai en courant alternatif ne peut pas être appliquée au disjoncteur à courant alternatif, par exemple en raison de composants de filtre CEM, l'essai doit être effectué en utilisant une tension d'essai en courant continu de 2 U_e × 1,415 avec un minimum de 1 415 V en courant continu.

La tension d'essai d'un disjoncteur à courant continu doit être égale à 2 U_e avec une tension minimale de 1 415 V en courant continu.

Pour des essais diélectriques qui impliquent le circuit principal, la valeur de U_e dont il est question au présent paragraphe est celle à laquelle les essais précédents de commutation et/ou de court-circuit ont été réalisés.

9.3.4.6.3 Application de la tension d'essai pour la tenue diélectrique

La tension d'essai doit être appliquée pendant 5 s conformément au 9.3.3.4.1, points 2) c) i), ii) et iii) de l'IEC 60947-1:2020 et, en complément, entre les bornes d'entrée et de sortie de chaque pôle, le disjoncteur étant ouvert. L'utilisation de la feuille métallique spécifiée en 9.3.3.4.1, point 1) de l'IEC 60947-1:2020 n'est pas exigée. Pour les besoins du présent document, les circuits qui comprennent des appareils à semiconducteurs reliés au circuit principal doivent être déconnectés pour les essais. Les positions normales de service comprennent la position de déclenchement, le cas échéant.

9.3.4.6.4 Critères d'acceptation de la tenue diélectrique

Le 9.3.3.4.1, point 3) d), de l'IEC 60947-1:2020 s'applique.

9.3.4.6.5 Mesurage du courant de fuite

Le courant de fuite doit être mesuré en position ouverte uniquement, conformément au 9.3.4.3, point (iii), excepté qu'il ne doit pas dépasser 2 mA. La tension d'essai correspondante doit être appliquée pendant 5 s.

9.3.4.7 Vérification de l'échauffement

À la suite de l'essai du 9.3.4.6, un essai d'échauffement doit être effectué au courant thermique conventionnel, conformément au 9.3.3.5. À la fin de l'essai, les valeurs des échauffements ne doivent pas dépasser celles spécifiées dans le Tableau 6.

9.3.4.8 Vérification des déclencheurs de surcharge

Immédiatement après l'essai effectué conformément au 9.3.4.7, 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 8.2.1.2.4, point b) 2)).

Tous les pôles doivent être reliés en série pour cet essai. Le cas échéant, les déclencheurs à maximum de courant de défaut à la terre doivent être désactivés lors de l'essai.

En variante, cet essai peut être effectué avec une alimentation triphasée.

Cet essai peut être effectué sous toute tension convenable.

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La durée de fonctionnement ne doit pas dépasser la durée conventionnelle de déclenchement.

Avec l'accord du fabricant, il peut y avoir un délai entre les essais du 9.3.4.7 et du 9.3.4.8.

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.

9.3.4.9 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 du 9.3.4.4.2.3 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 assignée d'alimentation du circuit de commande et doit fonctionner à 35 % de la tension maximale assignée d'alimentation du circuit de commande.

Les disjoncteurs équipés de déclencheurs shunt doivent être soumis à l'essai du 9.3.4.4.2.4, 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 du circuit de commande.

9.3.4.10 Vérification de la position des contacts principaux

Après la vérification du 9.3.4.8, un essai doit être effectué afin de vérifier l'efficacité de l'indication de la position des contacts principaux conformément au 9.2.6 de l'IEC 60947-1:2020. Pour le premier critère du 9.2.6.3.1 de l'IEC 60947-1:2020 (organe de commande étant laissé libre), la Figure 2 s'applique pour l'application de la force d'essai (voir 9.2.6.2.1 de l'IEC 60947-1:2020).

NOTE Pour les disjoncteurs conformes au présent document, dont la poignée de manœuvre tourne autour d'un axe, le terme "extrémité" employé en 9.2.6.2.1 de l'IEC 60947-1:2020 correspond à la longueur maximale du bras de levier perpendiculaire à cet axe.

9.3.5 Séquence d'essai II: Pouvoir assigné de coupure de service en court-circuit

9.3.5.1 Généralités

Sauf dans les cas où la séquence d'essai VI (combinée) s'applique (voir 9.3.9), cette séquence d'essai s'applique à tous les disjoncteurs et comprend les essais indiqués dans le Tableau 19.

Tableau 19 – Essais de la séquence d'essai II

Essai	Paragraphe
Pouvoir assigné de coupure de service en court-circuit	9.3.5.2
Vérification de l'aptitude au fonctionnement en service	9.3.5.3
Vérification de la tenue diélectrique et du courant de fuite	9.3.5.4
Vérification de l'échauffement	9.3.5.5
Vérification des déclencheurs de surcharge	9.3.5.6

Pour le cas où I_{cs} = I_{cu}, voir le 9.3.6.

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

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9.3.5.2 Essai du pouvoir assigné de coupure de service en court-circuit

Un essai de court-circuit est effectué dans les conditions générales du 9.3.3, la valeur du courant présumé I_{cs} déclarée par le fabricant étant conforme au 5.3.6.2.4.

Le facteur de puissance pour cet essai doit être conforme au Tableau 16, 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. Pour cela, l'intervalle de temps *t* peut être augmenté.

9.3.5.3 Vérification de l'aptitude au fonctionnement en service

Après l'essai selon le 9.3.5.2, l'aptitude au fonctionnement en service doit être vérifiée conformément au 9.3.4.4.4, excepté que cette vérification doit être effectuée à la même tension assignée d'emploi que celle utilisée pour l'essai du 9.3.5.2 et que le nombre de manœuvres doit être égal à 5 % du nombre indiqué dans la colonne 4 du Tableau 7.

Il n'est pas nécessaire de réaliser cette vérification lorsque, pour une taille donnée, l'essai du 9.3.5.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec le réglage minimal de déclencheur de surcharge spécifié dans le Tableau 15.

9.3.5.4 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.5.3, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6.

9.3.5.5 Vérification de l'échauffement

Après l'essai selon le 9.3.5.4, l'échauffement aux bornes principales doit être vérifié conformément au 9.3.3.5. L'échauffement ne doit pas dépasser les valeurs indiquées dans le Tableau 6.

Il n'est pas nécessaire de réaliser cette vérification lorsque, pour une taille donnée, l'essai du 9.3.5.2 a été effectué sur un disjoncteur avec un I_n minimal ou avec le réglage minimal du déclencheur de surcharge.

9.3.5.6 Vérification des déclencheurs de surcharge

Immédiatement après l'essai du 9.3.5.5, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.4.8.

Avec l'accord du fabricant, il peut y avoir un délai entre les essais du 9.3.5.5 et du 9.3.5.6.

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9.3.6 Séquence d'essai III: Pouvoir assigné de coupure ultime en court-circuit

9.3.6.1 Généralités

Sauf dans les cas où la séquence d'essai VI (combinée) s'applique (voir 9.3.9), 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 2 (5.3.6.4); 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}, il n'est pas nécessaire de réaliser cette séquence d'essai, auquel cas des essais de différences de construction sont exigés dans la séquence II (voir Tableau 15) et les vérifications suivantes doivent être effectuées en plus dans la séquence d'essai II:

– la vérification du 9.3.6.2, au début de la séquence d'essai;
– la vérification du 9.3.6.5, à la fin de la séquence d'essai.

Cette séquence d'essai comprend les essais indiqués dans le Tableau 20.

Tableau 20 – Essais de la séquence d'essai III

Essai	Paragraphe
Vérification des déclencheurs de surcharge	9.3.6.2
Pouvoir assigné de coupure ultime en court-circuit	9.3.6.3
Vérification de la tenue diélectrique et du courant de fuite	9.3.6.4
Vérification des déclencheurs de surcharge	9.3.6.5

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

9.3.6.2 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. Le cas échéant, les déclencheurs à maximum de courant de défaut à la terre doivent être désactivés lors de l'essai; en variante, chaque pôle doit être soumis à l'essai en série avec 2 autres pôles connectés en parallèle.

Cet essai est omis pour les unités de déclenchement électroniques.

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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En ce qui concerne les essais pour lesquels la caractéristique de déclenchement est indépendante de la température des bornes (déclencheurs magnétiques, par exemple), les données relatives au raccordement (type, section, longueur) peuvent être différentes de celles exigées en 9.3.3.3.4 de l'IEC 60947-1:2020. 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.

9.3.6.3 Essai de pouvoir assigné de coupure ultime en court-circuit

Après l'essai du 9.3.6.2, 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 spécifiées en 9.3.3.

La séquence de manœuvres doit être:

O – *t* – CO

9.3.6.4 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.6.3, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6, excepté que le courant de fuite ne doit pas dépasser 6 mA.

9.3.6.5 Vérification des déclencheurs de surcharge

Après l'essai selon le 9.3.6.4, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2, excepté que la valeur du courant d'essai doit être égale à 2,5 fois celle de leur courant de réglage, et que l'essai des unités de déclenchement électroniques est exigé.

Pour les déclencheurs à maximum de courant électromagnétiques, le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage d'un seul pôle à la température de référence.

Pour les déclencheurs à maximum de courant électroniques, le temps de fonctionnement doit respecter la bande de tolérance déclarée par le fabricant pour 2,5 fois la valeur du courant de réglage d'un seul pôle.

9.3.7 Séquence d'essai IV: Courant assigné de courte durée admissible

9.3.7.1 Généralités

Sauf lorsque la séquence d'essai VI (combinée) s'applique (voir 9.3.9), cette séquence d'essai s'applique aux disjoncteurs à courant assigné de courte durée admissible (voir 5.4); elle comprend les essais indiqués dans le Tableau 21.

Tableau 21 – Essais de la séquence d'essai IV

Essai	Paragraphe
Vérification des déclencheurs de surcharge	9.3.7.2
Courant assigné de courte durée admissible	9.3.7.3
Vérification de l'échauffement	9.3.7.4
Pouvoir de coupure en court-circuit au courant maximal de courte durée admissible	9.3.7.5
Vérification de la tenue diélectrique et du courant de fuite	9.3.7.6
Vérification des déclencheurs de surcharge	9.3.7.7

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Les disjoncteurs à fusibles incorporés de catégorie de sélectivité B doivent satisfaire aux exigences de cette séquence.

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

9.3.7.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2.

9.3.7.3 Essai du courant assigné de courte durée admissible

Le 9.3.4.3 de l'IEC 60947-1:2020 s'applique, avec l'ajout suivant:

Pour les besoins de cet essai seulement, tout déclencheur à maximum de courant, y compris la commande instantanée, le cas échéant, susceptible de fonctionner au cours de l'essai, doit être rendu inopérant.

9.3.7.4 Vérification de l'échauffement

Après l'essai selon le 9.3.7.3, l'échauffement aux bornes principales doit être vérifié conformément au 9.3.3.5. L'échauffement ne doit pas dépasser la valeur indiquée dans le Tableau 6.

Avec l'accord du fabricant, la vérification de l'échauffement peut être réalisée après la vérification de la tenue diélectrique (9.3.7.6). Il n'est pas nécessaire de réaliser cette vérification lorsque, pour une taille donnée, l'essai du 9.3.8.3 a été effectué sur un disjoncteur avec un I_n minimal ou avec le réglage minimal du déclencheur de surcharge.

9.3.7.5 Essai de pouvoir de coupure en court-circuit au courant maximal de courte durée admissible

Après l'essai selon le 9.3.7.4, un essai en court-circuit doit être effectué avec la séquence de manœuvres suivante:

O – *t* – CO

dans les conditions générales du 9.3.3, avec un courant présumé de valeur égale à celle de l'essai de tenue au courant de courte durée admissible (voir 9.3.7.3) 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 à retard 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 3.6), cette exigence ne s'applique pas à la manœuvre CO si le courant présumé dépasse la valeur prédéterminée, puisqu'alors il fonctionne; cette exception est également applicable à l'essai sur le quatrième pôle et le pôle adjacent, conformément au 9.3.3.6.4.3.

9.3.7.6 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.7.5, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6.

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9.3.7.7 Vérification des déclencheurs de surcharge

Après l'essai selon le 9.3.7.6, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2, excepté que la valeur du courant d'essai doit être égale à 2,5 fois celle de leur courant de réglage, et que l'essai des unités de déclenchement électroniques est exigé.

Pour les déclencheurs à maximum de courant électromagnétiques, le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage d'un seul pôle à la température de référence.

Pour les déclencheurs à maximum de courant électroniques, le temps de fonctionnement doit respecter la bande de tolérance déclarée par le fabricant pour 2,5 fois la valeur du courant de réglage d'un seul pôle.

9.3.8 Séquence d'essai V: Fonctionnement des disjoncteurs à fusibles incorporés

9.3.8.1 Généralités

Cette séquence d'essai s'applique aux disjoncteurs à fusibles incorporés. Elle remplace la séquence d'essai III et comprend les essais indiqués dans le Tableau 22.

Tableau 22 – Essais de la séquence d'essai V

	Essai	Paragraphe
Phase 1	Court-circuit au courant limite de sélectivité	9.3.8.2
	Vérification de l'échauffement	9.3.8.3
	Vérification de la tenue diélectrique et du courant de fuite	9.3.8.4
Phase 2	Vérification des déclencheurs de surcharge	9.3.8.5
	Court-circuit à 1,1 fois le courant d'intersection	9.3.8.6
	Court-circuit au pouvoir de coupure ultime en court-circuit	9.3.8.7
	Vérification de la tenue diélectrique et du courant de fuite	9.3.8.8
	Vérification des déclencheurs de surcharge	9.3.8.9

Cette séquence d'essai est divisée en deux phases:

– la phase 1 comprend les essais du 9.3.8.2 au 9.3.8.4;
– la phase 2 comprend les essais du 9.3.8.5 au 9.3.8.9.

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 du 9.3.8.4 peut être omis.

Il n'est nécessaire d'effectuer l'essai selon le 9.3.8.3 que si $I_{cs} > I_s$.

Les essais selon les 9.3.8.2, 9.3.8.6 et 9.3.8.7 doivent être effectués à la tension maximale d'emploi du disjoncteur.

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

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9.3.8.2 Court-circuit au courant limite de sélectivité

Un essai de court-circuit est effectué dans les conditions générales du 9.3.3, avec un courant présumé de valeur égale à celle du courant limite de sélectivité déclarée par le fabricant.

Pour cet essai, les fusibles doivent être en place.

Cet essai doit consister en une manœuvre O à l'issue de laquelle les fusibles doivent demeurer intacts.

9.3.8.3 Vérification de l'échauffement

NOTE Cette vérification de l'échauffement est effectuée dans la mesure où les fusibles peuvent avoir fondu au cours de l'essai de court-circuit de la séquence d'essai II (9.3.5.2), auquel cas l'essai du 9.3.8.2 est plus sévère.

Après l'essai selon le 9.3.8.2, l'échauffement aux bornes principales doit être vérifié conformément au 9.3.3.5.

L'échauffement ne doit pas dépasser la valeur indiquée dans le Tableau 6.

9.3.8.4 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.8.3, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6.

9.3.8.5 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2.

9.3.8.6 Court-circuit à 1,1 fois le courant d'intersection

Après l'essai selon le 9.3.8.5, un essai de court-circuit est effectué dans les mêmes conditions générales que celles du 9.3.8.2, avec un courant présumé de valeur égale à 1,1 fois celle du courant d'intersection déclarée par le fabricant.

Pour cet essai, les fusibles doivent être en place.

Cet essai doit consister en une manœuvre "O" à l'issue de laquelle:

– au moins trois des fusibles dans le cas d'un disjoncteur tétrapolaire;
– au moins deux des fusibles dans le cas d'un disjoncteur tripolaire;
– au moins un des fusibles dans le cas d'un disjoncteur bipolaire;
– le fusible dans le cas d'un disjoncteur unipolaire;

doivent avoir fondu.

9.3.8.7 Court-circuit au pouvoir assigné de coupure ultime en court-circuit

Après l'essai selon le 9.3.8.6, un essai de court-circuit est effectué dans les mêmes conditions générales que celles du 9.3.8.2, 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

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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.

9.3.8.8 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.8.7 et la mise en place d'un nouveau jeu de fusibles, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6, excepté que le courant de fuite ne doit pas dépasser 6 mA.

9.3.8.9 Vérification des déclencheurs de surcharge

Après l'essai selon le 9.3.8.8, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2, excepté que la valeur du courant d'essai doit être égale à 2,5 fois celle de leur courant de réglage, et que l'essai des unités de déclenchement électronique est exigé.

Pour les déclencheurs à maximum de courant électromagnétiques, le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage d'un seul pôle à la température de référence.

Pour les déclencheurs à maximum de courant électroniques, le temps de fonctionnement doit respecter la bande de tolérance déclarée par le fabricant pour 2,5 fois la valeur du courant de réglage d'un seul pôle.

9.3.9 Séquence d'essai VI: Séquence d'essai combinée

9.3.9.1 Généralités

Cette séquence d'essai peut être appliquée aux disjoncteurs de catégorie de sélectivité B:

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;

   ou

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 du Tableau 23.

Tableau 23 – Essais de la séquence d'essai I

Essai	Paragraphe
Vérification des déclencheurs de surcharge	9.3.9.2
Courant assigné de courte durée admissible	9.3.9.3
Pouvoir assigné de coupure de service en court-circuit*	9.3.9.4
Vérification de l'aptitude au fonctionnement en service	9.3.9.5
Vérification de la tenue diélectrique et du courant de fuite	9.3.9.6
Vérification de l'échauffement	9.3.9.7
Vérification des déclencheurs de surcharge	9.3.9.8
* Pour les disjoncteurs qui correspondent au cas du 9.3.9.1 b) ci-dessus, il s'agit également du pouvoir assigné de coupure ultime en court-circuit.	

Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15.

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9.3.9.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2.

9.3.9.3 Essai du courant assigné de courte durée admissible

Après l'essai selon le 9.3.9.2, un essai doit être effectué au courant assigné de courte durée admissible conformément au 9.3.7.3.

Il n'est pas nécessaire d'effectuer cet essai sur l'échantillon avec un I_n minimal spécifié dans le Tableau 15.

9.3.9.4 Essai du pouvoir assigné de coupure de service en court-circuit

Après l'essai selon le 9.3.9.3, un essai doit être effectué au pouvoir assigné de coupure de service en court-circuit, conformément au 9.3.5.2, à la tension la plus élevée applicable au courant assigné de court-circuit admissible. Le disjoncteur doit rester fermé pendant la courte durée qui correspond à la durée maximale de réglage possible du déclencheur de court-circuit à retard 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 pendant les manœuvres de refermeture uniquement.

9.3.9.5 Vérification de l'aptitude au fonctionnement en service

Après l'essai selon le 9.3.9.4, l'aptitude au fonctionnement en service doit être vérifiée conformément au 9.3.5.3.

9.3.9.6 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.9.5, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6.

9.3.9.7 Vérification de l'échauffement

Après l'essai selon le 9.3.9.6, l'échauffement aux bornes principales doit être vérifié conformément au 9.3.5.5.

L'échauffement ne doit pas dépasser la valeur indiquée dans le Tableau 6.

Il n'est pas nécessaire de réaliser cette vérification lorsque, pour une taille donnée, l'essai du 9.3.9.4 a été effectué sur un disjoncteur avec un I_n minimal ou avec le réglage minimal du déclencheur de surcharge.

9.3.9.8 Vérification des déclencheurs de surcharge

Après refroidissement à la suite de l'essai du 9.3.9.7, le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.4.8.

Le fonctionnement des déclencheurs de surcharge doit ensuite être vérifié sur chaque pôle individuellement selon le 9.3.6.2, excepté que le courant d'essai doit être égal à 2,5 fois la valeur de leur courant de réglage et que l'essai des unités de déclenchement électronique est exigé.

Pour les déclencheurs à maximum de courant électromagnétiques, le temps de fonctionnement ne doit pas dépasser la valeur maximale déclarée par le fabricant pour deux fois la valeur du courant de réglage d'un seul pôle à la température de référence.

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Pour les déclencheurs à maximum de courant électroniques, le temps de fonctionnement doit respecter la bande de tolérance déclarée par le fabricant pour 2,5 fois la valeur du courant de réglage d'un seul pôle.

9.3.10 Séquence d'essai VII: Courant continu critique de charge

Cet essai s'applique uniquement aux disjoncteurs qui ont des valeurs assignées en courant continu.

NOTE Une procédure commune pour la détermination du courant continu critique de charge est en cours de révision en vue de son intégration dans l'IEC 60947-1.

L'état et le mode d'installation du disjoncteur doivent être ceux spécifiés en 9.3.3.1, et le circuit d'essai doit être conforme au 9.3.3.5.2 de l'IEC 60947-1:2020, excepté que l'écran métallique et l'élément fusible ne doivent pas être utilisés.

Les échantillons à soumettre à l'essai doivent être choisis conformément au Tableau 15 – séquence d'essai 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 équipés 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, indiqué par la polarité et le marquage amont/aval. Dans le cas contraire, 5 manœuvres doivent être effectuées dans le sens direct et 5 manœuvres 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, mais sans dépasser 2 s.

La constante de temps doit être conforme à la valeur indiquée dans le Tableau 16 pour le fonctionnement en service. À 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 correspondre à celui spécifié dans le Tableau 7.

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 prenant en compte 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 au présent paragraphe n'est exigé.

Les tolérances applicables aux grandeurs d'essai autres que celles du courant doivent être conformes au 9.3.3.2.2.

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À 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 qui correspondent à la valeur critique.

Après cet essai, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6 avec une tension d'essai continue.

9.3.11 Séquence d'essai VIII: pouvoir assigné de coupure ultime en court-circuit sur un pôle séparément à la tension phase-neutre alternative

9.3.11.1 Généralités

Un disjoncteur doit être capable d'interrompre un défaut à la terre. Dans ce cas, le courant de court-circuit doit être coupé par un seul pôle de phase, à la tension phase-neutre.

Pour:

– les disjoncteurs unipolaires;
– les disjoncteurs tripolaires et tétrapolaires dont tous les pôles de phase sont de conception identique;
– les disjoncteurs bipolaires dont les pôles sont de conception identique à celle d'un disjoncteur tripolaire ou quadripolaire conforme au présent document;

le fonctionnement est traité en 9.3.6 et aucun essai supplémentaire n'est exigé. Dans ces cas, I_{cu1} est considéré comme égal à I_{cu}.

Les essais du 9.3.11.2 au 9.3.11.5 s'appliquent aux disjoncteurs bipolaires dont les pôles ne sont pas de conception identique à celle d'un disjoncteur tripolaire ou tétrapolaire conforme au présent document, ainsi qu'aux disjoncteurs tripolaires ou tétrapolaires dont les pôles de phase ne sont pas de conception identique.

Cette séquence d'essai comprend les essais du Tableau 24.

Tableau 24 – Essais de la séquence d'essai VIII

Essai	Paragraphe
Vérification des déclencheurs de surcharge	9.3.11.2
Pouvoir assigné de coupure ultime en court-circuit à la tension phase-neutre alternative	9.3.11.3
Vérification de la tenue diélectrique et du courant de fuite	9.3.11.4
Vérification des déclencheurs de surcharge	9.3.11.5

9.3.11.2 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.2.

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9.3.11.3 Pouvoir assigné de coupure ultime en court-circuit à la tension phase-neutre alternative

Un essai de court-circuit est effectué sur chaque pôle de phase individuel du disjoncteur dans les conditions générales du 9.3.3, à une valeur de courant égale à I_{cu1}. Le nombre d'échantillons à soumettre à l'essai et le réglage des déclencheurs réglables doivent être conformes au Tableau 15. La ou les tensions d'essai doivent être égales à la tension phase-neutre correspondante de la ou des tensions d'essai énumérées dans le Tableau 15, lesquelles correspondent à la tension assignée d'emploi maximale du disjoncteur, en tenant compte des exigences pour la tension de rétablissement du 9.3.3.2.6. Le facteur de puissance adapté au courant d'essai doit être conforme au Tableau 16. Le seuil de déclenchement à retard de courte durée ou instantané doit être réglé sur sa valeur maximale.

Le circuit d'essai doit être conforme au 9.3.4.1.2 et à la Figure 9 de l'IEC 60947-1:2020.

La séquence de manœuvres doit être: O – *t* – CO.

9.3.11.4 Vérification de la tenue diélectrique et du courant de fuite

Après l'essai selon le 9.3.11.3, la tenue diélectrique et le courant de fuite doivent être vérifiés conformément au 9.3.4.6, excepté que le courant de fuite ne doit pas dépasser 6 mA.

9.3.11.5 Vérification des déclencheurs de surcharge

Le fonctionnement des déclencheurs de surcharge doit être vérifié conformément au 9.3.6.5.

9.4 Essais individuels de série

9.4.1 Généralités

Pour la définition des essais individuels de série, voir les 3.8.2 et 9.1.3 de l'IEC 60947-1:2020.

Les essais suivants s'appliquent:

– fonctionnement mécanique (9.4.2);
– vérification de l'étalonnage des déclencheurs à maximum de courant (9.4.3);
– vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt (9.4.4);
– essais supplémentaires pour les DPR selon l'Annexe B (9.4.5);
– essais diélectriques (voir note) (9.4.6);
– vérification des distances d'isolement (9.4.7).

NOTE Si l'intégrité des propriétés diélectriques a été démontrée par le contrôle des matériaux et des procédés de fabrication, ces essais peuvent être remplacés par des essais sur prélèvement selon le plan d'échantillonnage reconnu (voir l'ISO 2859-1).

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, tant que les mêmes conditions sont applicables et que le nombre de manœuvres n'est pas inférieur à celui spécifié.

Les essais du 9.4.3, du 9.4.4 et du 9.4.5 doivent être effectués avec les déclencheurs montés sur le disjoncteur ou sur un matériel d'essai approprié qui simule le comportement du disjoncteur.

Dans le contexte des essais du 9.4.2, du 9.4.3, du 9.4.4, du 9.4.6 et du 9.4.7, le terme "disjoncteurs" englobe les DPR, le cas échéant.

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9.4.2 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 le 3.6.24 de l'IEC 60947-1:2020.

Les essais suivants doivent être effectués sur les disjoncteurs alimentés à 110 % de la tension assignée maximale d'alimentation du circuit de commande et/ou de la pression d'alimentation assignée et à 85 % de la tension assignée minimale d'alimentation du circuit 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.

9.4.3 Vérification de l'étalonnage des déclencheurs à maximum de courant

9.4.3.1 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 réalisée à toute température convenable, en apportant une correction pour toute différence de température par rapport à la température de référence (voir 5.7.3).

9.4.3.2 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 indiquées en 9.3.4.2.2 ou en 9.3.4.2.3, point a), selon 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 qui augmente lentement à partir d'une valeur au-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.

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9.4.4 Vérification du fonctionnement des déclencheurs à minimum de tension et des déclencheurs shunt

9.4.4.1 Déclencheurs à minimum de tension

Les essais suivants doivent être effectués pour vérifier que le déclencheur fonctionne conformément au 8.2.1.3 de l'IEC 60947-1:2020:

a) Tension de maintien

Le déclencheur doit entraîner la fermeture à une tension qui correspond à 85 % de la tension assignée minimale d'alimentation du circuit de commande.

b) Tension de retombée

Le déclencheur doit entraîner l'ouverture lorsque la tension est réduite à une valeur comprise dans la plage qui correspond aux limites de 70 % et 35 % de la tension assignée d'alimentation du circuit de commande, réglée afin de tenir compte de la nécessité de fonctionner dans les conditions spécifiées en 9.3.4.4.2.3 i). Dans le cas de déclencheurs qui ont une plage de tensions assignées d'alimentation du circuit de commande, la limite supérieure doit correspondre à la valeur minimale de la plage et la limite inférieure à la valeur maximale de la plage.

9.4.4.2 Déclencheurs shunt (pour l'ouverture)

Un essai doit être effectué pour vérifier que le déclencheur fonctionne conformément au 8.2.1.4 de l'IEC 60947-1:2020. L'essai peut être effectué à toute température convenable, à condition que la tension d'essai soit réduite afin de tenir compte de la nécessité pour le déclencheur de fonctionner dans les conditions spécifiées en 9.3.4.4.2.4. Dans le cas d'un déclencheur avec une plage de tensions assignées d'alimentation du circuit de commande, la tension d'essai doit correspondre à 70 % de la tension assignée minimale d'alimentation du circuit de commande.

9.4.5 Essais supplémentaires pour les DPR

Les essais supplémentaires suivants doivent être effectués sur les DPR ou les unités CR.

a) Fonctionnement de l'appareil d'essai

Le DPR doit être soumis à deux manœuvres de fermeture-déclenchement ou, dans le cas d'unités CR, 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 d'emploi la plus basse.

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 se déclenche pas avec un courant résiduel égal à 0,5 fois $I_{\Delta n}$ dans chaque pôle, au réglage minimal de $I_{\Delta n}$ s'il est réglable;
- le DPR se 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.

9.4.6 Essais diélectriques

Les conditions d'essai doivent être conformes au 9.3.3.4.1, point 1) de l'IEC 60947-1:2020, excepté que l'utilisation d'une feuille métallique n'est pas exigée. 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 qui ne comportent pas de circuits électroniques reliés aux pôles principaux, le disjoncteur étant en position de fermeture, entre chaque pôle et le ou les pôles adjacents et entre chaque pôle et le cadre, le cas échéant;

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– pour les disjoncteurs qui comportent des circuits électroniques reliés aux pôles principaux, le disjoncteur étant 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 admise, 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 spécifiée en a), b) ou c) ci-dessous, à la discrétion du fabricant.

a) Deux essais doivent être effectués:

   1) tension de tenue aux chocs

      La tension d'essai ne doit pas être inférieure à 30 % de la tension assignée de tenue aux chocs (sans facteur de correction d'altitude) ou à la valeur de crête qui correspond à 2 U_i si celle-ci est plus élevée; et

   2) tension de tenue à fréquence industrielle ou en courant continu

      L'appareillage d'essai doit être celui indiqué en 9.3.3.4.1, point 3) b) de l'IEC 60947-1:2020, excepté que la surintensité de déclenchement doit être réglée à 25 mA. Toutefois, le fabricant peut, pour des raisons de sécurité, utiliser un appareillage d'essai de puissance inférieure ou avec un réglage de déclenchement plus bas, mais le courant de court-circuit de l'appareillage d'essai doit être au moins égal à huit fois le réglage de déclenchement du relais à maximum de courant. Par exemple, pour un transformateur avec un courant de court-circuit de 40 mA, le réglage de déclenchement maximal du relais à maximum de courant doit être 5 mA ± 1 mA.

      La valeur de la tension d'essai doit être 2 U_e max, avec un minimum de 1 000 V en valeur efficace ou de 1 415 V en courant continu, appliquée pendant au moins 1 s. Le relais de surintensité ne doit pas se déclencher.

b) Un seul essai à fréquence industrielle ou en courant continu conformément au point a) 2) ci-dessus. Pour les essais en courant alternatif, la tension d'essai doit être telle que la valeur de crête de l'onde sinusoïdale corresponde à la valeur de crête la plus élevée parmi les valeurs suivantes: 30 % de U_{imp}, 2 U_i ou 1 000 V en valeur efficace. Pour les essais en courant continu, la tension d'essai doit être égale à la valeur la plus élevée parmi les valeurs suivantes: 30 % de U_{imp}, 2 U_i ou 1 415 V en courant continu.

c) Un essai de résistance d'isolement à 500 V en courant continu. La résistance d'isolement doit être d'au moins 1 MΩ en tout point.

Pour les essais a) 2) et b), les exigences suivantes s'appliquent:

– les disjoncteurs à courant alternatif doivent être soumis à l'essai avec la tension à fréquence industrielle. En variante, ils peuvent être soumis à l'essai avec une tension continue égale à la valeur de crête de la tension d'essai alternative;

– les disjoncteurs à courant continu doivent être soumis à l'essai avec la tension continue. En variante, ils peuvent être soumis à l'essai avec une tension alternative dont la valeur efficace doit être égale à la valeur de la tension d'essai continue.

Si les propriétés diélectriques sont vérifiées conformément à un plan d'échantillonnage selon la note du 9.4.1, un essai de tenue à fréquence industrielle doit être effectué conformément au 9.4.6, point a) 2) du présent paragraphe, mais avec une tension d'essai conforme au Tableau 19 de l'IEC 60947-1:2020. Les disjoncteurs qui ont une tension d'isolement assignée supérieure à 1 000 V en courant alternatif doivent être soumis à l'essai à une tension de U_i + 1 200 V en courant alternatif (valeur efficace) ou de 2 U_i si cette valeur est plus élevée.

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9.4.7 Essai pour la vérification des distances d'isolement inférieures à celles qui correspondent au Tableau 13, cas A de l'IEC 60947-1:2020

Le 9.3.3.4.3 de l'IEC 60947-1:2020 s'applique, excepté que pour les besoins du présent document, 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 60947-1:2020 est couvert par les essais du 9.4.6.

9.5 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 3.8.4 de l'IEC 60947-1:2020). 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 de ces essais pour être conforme au présent document.

L'Annexe Q de l'IEC 60947-1:2020 s'applique.

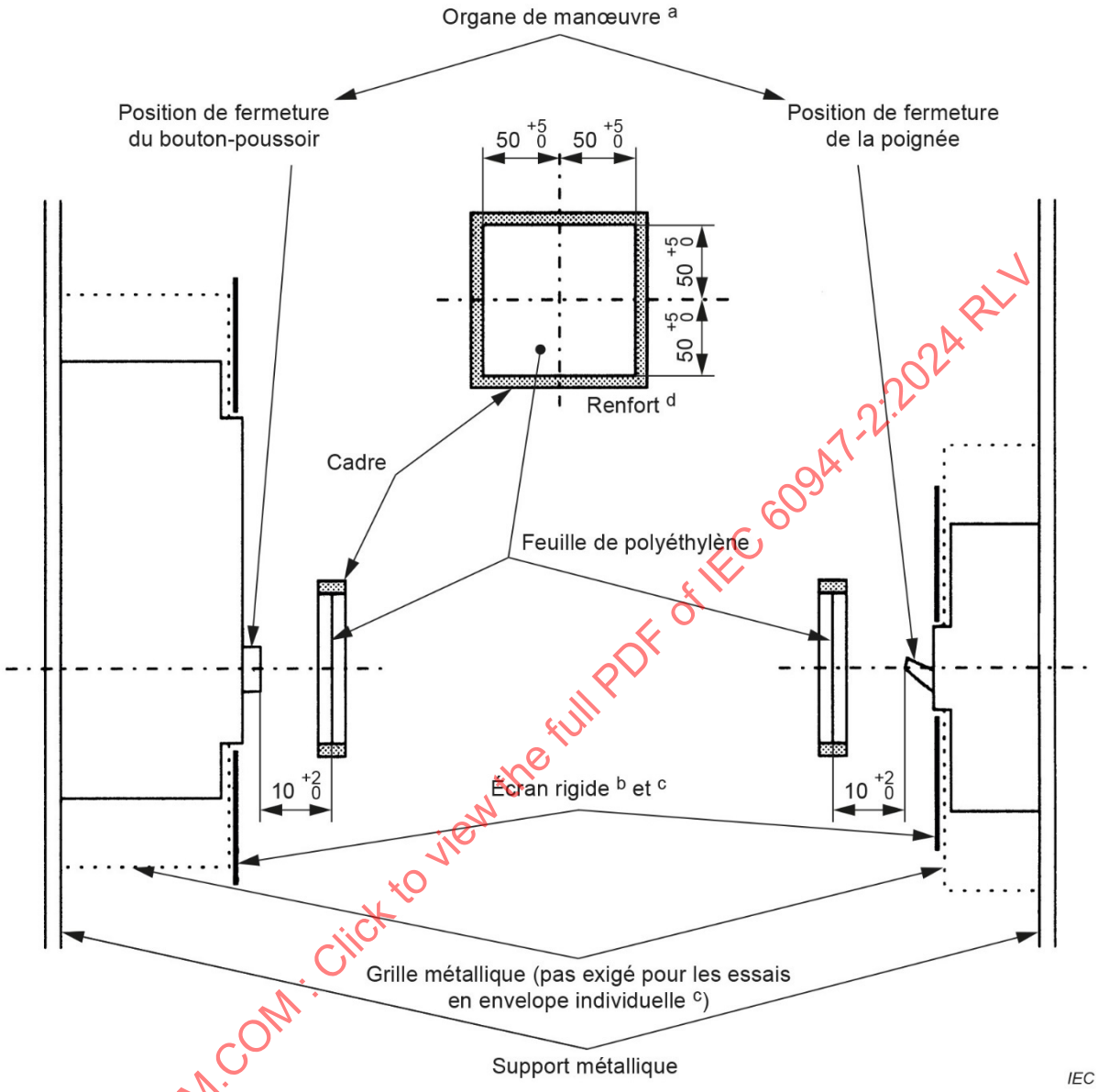
Au cours des séquences d'essai réalisées selon le Tableau Q.1 de l'IEC 60947-1:2020, seule la vérification finale de l'aptitude au fonctionnement en service est exigée. Elle doit être effectuée en réalisant les essais individuels de série du 9.4, à l'exception des essais diélectriques du 9.4.6, lesquels sont couverts par les essais du Tableau Q.1 de l'IEC 60947-1:2020.

En référence à la note e) du Tableau Q.1 de l'IEC 60947-1:2020 concernant l'essai de chaleur sèche, le disjoncteur ne doit pas être parcouru par le courant. Lorsqu'un déclencheur à minimum de tension est installé, il doit être alimenté sous sa tension assignée. Le disjoncteur doit être manœuvré conformément au 9.4.2 pendant la dernière heure de l'essai.

En référence à la note g) du Tableau Q.1 de l'IEC 60947-1:2020, pendant l'essai de chaleur humide, l'essai fonctionnel doit comprendre les manœuvres mécaniques du 9.4.2 du présent document. 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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Dimensions en millimètres



Cas d'un disjoncteur avec bouton-poussoir de fermeture

Cas d'un disjoncteur avec poignée de fermeture

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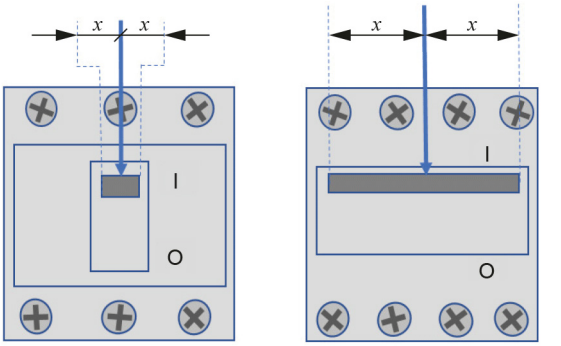
[a] L'organe de manœuvre comprend toute extension normalement utilisée pour la manœuvre de fermeture.

[b] L'écran rigide a pour objet 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).

[c] L'écran rigide et la façade de l'écran métallique peuvent être combinés en une seule plaque métallique conductrice.

[d] 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



Pour l'application de la force d'essai, voir le 9.2.6.2.1 de l'IEC 60947-1:2020.

Pour le premier critère (organe de commande étant laissé libre), voir le 9.2.6.3.1 de l'IEC 60947-1:2020.

Figure 2 – Exemples d'applications de la force d'essai pour la vérification de l'efficacité de l'indication de la position des contacts principaux (premier critère, organe de commande étant laissé libre)

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Annexe A
(normative)

Coordination entre un disjoncteur et un autre dispositif de protection contre les courts-circuits associés dans le même circuit

A.1 Généralités

L'Article X.1 de l'IEC 60947-1:2020 s'applique, avec la modification suivante:

Sur la Figure X.1 de l'IEC 60947-1:2020, "I_{cn}" est remplacée par "I_{cu}" (voir 5.3.6.2.2).

A.2 Objet

L'Article X.2 de l'IEC 60947-1:2020 s'applique.

A.3 Exigences générales de coordination d'un disjoncteur avec un autre DPCC

L'Article X.3 de l'IEC 60947-1:2020 s'applique, avec l'ajout suivant:

L'association doit également se conformer aux informations exigées au 2e alinéa du 8.2.1.2.4, point a).

A.4 Type et caractéristiques du DPCC associé

L'Article X.4 de l'IEC 60947-1:2020 s'applique.

A.5 Vérification de la sélectivité

L'Article X.5 de l'IEC 60947-1:2020 s'applique, avec la modification suivante:

Sur la Figure X.1 de l'IEC 60947-1:2020, "I_{cn}" est remplacé par "I_{cu}" (pouvoir assigné de coupure ultime en court-circuit, voir 5.3.6.2.2).

A.6 Vérification de la protection d'accompagnement

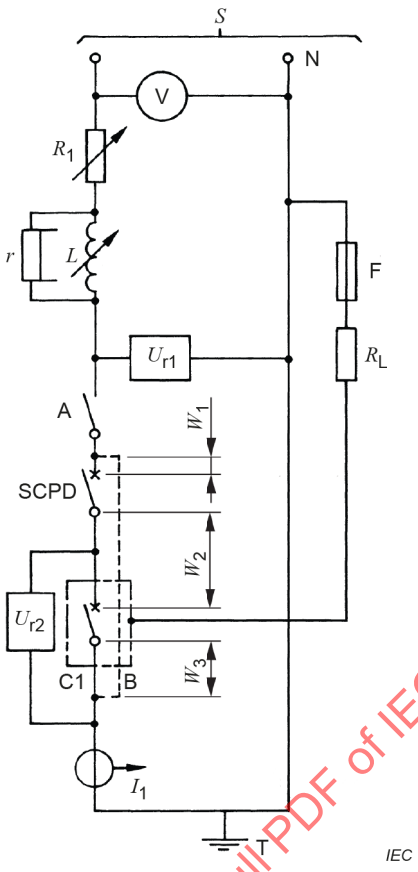
L'Article X.6 de l'IEC 60947-1:2020 s'applique, avec les ajouts suivants:

Après les essais, si C1 est un disjoncteur, il doit être conforme au 9.3.6.4 et au 9.3.6.5.

Pour la vérification du pouvoir de coupure sur un pôle séparément à la tension phase-neutre alternative (I_{cu1}, voir 9.3.11), la Figure A.1 s'applique.

NOTE La "protection d'accompagnement" est définie en 535.5 de l'IEC 60364-5-53:2019 en tant que "protection combinée contre les courts-circuits".

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Légende

S	alimentation
U_{r1}, U_{r2}	capteurs de tension
V	appareil de mesure de tension
A	appareil de fermeture
R_1	résistance variable
N	neutre de la source (ou neutre artificiel)
F	élément fusible (9.3.4.1.2, point d) de l'IEC 60947-1:2020)
L	inductances réglables
R_L	résistance de limitation du courant de défaut
B	connexions provisoires d'étalonnage
I_1	capteur de courant
T	terre: un seul point de mise à la terre (côté charge ou côté source)
r	résistance shunt (9.3.4.1.2, point b) de l'IEC 60947-1:2020)
W_1	75 cm de câble de courant assigné pour le DPCC
W_2	50 cm de câble de courant assigné pour C1
W_3	25 cm de câble de courant assigné pour C1
SCPD	disjoncteur C2 ou jeu de 3 fusibles
C1	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 de fermeture A se trouvant du côté basse tension.

Figure A.1 – Connexions câblées pour les essais de pouvoir de coupure en court-circuit conditionnel dans le cas d'un seul pôle sous tension phase-neutre alternative (C1)

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Annexe B
(normative)

Disjoncteurs à protection incorporée par courant différentiel résiduel (DPR)

B.1 Généralités

B.1.1 Préambule

Pour procurer la protection contre les dangers occasionnés par les chocs électriques, des appareils qui agissent 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, à savoir:

– procurer la protection des installations contre les surcharges et contre les courants de court-circuit;

– procurer la protection en cas de défaut, c'est-à-dire d'augmentations dangereuses du potentiel à la terre dues à une isolation défectueuse.

NOTE 1 Dans l'IEC 61140, la "protection en cas de défaut" était auparavant désignée par le terme "protection des personnes contre les contacts indirects".

Les appareils à courant différentiel résiduel peuvent également procurer 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 qui ne peut pas être détecté par le dispositif 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 dispositifs de protection principale supplémentaires en cas de défaillance des dispositifs de protection prévus.

NOTE 2 Dans l'IEC 61140, la "protection principale" était auparavant désignée par le terme "protection des personnes contre les contacts directs".

Les exigences pour l'installation de tels appareils sont spécifiées dans les différentes parties 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 qui peuvent 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 Objet

La présente annexe s'applique aux disjoncteurs qui assurent la protection par courant différentiel résiduel (DPR). Elle contient les exigences pour les appareils qui à la fois assurent la détection des courants différentiels résiduels, comparent ces mesures à une valeur réglée au préalable et provoquent la coupure du circuit protégé lorsque cette valeur est dépassée.

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La présente annexe s'applique:

– 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 qui combinent un appareil à courant différentiel résiduel (désignés ci-après unités CR) 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.

NOTE 1 Les unités CR n'ont aucun effet négatif sur le fonctionnement du disjoncteur, comme cela est vérifié par les essais de fonctionnement selon l'Article 9.

NOTE 2 Les organes de détection du courant peuvent être extérieurs au DPR.

La présente annexe couvre les DPR du type AC, du type A et du type B (voir B.4.4).

La présente annexe ne s'applique qu'aux DPR destinés à être utilisés dans des circuits à courant alternatif.

NOTE 3 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 de courant différentiel résiduel des DPR visés par la présente annexe peut ou non dépendre fonctionnellement de la tension d'alimentation. Les DPR qui dépendent d'une autre source d'alimentation ne sont pas couverts par la présente annexe.

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 des 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, y compris les essais de compatibilité électromagnétique;
d) les informations correspondantes sur le matériel.

B.2 Termes et définitions

En complément de l'Article 3 du présent document, les termes et définitions suivants s'appliquent.

B.2.1 Termes et définitions relatifs aux courants qui circulent 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 à la terre, en l'absence de tout défaut d'isolement

[SOURCE: IEC 60050-442:1998, 442-01-24]

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B.2.2 Termes et définitions relatifs 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 impliquer, par exemple, l'alimentation de certains organes auxiliaires.

[SOURCE: IEC 60050-442:1998, 442-05-58, modifié – 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 60050-442:2019, 442-05-19, modifié – 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 60050-442:2019, 442-05-20, modifié – 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 60050-442:2019, 442-05-21, modifié – 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 3.1) 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

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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 qui consiste 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 60050-442:2019, 442-05-24]

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 60050-442:2019, 442-05-25, modifié – Dans le terme, "(d'un courant différentiel)" 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 ouverte, interrompant ainsi le ou les courants qui les traversent

[SOURCE: IEC 60050-442:2019, 442-05-26, modifié – 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
durée maximale pendant laquelle on peut appliquer au DPR un courant différentiel supérieure à la valeur assignée du courant différentiel de non-fonctionnement, sans provoquer son fonctionnement effectif

[SOURCE: IEC 60050-442:2019, 442-05-23, modifié – 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

[SOURCE: IEC 60050-442:2019, 442-05-05, modifié – Dans le terme et la définition, "dispositif différentiel résiduel" a été remplacé par "DPR".]

B.2.3.9
DPR à réarmement
DPR équipé d'une unité CR 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

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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.

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 qui apparaît lors d'une défaillance de la tension d'alimentation.

NOTE Les cas indiqués dans le présent 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 fixes;
– 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 fixes;

– par variation continue.

B.3.4 Classification selon le comportement en présence d'une composante continue

B.3.4.1 DPR du type AC (voir B.4.4.1)

B.3.4.2 DPR du type A (voir B.4.4.2)

B.3.4.3 DPR du 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

Des valeurs plus élevées peuvent s'appliquer.

$I_{\Delta n}$ peut s'exprimer en pourcentage du courant assigné.

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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 au 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 indiquée 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 issues de l'IEC 60479-1 et sont valides pour une fréquence de 50 Hz et de 60 Hz.				
[a] Pour les DPR avec $I_{\Delta n}$ ≤ 30 mA, 0,25 A peut être utilisé à la place de 5 $I_{\Delta n}$.				
[b] Pour les DPR avec $I_{\Delta n}$ ≤ 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 s'appliquer (voir B.8.7 et B.8.8).				

Les DPR avec $I_{\Delta n}$ ≤ 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 de 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 indiquées 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 avec 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 issues 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 s'appliquer (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 $I_{\Delta m}$ correspond à 25 % de I_{cu}.

Des valeurs supérieures peuvent être soumises à l'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 à 10 mA, si cette valeur est 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 à 10 mA, si cette valeur est 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 cela est spécifié en 6.2 et, en outre, conformément au Tableau B.3.

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Tableau B.3 – Informations sur le matériel

Point	Information	Emplacement du marquage	
		DPR intégré	Unité CR
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 du type AC avec le symbole  (IEC 60417-6148:2012-01) – pour les DPR du type A avec le symbole  (IEC 60417-6149:2012-01) – pour les DPR du 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 [a]	Marqué [a]
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 [a]	Marqué [a]
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 ≤ ...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 commerciale	-	Marqué
B2.8	désignation du type ou référence du catalogue	-	Marqué
B2.9	identification du ou des disjoncteurs avec lesquels l'unité CR peut être assemblée, sauf si un assemblage incorrect (qui rend 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 dépendants 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

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

[a] Voir 5.7.3.

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B.6 Conditions normales de service, de montage et de transport

L'Article 7 s'applique.

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 qui combinent une unité CR et un disjoncteur doivent être conçus et réalisés de sorte que:

– l'assemblage de l'unité CR et du disjoncteur associé n'exige aucune liaison mécanique et/ou électrique qui peut affecter défavorablement l'installation ou qui présente des risques pour l'utilisateur;
– l'adjonction de l'unité CR ne compromette en aucune manière le fonctionnement normal ou les performances du disjoncteur;
– l'unité CR ne soit 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, indépendamment du déphasage du courant par rapport à la tension d'alimentation.

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 du B.8.11.

B.7.2.3 Aptitude au fonctionnement en service

Les DPR doivent satisfaire aux essais du B.8.1.2.1.

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 décrit en B.8.12.

B.7.2.5 Propriétés diélectriques

Les DPR doivent satisfaire aux essais du B.8.3.

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B.7.2.6 Appareil d'essai

Les DPR doivent être équipés d'un appareil d'essai qui permet à l'appareil de détection d'être traversé par un courant qui simule 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 décrits en B.8.4.

Le cas échéant, aucune tension ne doit apparaître sur le conducteur de protection lors du fonctionnement de l'appareil d'essai.

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 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.

B.7.2.7 Valeur de surintensité de non-fonctionnement dans le cas d'une charge monophasée

Les DPR doivent supporter sans se déclencher la plus faible des deux valeurs de surintensité suivantes:

– 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 du présent 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 couverts par les exigences du présent 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 la capacité du réseau

Les DPR doivent satisfaire à l'essai du B.8.6.2.

B.7.2.8.2 Résistance aux déclenchements intempestifs en cas d'amorçage sans courant de suite

Les DPR doivent satisfaire à l'essai du B.8.6.3.

B.7.2.9 Comportement des DPR du type A en cas de courant de défaut à la terre qui comprend une composante continue

Le comportement des DPR en cas de courant de défaut à la terre qui comprend une composante continue doit être tel que les durées maximales de coupure définies dans le Tableau B.1 et le

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Tableau B.2, selon le cas, doivent également être respectées, les valeurs du courant d'essai spécifiées étant cependant augmentées:

– du facteur 1,4 pour les DPR qui ont $I_{\Delta n}$ ≥ 0,030 A;

– du facteur 2 pour les DPR qui ont $I_{\Delta n}$ < 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, qui comprennent une composante de 10 Hz et une composante de 1 kHz, comme cela est défini dans le Tableau B.7.

Le courant différentiel résiduel de fonctionnement doit se situer dans les limites indiquées 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 l'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 inférieure ou égale à 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 continu lissé de valeur égale à 0,4 fois le courant différentiel résiduel assigné ($I_{\Delta n}$) ou à 10 mA, si cette valeur est plus élevée.

Pour les DPR du type B avec un courant différentiel résiduel assigné de 0,006 A ou de 0,01 A, la valeur de 3 mA ou de 5 mA, respectivement, doit être utilisée pour cet essai.

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 à 10 mA, si cette valeur est plus élevée.

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Le courant de déclenchement ne doit pas être supérieur à 1,4 $I_{\Delta n}$ pour les DPR avec $I_{\Delta n}$ > 0,03 A ou à 2 $I_{\Delta n}$ pour les DPR avec $I_{\Delta n}$ ≤ 0,03 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 qui peuvent 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 qui résultent 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 qui résultent 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 qui peuvent 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 qui résultent 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 qui résultent 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).

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 l'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 les DPR à réarmement (voir B.2.3.9) en position de fermeture après un déclenchement dû à un courant différentiel résiduel s'ils n'ont pas été réarmés.

La conformité est vérifiée pendant l'essai décrit en 9.3.4.4.4, conformément au B.8.1.2.1.

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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 le présent paragraphe à toutes les fréquences.

La conformité est vérifiée en effectuant les essais du B.8.2 et du B.8.4.

Selon leur classification, les DPR fonctionnellement dépendants de la tension d'alimentation doivent satisfaire aux exigences indiquées dans le Tableau B.4.

Tableau B.4 – Exigences relatives aux DPR fonctionnellement dépendants de la tension d'alimentation

Classification de l'appareil selon le B.3.1		Comportement en cas de défaillance de la tension d'alimentation
DPR qui s'ouvrent automatiquement en cas de défaillance de la tension d'alimentation (B.3.1.2.1)	Sans retard	Ouverture sans retard conformément au B.8.9.3, point a)
	Avec retard	Ouverture avec retard conformément au B.8.9.3, point b)
DPR qui ne s'ouvrent 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 le 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 du B.7.2.12.

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.

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Les essais spécifiés dans la présente annexe s'ajoutent aux essais de l'Article 9.

a) Essais de type

Les DPR doivent être soumis à toutes les séquences d'essai de l'Article 9 qui leur sont applicables. Pour les vérifications de la tenue diélectrique au cours de ces séquences d'essai (voir 9.3.4.6), 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 qui comprennent une unité CR 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 la valeur maximale.

Dans le cas des DPR à déclenchement instantané réglable, le déclencheur instantané doit, sauf indication contraire, être réglé à la valeur maximale.

b) Essais individuels de série

Le 9.4.5 s'applique.

B.8.1.2 Essais à réaliser au cours des séquences d'essai de l'Article 9

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 (9.3.4.2) doit être modifiée comme suit:

– pour la vérification des déclencheurs de court-circuit des déclencheurs à maximum de courant électroniques, le pôle en essai doit être soumis à l'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 l'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.

Au cours des cycles de manœuvres avec courant (voir 9.3.4.4.4) spécifiés dans le Tableau 7 (voir 8.2.4.2), 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), les manœuvres restantes étant soumises à l'essai conformément au 9.3.4.4.4.

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 effectuée au début et à la fin de l'essai d'aptitude au fonctionnement en service avec courant (9.3.4.4.4).

Aucun défaut de déclenchement ne doit être admis.

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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 9.3.5, la vérification du fonctionnement correct du DPR en cas de courant différentiel résiduel doit être effectuée conformément au 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 9.3.6.2 et en 9.3.6.5 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 9.3.6.2 et en 9.3.6.5, mais applicables à deux pôles.

Après les essais décrits en 9.3.6, la vérification du fonctionnement correct du DPR doit être effectuée conformément au 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 9.3.7.3 ou en 9.3.9.3, selon le cas.

b) Vérification des déclencheurs de surcharge

   – Pour la séquence d'essai IV

     Afin de vérifier le fonctionnement correct des déclencheurs de surcharge conformément au 9.3.7.2 et au 9.3.7.7, les essais sur un seul pôle spécifiés en 9.3.6.2 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 conformément au 9.3.9.2, l'essai sur un seul pôle spécifié en 9.3.6.2 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 conformément au 9.3.9.7, l'essai spécifié en 9.3.4.8 doit être réalisé en utilisant une alimentation triphasée.

c) Vérification de l'appareil de déclenchement au courant différentiel résiduel

   Après les essais du 9.3.7 ou du 9.3.9, selon le cas, la vérification de l'appareil de déclenchement au courant différentiel résiduel doit être effectuée conformément au B.8.2.4.4.

B.8.1.2.2.4 DPR à fusibles incorporés (séquence d'essai V)

Pour vérifier le fonctionnement correct des déclencheurs de surcharge, les essais sur un seul pôle spécifiés en 9.3.8.5 et en 9.3.8.9 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 9.3.8.5 et en 9.3.8.9, mais applicables à deux pôles.

Après les essais décrits en 9.3.8, la vérification du fonctionnement correct du DPR doit être effectuée conformément au B.8.2.4.4.

B.8.1.2.2.5 Séquence d'essai VI (combinée)

Après les essais décrits en 9.3.9, la vérification du fonctionnement correct du DPR doit être effectuée conformément au B.8.2.4.4.

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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 du type A et du type B	B.8.7
	Vérifications supplémentaires pour les DPR du type B	B.8.8
	Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon le B.3.1.2.1	B.8.9
	Vérification du comportement des DPR fonctionnellement dépendants de la tension d'alimentation, classés selon le 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 qui comportent 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 l'essai, aucun essai supplémentaire n'est exigé. Si la construction des variantes n'est pas identique à celle de la variante soumise à l'essai, ces variantes doivent alors être aussi soumises à l'essai.

Un échantillon doit être soumis à l'essai pour chacune des séquences d'essai B I, B II et B III.

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.

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 toute tension convenable.

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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 en 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 qui ont des fonctions non dépendantes de la tension d'alimentation, les essais relatifs à ces fonctions peuvent être réalisés sous toute tension convenable.

Les DPR qui ont plus d'une fréquence assignée ou une plage de fréquences assignées doivent être soumis à l'essai à la fréquence assignée la plus élevée et à la fréquence assignée la plus basse, dans chaque cas. Cependant, pour les DPR de 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 au cours desquels 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 le laboratoire d'essai, et doivent être indiqués dans le rapport d'essai.

B.8.2.4 Essais à vide à 20 °C ± 5 °C

B.8.2.4.1 Généralités

Les connexions étant celles représentées à la Figure B.1, le DPR doit être soumis aux essais du B.8.2.4.2, du B.8.2.4.3 et du B.8.2.4.4 ainsi qu'à celui du 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.

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 qui ne dépasse pas 0,2 $I_{\Delta n}$, de manière à 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.8.2.4.1), et 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 en B.4.2.4.2.2, selon le cas.

B.8.2.4.4 Vérification du fonctionnement correct en cas d'apparition subite d'un 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 en B.4.2.4.2.2, selon 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 se déclencher au cours de chaque essai.

Trois mesurages de la durée de coupure sont effectués à chaque valeur de I_{Δ}. Aucune valeur ne doit dépasser la valeur limite applicable.

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 au B.4.2.4.2.1.

Au cours de chacune des trois vérifications, le DPR ne doit pas se déclencher. Si le DPR permet d'ajuster le courant différentiel résiduel de fonctionnement et/ou la temporisation, l'essai doit être réalisé, selon le cas, au réglage minimal du courant différentiel résiduel de fonctionnement et au réglage maximal de la temporisation.

B.8.2.4.6 Vérification du fonctionnement correct en cas d'apparition subite de courant différentiels résiduels supérieurs à 5 $I_{\Delta n}$

Le circuit d'essai doit être étalonné à deux valeurs de courant différentiel résiduel quelconques choisies par le laboratoire d'essai dans la liste suivante: 5 A, 10 A, 20 A, 50 A, 100 A et 200 A. L'interrupteur S1 et le DPR étant en position de fermeture, le courant différentiel résiduel doit être établi subitement par la fermeture de l'interrupteur S2.

L'essai doit être réalisé une fois pour chacune des deux valeurs choisies. Le DPR doit se déclencher lors de chaque essai et la durée de coupure ne doit pas dépasser la valeur limite spécifiée en B.4.2.4.1 ou en B.4.2.4.2.2, selon le cas.

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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 fixées par accord.

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 du B.8.2.4.4 et, le cas échéant, du 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 5.7.3) 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 du B.8.2.4.4 et, s'il y a lieu, du B.8.2.4.5.

Pour les essais de déclenchement, la circulation du courant assigné peut être interrompue, à condition que la durée d'interruption totale ne dépasse pas 30 s. Dès que la somme des durées d'interruption dépasse 30 s, le DPR doit être chargé à nouveau sous son courant assigné jusqu'à atteindre l'équilibre thermique, avant le mesurage suivant de la durée de déclenchement. L'équilibre thermique, mesuré à l'une des bornes principales, doit être conforme au 9.3.3.3.2 de l'IEC 60947-1:2020.

B.8.3 Vérification des propriétés diélectriques

Les DPR doivent satisfaire au 9.3.4.3.

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.

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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.

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 conformément à 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 l'essai sous toute 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 chemins de courant, avec un intervalle d'au moins 1 min entre deux manœuvres de fermeture successives.

Le DPR ne doit pas se 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 à la valeur minimale.

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 l'essai en utilisant un générateur de courant de choc capable de délivrer un courant oscillatoire amorti, comme cela est représenté à la Figure B.4.

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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:

– 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 se déclencher.

B.8.6.3 Vérification de la résistance aux déclenchements intempestifs en cas d'amorçage sans courant de suite

Le DPR doit être soumis à l'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 cela est 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'environ 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 admis; et
– 3 000 A $^{+10}_{0}$ %, lorsque le déclenchement est admis;
– 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 en B.8.6.3, le fonctionnement du DPR doit être vérifié conformément au 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 du type A et du type B

B.8.7.1 Conditions d'essai

Les conditions d'essai du B.8.1.1, du B.8.2.1, du B.8.2.2 et du B.8.2.3 s'appliquent, excepté que les circuits d'essai doivent être ceux représentés à la Figure B.8 et à la Figure B.9, selon le cas.

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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 à la valeur minimale.

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 l'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.

À chaque essai, le courant doit être augmenté progressivement à partir de zéro 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 qui comprend une composante continue

Angle α	Courant de déclenchement A	
	Limite inférieure	Limite supérieure
0°	0,35 $I_{\Delta n}$	2 $I_{\Delta n}$ pour $I_{\Delta n}$ < 0,030 A
90°	0,25 $I_{\Delta n}$	ou
135°	0,11 $I_{\Delta n}$	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 conformément à 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 conformément au 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 pour alimenter le DPR. En conséquence, dans ce cas, la vérification est considérée comme étant réalisée en établissant le courant différentiel résiduel par la fermeture de S_1, le DPR soumis à l'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.

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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 doivent être répétés, le pôle soumis à l'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.

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

Il n'est pas nécessaire d'appliquer cet essai aux DPR du type B, car ces exigences sont couvertes par l'essai décrit en B.8.8.5.

Le DPR doit être soumis à l'essai conformément à 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 l'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, qui part 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, qui part 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 du 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 partant de la valeur donnée dans le Tableau B.7, de manière à atteindre, dans un délai 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 choisi 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, ce qui représente la condition la plus sévère.			

Tableau B.8 – Plage de courants 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 conformément à 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 $I_{\Delta n}$, selon le cas.

Les DPR du type temporisé doivent en outre être soumis à l'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 à intervalles d'au moins 1 min. Le DPR ne doit pas se déclencher au cours de ces essais.

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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 conformément à la Figure B.14.

L'essai est réalisé en deux étapes: une première étape a) qui vise à vérifier le courant de déclenchement, et une deuxième étape b) qui vise 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 est augmenté de façon régulière, à partir d'une valeur qui ne dépasse pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de courant différentiel résiduel de fonctionnement donnée dans le Tableau B.9 dans un délai d'environ 30 s, 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 qui correspond à 1 000 Hz, conformément au Tableau B.9, 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.

   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 conformément à 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 à 10 mA, si cette valeur est 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 qui ne dépasse pas 0,2 $I_{\Delta n}$, de manière à atteindre la valeur de $I_{\Delta n}$ dans un délai d'environ 30 s, le courant de déclenchement étant mesuré.

Le DPR doit être soumis à l'essai deux fois pour chacune des positions I et II de l'interrupteur S_3.

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