

INTERNATIONAL STANDARD



**Railway applications – Electric equipment for rolling stock –
Part 4: Electrotechnical components – Rules for AC circuit-breakers**

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INTERNATIONAL STANDARD



**Railway applications – Electric equipment for rolling stock –
Part 4: Electrotechnical components – Rules for AC circuit-breakers**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ELECTRIC EQUIPMENT FOR ROLLING STOCK –****Part 4: Electrotechnical components –
Rules for AC circuit-breakers**

FOREWORD

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International Standard IEC 60077-4 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition, issued in 2003. It constitutes a technical revision.

This edition includes the following main technical changes with regard to the previous edition:

- a) standard values of transient recovery voltages and test procedure are reviewed;
- b) procedure of verification of temperature rise is changed;
- c) air-tightness test as type test, insulation resistance measurement are added.

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

FDIS	Report on voting
9/2538/FDIS	9/2554/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

This document should be read in conjunction with IEC 60077-1 and IEC 60077-2.

A list of all parts in the IEC 60077 series, published under the general title *Railway applications – Electric equipment for rolling stock*, can be found on the IEC website.

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

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- withdrawn,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

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INTRODUCTION

~~This International Standard is Part 4 of the IEC 60077 series.~~

~~The purpose of this product standard is to give additional or amended requirements on AC circuit breakers as a supplement to those given by IEC 60077-2.~~

~~During preparation of this product standard, IEC 60056 and IEC 60694 have been considered and their requirements have been kept as far as it has been possible.~~

~~This product standard makes reference to the general rules for electrotechnical components given in IEC 60077-2, but for general conditions reference is made directly to IEC 60077-1.~~

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RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 4: Electrotechnical components – Rules for AC circuit-breakers

1 Scope

In addition to the general requirements of IEC 60077-2, this part of IEC 60077 gives rules for AC circuit-breakers, the main contacts of which are ~~to be~~ connected to AC overhead contact lines; the nominal voltage of these circuits being in accordance with IEC 60850.

This document, together with IEC 60077-2, states specifically:

- a) the characteristics of the circuit-breakers;
- b) the service conditions with which circuit-breakers ~~have to~~ comply with reference to:
 - operation and behaviour in normal service;
 - operation and behaviour in short-circuit;
 - dielectric properties;
- c) the tests for confirming the compliance of the components with the characteristics under the service conditions and the methods to be adopted for these tests;
- d) the information to be marked on, or given with the circuit-breaker.

NOTE 1 Circuit-breakers which are dealt with in this document ~~may~~ can be provided with devices for automatic opening under pre-determined conditions other than those of overcurrent, for example, undervoltage and reversal of power ~~current~~ flow direction. This document does not deal with the verification of operation under such predetermined conditions.

NOTE 2 The incorporation of electronic components or electronic sub-assemblies into electrotechnical components is now common practice.

Although this document is not applicable to electronic equipment, the presence of electronic components does not provide a reason to exclude such electrotechnical components from the scope.

Electronic sub-assemblies included in the circuit-breakers ~~should~~ comply with the relevant standard for electronics (IEC 60571).

NOTE 3 Certain of these rules ~~may~~, after agreement between the user and the manufacturer, ~~be~~ are used for electrotechnical components installed on vehicles other than rail rolling stock such as mine locomotives, trolleybuses, etc. In this case, particular additional requirements can be necessary.

This document does not cover industrial circuit-breakers which ~~have to~~ comply with ~~IEC 60056~~ IEC 62271-100. For these, in order to ensure satisfactory operation, this document ~~should be~~ is used to specify only the particular requirements for rolling stock. In such cases, a specific document ~~should state~~ states the additional requirements with which the industrial circuit-breakers ~~are to~~ comply, for example:

- either to be adapted (e.g. for control voltage, environmental conditions, etc.);
- or to be installed and used so that they do not have to endure specific rolling stock conditions;
- or to be additionally tested to prove that these components can withstand satisfactorily the rolling stock conditions.

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 60050(441):1984, International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and Fuses~~

~~IEC 60056:2001, High voltage alternating current circuit-breaker*~~

IEC 60060-1:1989/2010, High-voltage test techniques – Part 1: General definitions and test requirements

IEC 60077-1:1999/2017, Railway applications – Electric equipment for rolling stock. – Part 1: General service conditions and general rules

IEC 60077-2:1999/2017, Railway applications – Electric equipment for rolling stock. – Part 2: Electrotechnical components – General rules

IEC 60529, Degrees of protection provided by enclosures (IP Code)

~~IEC 60571:1998, Railway applications — Electronic equipment used on rail vehicles~~

~~IEC 60694:1996, Common specification for high voltage switchgear and controlgear standards~~

~~IEC 60850:2000, Supply voltage of traction systems~~

IEC 61373:1999, Railway applications – Rolling stock equipment – Shock and Vibration tests

IEC 62271-1:2017, High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear

IEC 62271-100:2004/2008, High-voltage switchgear and controlgear – Part 100: ~~High-voltage Alternating-current circuit-breakers~~

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-102, High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches

3 Terms, definitions and abbreviated terms

~~For the purposes of this of IEC 60077, the definitions given in clause 3 of IEC 60077-1 and clause 3 of IEC 60077-2 are applicable together with the following additional definitions.~~

For the purposes of this document, the terms and definitions given in Clause 3 of IEC 60077-1:2017 and Clause 3 of IEC 60077-2:2017, and the following apply.

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

* ~~In preparation.~~

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

3.1 Components

3.1.1

indoor circuit-breaker

circuit-breaker designed solely for protected installation against wind, rain, snow, abnormal dirt deposits, abnormal conditions, ice and hoarfrost

~~[IEV 441-11-04, modified]~~

3.1.2

outdoor circuit-breaker

circuit-breaker suitable for installation in open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoarfrost

~~[IEV 441-11-05, modified]~~

3.1.3

oil circuit-breaker

circuit-breaker in which the contacts open and close in oil

Note 1 to entry: Typical examples of oil circuit-breakers are live tank minimum oil circuit-breakers and dead tank bulk oil circuit-breakers.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-28]

3.1.4

vacuum circuit-breaker

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

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-29]

3.1.5

air-blast circuit-breaker, <for rolling stock>

circuit-breaker in which the contacts open in a blast of air

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-32, modified – “gas-blast” has been deleted. “the gas used is air” has been replaced with “the contacts open in a blast of air”.]

3.1.6

air circuit-breaker

circuit-breaker in which the contacts open and close in air

3.1.7

gas circuit-breaker

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

Note 1 to entry: An example of a gas circuit-breaker is the sulphur hexafluoride circuit-breaker.

3.1.8

semiconductor circuit-breaker

~~circuit-breaker whose operation is produced by means of semi-conductors inserted into the main circuit in association with contacts~~

circuit-breaker designed to make and break the current in an electric circuit by means of the controlled conductivity of a semiconductor

Note 1 to entry: There can be mechanical contacts associated with these semiconductor devices.

[SOURCE: IEC 60050-811:2017, 811-29-42]

3.2 Component parts

3.2.1

release, <for a circuit breaker>

device which releases the holding means and permits the opening or closing of the circuit-breaker

Note 1 to entry: A circuit-breaker ~~may~~ can be activated by several releases each becoming operational according to specified conditions.

Note 2 to entry: These releases ~~may~~ can be mechanically or electrically connected to the switching device.

[SOURCE: IEC 60050-811:2017, 811-29-44]

3.2.2

overcurrent (~~instantaneous~~) release

~~device which causes a tripping operation without any intentional time delay when the current exceeds a specified value~~

~~[IEV 441-16-32, modified]~~

release which permits a mechanical switching device to open with or without time-delay when the current in the release exceeds a predetermined value

Note 1 to entry: This value can in some cases depend upon the rate-of-rise of current.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-33]

3.2.3

definite time-delay overcurrent release

overcurrent release which operates with a definite time-delay which may be adjustable, but is independent of the value of the overcurrent

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-34]

3.2.4

direct overcurrent release

overcurrent release directly energised by the current in the main circuit of ~~the circuit-breaker~~ a mechanical switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-36, ~~modified~~]

3.2.5

indirect overcurrent release, <for a circuit-breaker>

overcurrent release initiated by the current in the main circuit of a mechanical switching device through a current sensor ~~(transformer or current transducer)~~

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-37, modified – “energized” and “a current transformer or a shunt” have been replaced with “initiated” and “a current sensor”.]

3.2.6

anti-pumping device

device which prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing

Note 1 to entry: The opening operation may be either an opening command or a tripping operation.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-48, modified – Note 1 to entry has been added.]

3.2.7

enclosure, <of an assembly>

part of an assembly providing a specified degree of protection ~~for the circuit-breaker~~ of equipment against external ~~pollution~~ influences and a specified degree of protection against ~~access~~ approach to or contact with live parts and against contact with moving parts

Note 1 to entry: The enclosure may also provide a protection of adjacent parts against the influence of the circuit-breaker (for example, arcing).

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-13-01, modified – Note 1 to entry has been added.]

3.2.8

integral enclosure

enclosure forming an integral part of the circuit-breaker

3.3 Operational features

3.3.1

trip-free circuit-breaker

circuit-breaker, the moving main contacts of which return to and remain in the open position when the opening (i.e. tripping) operation is initiated after the initiation of the closing operation even if the closing command is maintained

~~[IEV 441-16-31, modified]~~

Note 1 to entry: To ensure ~~satisfactory~~ proper breaking of the current ~~after initiation of a closing command~~ which may have been established, it may be necessary that the contacts momentarily reach the closed position.

Note 2 to entry: The trip free operation may require an anti-pumping device.

3.3.2

current setting, <of an overcurrent release>

~~value of current in the main circuit to which the operating characteristics of the over-current release are referred and for which the release is set~~

value of the operating current for which the release is adjusted and in accordance with which its operating conditions are defined

Note 1 to entry: A release may have more than one current setting.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-46, modified – Note 1 to entry has been added.]

3.3.3

current setting range, <of an overcurrent release>

range between the minimum and maximum values over which the current setting of the release can be adjusted

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-47]

3.3.4

tripping operation

opening operation of a circuit-breaker initiated by a release

3.4 Making and breaking characteristics

NOTE See Annex B.

3.4.1**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: The instant of initiation of the opening operation is specified by the manufacturer for all the opening commands other than overcurrent.

Note 2 to entry: The opening time includes the operating time of any auxiliary equipment necessary to open the circuit-breaker and forming an integral part of the circuit-breaker.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-36, modified – Note 1 to entry has been modified and Note 2 to entry has been added.]

3.4.2**prospective current**, <of a circuit and with respect to a switching device or a fuse>

current that would flow in the circuit if each pole of the ~~circuit-breaker~~ switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: This term is commonly associated with fault conditions.

Note 2 to entry: The prospective current is composed of an RMS AC value plus a DC component (if any).

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modified – Notes to entry have been replaced.]

3.4.3**prospective peak current**

peak value of a prospective current during the transient period following initiation

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-02, modified – Note has been deleted.]

3.4.4**prospective symmetrical current**, <of an AC circuit>

prospective current when it is initiated at such an instant that no transient phenomenon follows the initiation

Note 1 to entry: The prospective symmetrical current is expressed by its RMS value.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-03, modified – Note 1 has been deleted.]

3.4.5~~**maximum prospective peak current (of an AC circuit)**~~

~~prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value~~

~~[IEV 441-17-04]~~

3.4.5**breaking current**, <of a switching device or a fuse >

current in a ~~circuit-breaker~~ pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-07, ~~modified~~]

3.4.6**breaking capacity**, <of a switching device or a fuse>

value of prospective current that a ~~circuit-breaker~~ switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-08, modified – Notes have been deleted.]

3.4.7

making capacity, <of a switching device or a fuse>

value of prospective making current that a ~~circuit-breaker~~ switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-09, modified – Note has been deleted.]

3.4.8

short-circuit making capacity

making capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-10, ~~modified~~]

3.4.9

short-circuit breaking capacity

breaking capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-11, ~~modified~~]

3.4.10

short-time withstand current

current that a circuit ~~breaker~~ or a switching device in the closed position can carry during a specified short time under specified conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-17, ~~modified~~]

3.4.11

peak withstand current

value of peak current that a circuit ~~breaker~~ or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-18, ~~modified~~]

3.4.12

recovery voltage

voltage which appears across the terminals of a ~~circuit-breaker~~ pole of a switching device or a fuse after the breaking of the current

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-25, modified – Note has been deleted.]

~~NOTE—This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency or the steady state recovery voltage alone exists.~~

3.4.13

transient recovery voltage

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: The transient recovery voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and the switching device.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-26, modified – The second sentence of Note 1 to entry has been deleted. Note 2 to entry has been deleted.]

3.4.14

prospective transient recovery voltage, <of a circuit>

transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

Note 1 to entry: The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-29]

3.4.15

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-27]

3.5 Abbreviated terms

AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
RMS	Root Mean Square (value)
RRRV	Rate of Rise of Recovery Voltage
TRV	Transient Recovery Voltage

4 Classification

This clause is intended to list the characteristics of a circuit-breaker on which information is given by the manufacturer and which shall be verified by testing where relevant.

The circuit-breakers are classified:

- according to their operational frequency C1, C2 or C3. The characteristics of these operational frequencies are given in 5.4;
- according to the type of design, i.e. outdoor or indoor circuit-breaker;
- according to the degree of protection provided by the enclosure (see IEC 60529).

5 Characteristics

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 values and limiting values for the main circuit (5.3);
- operational frequencies (5.4);
- electric and pneumatic control circuits (5.5);
- electric and pneumatic auxiliary circuits (5.6);
- overcurrent release (5.7);
- peak value of the recovery voltage (5.8).

5.2 Type of circuit-breaker

It is necessary to state:

- the kind of device (e.g. air-blast circuit-breaker, air circuit-breaker, vacuum circuit-breaker, gas circuit-breaker, oil circuit-breaker, semiconductor circuit-breaker, etc.);
- the type of design (see Clause 4);
- the degree of protection provided by the enclosure (see Clause 4);
- operational features (e.g. trip-free circuit-breaker direct or indirect overcurrent release, time-delay overcurrent release).

5.3 Rated values and limiting values for the main circuit

5.3.1 General

Rated values are assigned by the manufacturer but it is not necessary to establish all the ratings listed.

5.3.2 Rated voltages

~~The rated voltages for a circuit-breaker are the following:~~

A component is defined by the following rated voltages given in 5.2 of IEC 60077-1:2017:

- rated operational voltage (U_e , U_r), ~~(see 5.1.2 of IEC 60077-1);~~

NOTE 1 A circuit-breaker ~~may have~~ has more than one rated operational voltage or ~~may have~~ has a rated operational voltage range.

- rated insulation voltage (U_i , U_{Nm}), ~~(see 5.1.3 of IEC 60077-1);~~

NOTE 2 When no rated insulation voltage has been assigned to a circuit-breaker, the rated insulation voltage is considered to be equal to the highest value of the rated operational voltage.

- rated impulse ~~withstand~~ voltage (U_{imp} , U_{Ni}), ~~(see 5.1.5 of IEC 60077-1);~~
- power-frequency test voltage (U_a).

5.3.3 Rated currents

~~The rated currents of a circuit-breaker are the following:~~

A component is defined by the following rated currents given in 5.4 of IEC 60077-1:2017 and 5.3.3 of IEC 60077-2:2017:

- rated operational current (I_e , I_r), ~~(see 5.3.1 of IEC 60077-1)~~ at the rated power factor $T2$ (see 5.3.5);

NOTE 1 A circuit-breaker ~~may~~ can have more than one rated operational current or ~~may~~ can have a rated operational current range.

- conventional free air thermal current (I_{th}), ~~(see 5.3.3 of IEC 60077-2);~~
- conventional free air thermal current for DC (I_{th_DC});

NOTE 2 The conventional free air thermal current for DC is the maximum value of the DC test current to be used for temperature rise tests of equipment in free air at the maximum ambient air temperature.

NOTE 3 AC circuit-breaker used for AC-DC dual system electric rolling stock can have a different thermal current for DC. For DC system only conducting performance is relevant.

- conventional enclosed thermal current (I_{the});
- rated short-time withstand current (I_{cw}), ~~(see 5.3.2 of IEC 60077-1);~~
- rated peak withstand current (I_p).

NOTE 4 Where the circuit-breaker is used to energize and protect a transformer or an inductor or a reactive filter circuit, the inrush of current on energization ~~may~~ can contain a large and prolonged DC component.

5.3.4 ~~Rated frequencies~~ Rated operational frequency

The rated operational frequency (f_r) of a circuit-breaker is the frequency relevant to the rated operational voltage (see 5.5 of IEC 60077-1:2017).

NOTE A circuit-breaker may have more than one rated operational frequency.

5.3.5 Rated power factors

The rated power factors are used to characterize the performance as follows:

- 0,1 for short-circuit conditions ($T1$);
- 0,8 for normal service conditions ($T2$).

The rated power factor for the short-circuit is dependent on the electrical characteristics of the sub-station, the supply lines to the vehicle and the load.

If necessary, other power factor values may be defined by agreement between the manufacturer and the user.

5.3.6 Short-circuit characteristics ~~(see also Annex B)~~

5.3.6.1 Rated peak withstand current

The rated peak withstand current (I_P) is the peak current associated with the first major loop of the rated short-time withstand current that the switchgear and controlgear can carry in the closed position under its service conditions.

The rated peak withstand current is obtained by multiplying the RMS value of the rated short-time withstand current with a peak factor. This peak factor is a function of the DC time constant of the network and the rated frequency. The preferred value of the peak factor is 2,5.

5.3.6.2 Rated short-circuit making capacity

The manufacturer shall declare the rated short-circuit making current corresponding to the power factor $T1$.

The rated short-circuit making capacity of a circuit-breaker is the peak value (I_P) of the making current corresponding to the rated operational voltage. ~~It shall be 2,5 times the RMS value of the AC component of the rated short-circuit breaking current.~~ The circuit-breaker shall satisfy the rated short-circuit making test specified in 9.3.4 and shall be capable of subsequent operation.

5.3.6.3 Rated short-circuit breaking capacity

The manufacturer shall declare the rated short-circuit breaking current corresponding to the power factor $T1$.

It is the highest short-circuit current which the circuit-breaker shall be capable of breaking under the conditions of test specified in this document in a circuit having a power-frequency recovery voltage corresponding to the rated operational voltage and having a transient recovery voltage equal to the rated value specified in 5.3.6.4.

The rated short-circuit breaking current is characterized by two values:

- the RMS value of its AC component, termed “rated short-circuit current”;

– and the percentage DC component.

NOTE If the DC component does not exceed 20 %, the rated short-circuit breaking capacity is characterized only by the RMS value of its AC component. See also Annex B.

The circuit-breaker shall be capable of breaking any short-circuit current up to its rated short-circuit breaking current containing any AC component up to the rated value and associated with it any percentage DC component up to that specified, under the conditions mentioned above.

The circuit-breaker shall satisfy the rated short-circuit breaking test specified in 9.3.4 and shall be capable of subsequent operation.

At voltages below the rated operational voltage, it shall be capable of breaking its rated short-circuit breaking current.

5.3.6.4 Rated transient recovery voltage

The rated transient recovery voltage for a short-circuit is related to the rated short-circuit breaking capacity in accordance with 5.3.6.3. It is the reference voltage which constitutes the limit of the prospective transient recovery voltage of circuits which the circuit-breaker shall be capable of breaking in the event of a short-circuit.

~~NOTE—Further detailed requirements are given in 4.102.1 and 4.102.2 of IEC 62271-100.~~

Standard values of transient recovery voltage (TRV) are given in Table 1.

Table 1 also indicate values of rate of rise of recovery voltage (RRRV), taken as u_c/t_3 , which together with TRV peak values u_c may be used for purposes of specification of TRV.

The values given in Table 1 are prospective values. They apply to railway on board circuit-breakers in traction systems consisting of transformers, lines and cables.

Where a circuit-breaker has to operate under more severe conditions of TRV than those in Table 1, these shall be identified in the purchaser's specification.

Table 1 – Standard values of transient recovery voltage – Representation by two parameters

Nominal voltage	Maximum permanent voltage	First- pole-to-clear factor	Amplitude factor	TRV peak value	Time	Time delay	Voltage	Time	RRRV
U_n kV	U_{max1}^a kV	k_{pp} p.u.	k_{af} p.u.	u_c kV	t_3 μs	t_d μs	u' kV	t' μs	u_c/t_3 kV/μs
12 also 12,5	N/A ^b	1	1,4	25	73	11	8	35	0,34
15	17,25	1	1,4	34	80	15	11	39	0,42
20	22,0	1	1,4	44	92	14	15	45	0,47
25	27.5	1	1,4	54	95	14	18	46	0,57
25	30,0	1	1,4	62	103	15,5	21	50	0,60

where:

$$u_c = \sqrt{2} \times k_{pp} \times k_{af} \times U_{max1};$$

$$u_c = u_c / 3;$$

$$t_d = 0,15 \times t_3.$$

NOTE $k_{pp} = 1$ is used for a single phase system.

^a See IEC 60850.

^b N/A not applicable.

5.3.6.5 Rated duration of short-circuit

The rated duration of short-circuit is the interval of time for which a circuit-breaker shall be capable of carrying, in the closed position, a current equal to its rated short-time withstand current.

The standard value of rated duration of short-circuit ~~shall be~~ is 1 s.

~~NOTE For further details see 4.7 of IEC 62271-100 and 4.7 of IEC 60694.~~

If it is necessary, a value lower or higher than 1 s may be chosen. The recommended values are 0,5 s, 2 s and 3 s.

5.4 Operational frequencies

The operational frequencies are used to characterize the performance capability as given in Table 2.

The operational frequencies C1, C2 and C3 are defined as:

- C1: light operational frequency (e.g. the circuit-breaker opens only when a short-circuit is detected);
- C2: medium operational frequency (e.g. in addition to C1 the circuit-breaker opens by a command produced by exceeding a predetermined limiting value, for example due to overload conditions, etc.);
- C3 heavy operational frequency (e.g. in addition to C2, the circuit-breaker opens for other reasons, for example at each gap section, each sectioning point, each end of service, etc.).

5.5 Electric and pneumatic control circuits

The characteristics of the electric and pneumatic control circuits are given in 5.6 and 5.7 of IEC 60077-2:2017.

5.6 Electric and pneumatic auxiliary circuits

The characteristics of the auxiliary circuits are the number and nature of the contacts (“a” contact, “b” contact, etc.) of each of these circuits and their rated characteristics. These characteristics are given in 5.9 and 5.10 of IEC 60077-2:2017.

5.7 Overcurrent release

The following characteristics shall be declared by the manufacturer for each overcurrent release:

- type of overcurrent release (e.g. direct, indirect, time-delay, etc.);

NOTE – an anti-pumping device may be included.

- current setting (or setting range);
- characteristics of the opening time as a function of the quantities which influence the release.

5.8 Recovery voltages

The manufacturer shall specify the peak value of the recovery voltage when it is tested in accordance with the provisions of the making and breaking tests of sequences I₇ and II ~~and IV~~ of Table 3.

Under no circumstances shall this value exceed that of the rated impulse withstand voltage of the circuit-breaker.

6 Product information

6.1 Component documentation

This information shall be given in the manufacturer's catalogue or manual.

6.1 of IEC 60077-2:2017 applies supplemented by the following:

- rated operational voltage of the control circuit of built-in releases and rated frequency if applicable;
- current setting or current setting range of the relevant overcurrent releases (e.g. direct or indirect overcurrent release, definite time-delay overcurrent release, etc.);
- opening time.

6.2 Marking

The data or identification shall be marked in accordance with 6.2 of IEC 60077-2:2017.

7 Normal service conditions

These conditions are given in Clause 7 of IEC 60077-1:2017.

8 Constructional and performance requirements

8.1 Constructional requirements

These requirements are given in 8.1 of IEC 60077-2:2017.

8.2 Performance requirements

8.2.1 Operating conditions

These requirements are given in 8.2.1 of IEC 60077-2:2017.

8.2.2 Temperature ~~rise~~ limits

These requirements are given in 8.2.2 of IEC 60077-2:2017.

8.2.3 Operation following inactivity

These requirements are given in 8.2.3 of IEC 60077-1:2017.

8.2.4 Electromagnetic compatibility (EMC)

These requirements are given in 8.2.4 of IEC 60077-1:2017.

8.2.5 Acoustic noise emission

These requirements are given in 8.2.5 of IEC 60077-1:2017.

8.2.6 ~~Dielectric properties~~ Clearances

These requirements are given in 8.2.6 of IEC 60077-1:2017.

8.2.7 Creepage distances

These requirements are given in 8.2.7 of IEC 60077-1:2017.

8.2.8 Switching overvoltages

These requirements are given in 8.2.8 of IEC 60077-1:2017.

In addition the manufacturer shall declare recovery voltages generated by the breaking tests of sequences I and, II ~~and IV~~ of Table 3.

8.2.9 Operational performance capability

The circuit-breaker shall be capable of complying (as a function of the operational frequency) with the provisions of Table 2 under the test conditions stated in 9.3.3.6.

Each operating cycle shall consist either of a closing operation followed by an opening operation (cycle without current), or a making operation followed by a breaking operation (cycle with current).

The total number of operating cycles shall consist of performing a number of operating cycles without current, specified in Table 2, column 2, followed by a number of operating cycles with current, specified in Table 2, column 3.

The rate of operating cycles, selected by mutual agreement between the manufacturer and the user, is chosen to keep all parts of the circuit-breaker within acceptable limits of temperature rise and is to be mentioned in the test report.

Table 2 – Operational performance capability

Column 1	Column 2	Column 3
Operational frequency	Total number of operating cycles	
	Without current	With current
C1	10 000	0
C2	100 000	200
C3	200 000	200
<p>NOTE 1 – The rate of operating cycles is chosen to keep all parts of the circuit-breaker within acceptable limits of temperature rise.</p> <p>NOTE 2 – The rate of operating cycles selected by mutual agreement between the manufacturer and the user is to be mentioned in the test report</p> <p>NOTE 3 During each operating cycle, the circuit-breaker remains in the closed position for a sufficient time to ensure that the current is fully established, but not exceeding 2 s.</p>		

8.2.10 Ability to withstand vibration and shock

The circuit-breaker shall be capable of withstanding the vibration and shock given by test requirements (see 9.3.5.2 and 9.3.5.3).

8.2.11 Ability to make and break under short-circuit conditions

The circuit-breaker shall be capable of satisfying the short-circuit tests under the following conditions:

- current setting of the overcurrent release equal to the maximum value of the current setting range, if applicable;
- rated short-circuit breaking current at the rated operational voltage as stated in 5.3.6.3;
- recovery voltage equal to the rated operational voltage;
- transient recovery voltage equal to the rated transient recovery voltage as stated in 5.3.6.4;
- a sequence of operations: O – t_1 – CO – t_2 – CO;
 - O representing a breaking operation;
 - CO representing a making operation followed by a breaking operation after the appropriate opening time;
 - t_1 representing the time interval between the first opening and the first closing;
 - t_2 representing the time interval between the second opening and the second closing.

Unless otherwise agreed between the manufacturer and the user, t_1 and t_2 are 180 s.

9 Tests

9.1 Kind of tests

9.1.1 General

9.1.1 of IEC 60077-1:2017 applies except that sampling tests are not permissible for circuit-breakers.

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

- type tests (see 9.1.2);
- routine tests (see 9.1.3);
- **investigatory** investigation tests (see 9.1.4).

9.1.2 Type tests

The type tests comprise the following:

- verification of constructional requirements (see 9.2.2);
- verification of performance requirements (see 9.3).

9.1.3 Routine tests

The routine tests comprise the following:

- verification of constructional requirements (see 9.2.3);
- verification of performance requirements (see 9.4).

9.1.4 **Investigatory** Investigation tests

These are supplementary tests to the type tests for a special application. They form the subject of a programme agreed between the manufacturer and the user, and may concern:

- influence of harmonics on the temperature rise and breaking characteristics;
- temperature rise for temporary overload conditions.

9.2 ~~Tests for~~ Verification of constructional requirements

9.2.1 General

The compliance of the circuit-breaker with the constructional requirements given in the appropriate parts of 8.1 of IEC 60077-1:2017 shall be proven prior to verification of the performance requirements as detailed in 9.3 and 9.4. The compliance of properties where testing is not appropriate shall be by visual examination, measurements, etc.

9.2.2 Type tests

Verification of compliance with the constructional requirements for the type test concerns:

- physical properties; a check shall be made that the circuit-breaker conforms to the drawings (e.g. dimensions, materials, electrical risks, protective bonding, etc.);
- clearance and creepage distances (see 9.3.3.2.1 and 9.3.3.2.3 of IEC 60077-1:2017);
- terminals and connecting capacity (tested as part of performance requirements in accordance with 9.3.3.8).

9.2.3 Routine tests

Verification of compliance with the constructional requirements for the routine test concerns:

- visual examination (compliance of the manufacture and assembly with the drawings);
- measurements of resistances. The tests required in 9.2.3 of IEC 60077-1:2017 shall be applied. The measured values for main and control circuits and the ambient temperature shall be recorded in the routine test report.

NOTE For measurement of main circuit resistance see also 9.3.4.2.

9.3 Type tests for verification of performance requirements

9.3.1 Test sequences

Type tests are grouped together in a number of test sequences as shown in Table 3.

For each sequence, the tests shall be carried out in the order listed in Table 3.

A new sample may be used for each sequence.

A routine test (see 9.1.3) shall be carried out on every sample before type test.

Table 3 – List of type test sequences for performance requirements

Test sequences	Tests	Subclause
I – General performance characteristics (9.3.3)	Operating limits	9.3.3.2
	Measurement of the resistance of circuits	9.3.3.3
	Temperature rise	9.3.3.4
	Dielectric properties	9.3.3.5
	Operational performance capability	9.3.3.6
	Verification of dielectric withstand	9.3.3.7
	Verification of temperature rise	9.3.3.8
	Verification of tripping operation	9.3.3.9
II – Rated service short-circuit making and breaking capacities (9.3.4)	Measurement of the resistance of the main circuit	9.3.4.2
	Short-time withstand current and peak withstand current	9.3.4.4
	Ability to make and break under short-circuit conditions	9.3.4.5
	Verification of dielectric withstand	9.3.4.6
	Verification of the resistance of the main circuit temperature rise	9.3.4.7
	Verification of tripping operation	9.3.4.8
III – Capability Ability to withstand vibration and shock (9.3.5)	Vibration	9.3.5.2
	Shock	9.3.5.3
	Verification of mechanical operation	9.3.5.4
	Verification of tripping operation	9.3.5.5
	Verification of dielectric withstand	9.3.5.6
IV – Transient recovery voltage	Searching for maximum transient recovery voltage	9.3.6
IV – Climatic conditions	Environmental tests (wet, dry heat, damp heat, cold, ice, etc.)	9.3.6
VI – Other tests (if required)	Electromagnetic compatibility (EMC)	9.3.7
	Acoustic noise emission	9.3.7

9.3.2 General test conditions

The circuit-breakers to be tested shall comply in all details with the drawings of the type which they represent.

During a test sequence no maintenance or repair is permissible.

Each of the sequences (described in Table 3) shall be made on a circuit-breaker in a clean and new condition (or considered as such after a repair).

The tests shall be performed at the rated operational values (current, voltage, frequency, air pressure) for the circuits (main, control and auxiliary) and in accordance with the values indicated in 5.3, 5.5 and 5.6.

The test values shall be within the tolerances indicated in Table 4.

Table 4 – Tolerances on test values

All tests	Tests under normal load conditions	Tests under short-circuit conditions
Main circuit Voltage: $\begin{matrix} +5 \\ 0 \end{matrix}$ Frequency: $\pm 10 \%$	Main circuit Current: $\begin{matrix} +10 \\ 0 \end{matrix} \%$ Power factor: $\pm 0,05$	Main circuit Current: $\begin{matrix} +10 \\ 0 \end{matrix} \%$ Power factor: $\begin{matrix} 0 \\ -0,05 \end{matrix}$
Control and auxiliary circuit Current: $\pm 5 \%$ Voltage: $\pm 5 \%$ Air pressure: $\pm 5 \%$		

For all the tests, the ambient air temperature shall be measured and recorded in the test report.

The complete circuit-breaker under test shall be mounted together with its external associated over-voltage protection when appropriate:

- in its integral enclosure if it has one;
- or in an enclosure representing the conditions of installation when these are prescribed by the manufacturer;
- or under the conditions of installation envisaged on the rolling stock.

9.3.3 Test sequence I: General performance characteristics

9.3.3.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.3.2 Operating limits

The tests required in 9.3.3.2 of IEC 60077-2:2017 shall be carried out.

Air-tightness tests for pneumatic equipment required in 9.3.4.2 of IEC 60077-1:2017 shall be carried out. The test shall be done for all the temperature conditions, at least at the lowest and the highest ambient temperatures. For low temperature different criteria may be used.

9.3.3.3 Measurement of the resistance of circuits

The tests required in 9.3.3.3 of IEC 60077-2:2017 shall be carried out.

NOTE The value before the test can be taken from the routine test result.

9.3.3.4 Temperature rise

The tests required in 9.3.3.4 of IEC 60077-2:2017 shall be carried out at the conventional free air thermal current, and at the conventional free air thermal current for DC if applicable.

9.3.3.5 Dielectric properties

~~An impulse test using the test values given in Table 4 shall be carried out on the main circuit in accordance with 9.3.3.1 and 9.3.3.2.2a) of IEC 60077-1. Atmospheric correction factors shall be applied in accordance with 11.2 of IEC 60060-1.~~

Table 4 – Determination of voltage for impulse test

Nominal voltages at contact supply line AC RMS kV	Rated impulse withstand voltages (U _{1,2/50 μs}) kV
6,25	60
15	95
25	170
50	300

The tests required in 9.3.3.5 of IEC 60077-2:2017 shall be carried out.

The insulation resistance should be measured before starting the dielectric tests, if requested by the end user. Unless agreed between the user and the manufacturer about the specified value, the insulation resistance shall be not less than 100 MΩ by a megohmmeter applying a DC voltage of at least 1 000 V between the high voltage conductive parts and the earth and between open contacts.

9.3.3.6 Operational performance capability

The tests shall be performed to verify compliance with the requirements of 8.2.9.

The operations of making and breaking shall be carried out at the rated operational current, the rated operational voltage and for a power factor of 0,8. For details of a test circuit see Annex A.

At the end of the tests, no maintenance operation shall be carried out before the verifications required in 9.3.3.7, 9.3.3.8 and 9.3.3.9.

NOTE The total number of operating cycles includes operations without and with current as appropriate for the characteristics.

9.3.3.7 Verification of dielectric withstand

After the test described in 9.3.3.6, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

9.3.3.8 Verification of temperature rise

~~After the verification described in 9.3.3.5 a temperature rise test shall be carried out on the main circuit in accordance with 9.3.3.2.~~

~~At the end of the test, the temperature rise values shall not exceed those recorded in 9.3.3.2 by more than 20 K and they shall not exceed the values specified in 8.2.2 of IEC 60077-2.~~

After the verification described in 9.3.3.7, resistance measurement shall be carried out according to 9.3.3.3 of IEC 60077-2:2017.

The verification of the temperature rise according to 9.3.3.4 is required only when the resistance of the main circuit (without maintenance) has increased by more than 50 % of the value before the test according to 9.3.3.3 of IEC 60077-2:2017. A small number of no-load operations are allowed in an endeavour to bring the resistance down below this figure; if the test has to be performed, then the temperature rise limits and temperature limits on the contacts mentioned in Table 2 of IEC 60077-2:2017 are allowed to be exceeded by 10 K.

NOTE The number of no-load operations is 10 as a maximum.

For the measurement points, refer to 9.3.2.2 of IEC 60077-1:2017.

9.3.3.9 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the verification described in 9.3.3.8, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.4 Test sequence II: Rated short-circuit making and breaking capacities

9.3.4.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.4.2 Measurement of the resistance of the main circuit

~~The measurement shall be made with direct current by measuring the voltage drop across the terminals of each pole.~~

~~The current during the test shall have any convenient value between 50 A and the rated operational current.~~

~~NOTE Further details are given in 6.4.1 of IEC 60694.~~

The tests required in 9.3.3.3 of IEC 60077-2:2017 shall be carried out.

NOTE The value before the test can be taken from the routine test result.

9.3.4.3 Circuit for making and breaking capacity tests

For details of a test circuit see Annex A.

9.3.4.4 Short-time withstand current and peak withstand current

This test shall be carried out according to 7.6 of ~~IEC 60694~~ IEC 62271-1:2017 using the standard value of rated duration of short-circuit.

~~NOTE Further details are given in 8.103.6 of IEC 62271-100 and clause 6 of IEC 60694.~~

9.3.4.5 Ability to make and break under short-circuit conditions

This test shall be carried out according to 6.106 of IEC 62271-100:2008/AMD1:2012/AMD2:2017 for ~~all the~~ test duties ~~stated~~ T10, T30, T60, T100s and T100a, but using the sequence of operation given in 8.2.11.

For test duties T100s and T100a, the specified TRV values are given by the standard values in Table 1.

For test duties T10, T30 and T60, the specified TRV values are given in Table 5.

Table 5 – Standard values of prospective transient recovery voltage – Representation by two parameters

Nominal voltage	Maximum permanent voltage	Test duty	TRV peak value	Time	Time delay	Voltage	Time	RRRV
U_n kV	U_{max1}^a kV		u_c kV	t_3 μ s	t_d μ s	u' kV	t' μ s	u_c/t_3 kV/ μ s
12 and 12,5	N/A ^b	T60	27	31	5	9	15	0,85
		T30		16	2		8	1,69
		T10						
15	17,25	T60	36	35	5	12	17	1,03
		T30		17	3		8	2,13
		T10						
20	22,0	T60	47	40	6	16	19	1,16
		T30		20	3		10	2,32
		T10						
25	27,5	T60	58	40	6	19	20	1,43
		T30		20	3		10	2,87
		T10						
25	30,0	T60	62	51	5	21	22	1,22
		T30						
		T10						

Where:

$$u_c = \sqrt{2} \times 1,5 \times 1,0 \times U_{max1};$$

$$u' = u_c / 3;$$

$$t_d = t_3 \times 0,15.$$

^a See IEC 60850.

^b N/A not applicable.

NOTE 1 For definitions of test duties T10, T30, T60, T100s and T100a, refer to IEC 62271-100:2008/AMD1:2012/AMD2:2017, 6.104.5.

The prospective transient recovery voltage wave of the test circuit shall at no time have its envelope below the specified reference line.

For T10 and T30, it may be difficult to meet the small values of time t_3 . The shortest time that can be met should be used.

The transient recovery voltage during the test shall be recorded.

NOTE 2 The test transient recovery voltage will differ from the prospective transient recovery voltage wave of the test circuit upon which the performance requirements are based to a degree depending upon the characteristics of the circuit-breaker.

9.3.4.6 Verification of dielectric withstand

After the test described in 9.3.4.5, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

9.3.4.7 Verification of ~~the resistance of the main circuit~~ temperature rise

~~After the verification described in 9.3.4.5, a measurement of the resistance of the main circuit shall be carried out in accordance with 9.3.4.1.~~

~~The values shall not differ by more than 20 % of the values recorded in 9.3.4.1.~~

The resistance measurement and the verification of temperature rise described in 9.3.3.8 shall be carried out.

9.3.4.8 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the verification described in 9.3.4.7, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.5 Test sequence III: ~~Capability~~ Ability to withstand vibration and shock

9.3.5.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.5.2 Vibration

The vibration tests shall be carried out in accordance with the relevant method of IEC 61373.

The test shall be carried out so that:

- both operational states are tested;
- the distribution of these states shall be 50 % open and 50 % closed;
- the circuit-breaker shall not change state during the functional vibration test.

9.3.5.3 Shock

After the tests described in 9.3.5.2, the shock tests shall be carried out in accordance with the relevant method of IEC 61373. The test shall include both operational states and the circuit-breaker shall not change state during the test.

9.3.5.4 Verification of mechanical operation

After the test described in 9.3.5.3 the mechanical operation shall be checked in accordance with the requirements of 9.4.2 of IEC 60077-2:2017.

9.3.5.5 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the test described in 9.3.5.4, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.5.6 Verification of dielectric withstand

After the test described in 9.3.5.5, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

~~9.3.6 Test sequence IV: Transient recovery voltage test~~

~~This test shall be carried out only for circuit-breakers of categories C2 and C3, as characterized in 5.4.~~

~~This test shall be carried out with:~~

- ~~— a test voltage equal to the rated operational voltage;~~
- ~~— a current range going from the rated operational current to 0 A;~~
- ~~— a power factor of T1.~~

~~This test shall be carried out in accordance with 6.104.5 of IEC 62271-100. For details of a test circuit see Annex A.~~

~~NOTE The test enables the manufacturer to supply curves of transient recovery voltage as a function of the current broken.~~

9.3.6 Test sequence IV: Climatic conditions

The external surfaces of insulation of outdoor circuit-breakers shall be subjected to wet ~~withstand~~ tests under the standard test procedure given in 4.4 of IEC 60060-1:2010.

~~If by agreement between user and manufacturer other tests are required, these tests shall be selected from 9.3.6 of IEC 60077-2 and IEC 62271-100 (6.101.3, 6.101.4 and 6.101.5)~~

If by agreement between the user and the manufacturer other tests are required, these tests shall be selected from 9.3.7 of IEC 60077-2:2017.

The test under severe ice conditions is applicable only to outdoor circuit-breakers having moving external parts and for which a class of 10 mm or 20 mm of ice thickness is specified. The test shall be performed under the conditions described in IEC 62271-102.

9.3.7 Test sequence VI: Other tests

This sequence may include supplementary tests such as:

- electromagnetic compatibility (EMC);
- acoustic noise emission.

~~These tests shall be carried out according to a test specification agreed between the manufacturer and the user.~~

When tests are required, 9.3.8 of IEC 60077-2:2017 shall be applied.

9.4 Routine tests for verification of performance requirements

9.4.1 General

The following routine tests shall be carried out on each circuit-breaker:

- mechanical operation (see 9.4.2);
- calibration of releases if applicable (see 9.4.3);
- air tightness, if applicable (see 9.4.4);

– dielectric withstand (see 9.4.5).

The measured values shall be recorded in the routine test report.

9.4.2 ~~Mechanical operation~~ Functional test

The tests required in 9.4.2 of IEC 60077-2:2017 shall be applied.

9.4.3 Calibration of releases

This test is only applicable when the circuit-breaker has built-in releases.

A check shall be made that the current causing a tripping operation of the circuit-breaker is within a tolerance of $\pm 10\%$ for any marked value of the current range using a steady state current.

NOTE 1 The $\pm 10\%$ tolerance includes a $\pm 5\%$ allowance for the calibration marking in addition to the setting tolerance.

NOTE 2 Steady state current means an RMS current with a rise of less than 200 A/s.

9.4.4 Air-tightness (for pneumatic circuit-breaker)

~~The tests required in 9.3.4.2 of IEC 60077-1 shall be applied.~~

The tests required in 9.4.4 of IEC 60077-2:2017 shall be applied.

9.4.5 Dielectric withstand

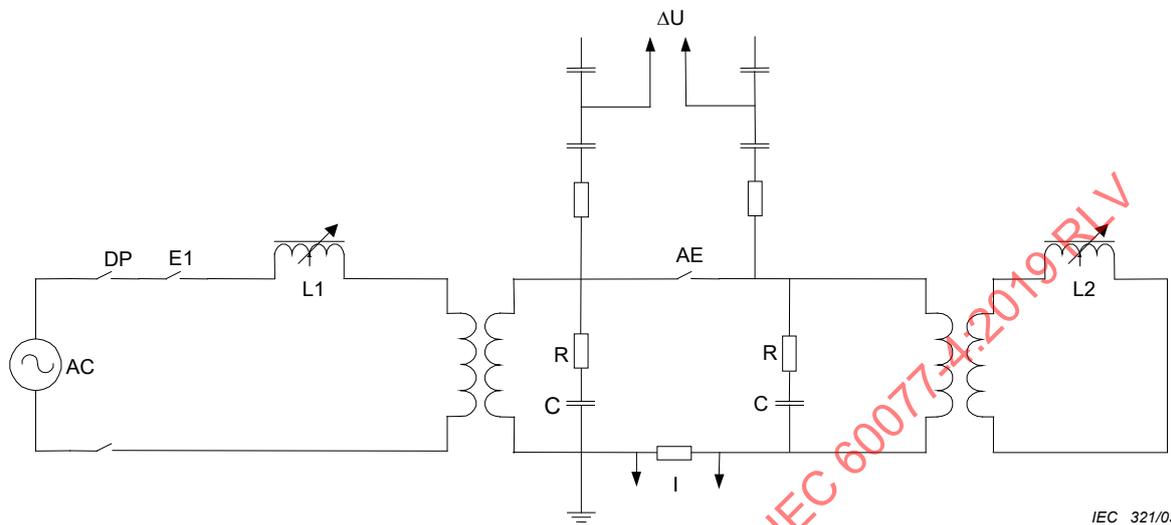
~~The tests required in 9.3.3.3 of IEC 60077-1 shall be applied.~~

The tests required in 9.4.5 of IEC 60077-2:2017 shall be applied.

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Annex A (informative)

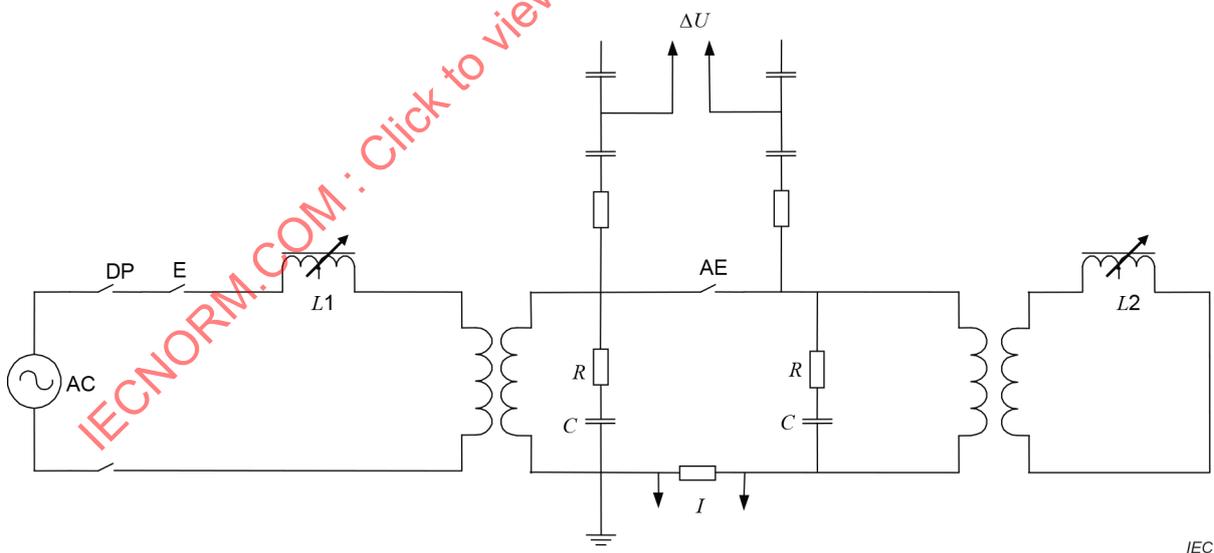
Test circuit to verify the making and breaking capacities



IEC 321/03

Key

DP	Master breaker	R, C	Transient recovery voltage control
E1	Making breaker	ΔU	Measurement of currents and voltages
AE	Breaker being tested	L1, L2	Inductance
AC	Test supply		



IEC

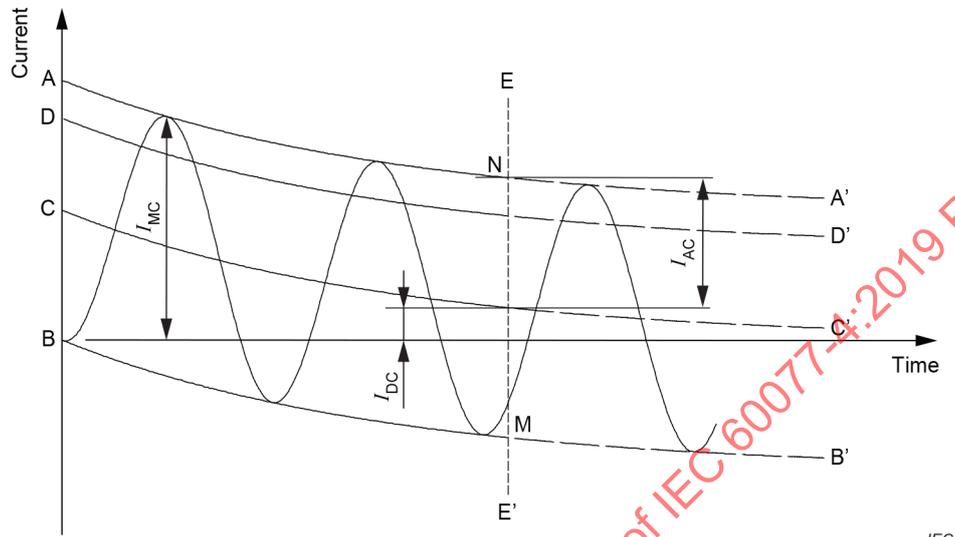
Key

DP	Master breaker	R	Resistor for transient recovery voltage control
E	Making breaker	C	Capacitor for transient recovery voltage control
AE	Breaker being tested	$I, \Delta U$	Measurement of currents and voltages
AC	Test supply	L1, L2	Inductance

Figure A.1 – Principle Diagram of the test circuit

Annex B
(informative)

**Determination of short-circuit making and breaking currents,
and of percentage DC component**



IEC

Key

AA'; BB' Envelope of current-wave

CC' Displacement of current-wave zero line at any instant

DD' RMS value of the AC component of current at any instant measured from CC'

EE' Instant of contact separation (initiation of the arc)

I_{MC} Making current

I_{AC} Peak current of AC component at instant EE'

$I_{AC}/\sqrt{2}$ RMS value of the AC component of current at instant EE'

I_{DC} DC component of current at instant EE'

$\frac{I_{DC} \times 100}{I_{AC}}$ Percentage value of the DC component

**Figure B.1 – Determination of short-circuit making and breaking currents,
and of percentage DC components**

Bibliography

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60850, *Railway applications – Supply voltage of traction systems*

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Railway applications – Electric equipment for rolling stock –
Part 4: Electrotechnical components – Rules for AC circuit-breakers**

**Applications ferroviaires – Équipements électriques du matériel roulant –
Partie 4: Composants électrotechniques – Règles pour disjoncteurs
à courant monophasé**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ELECTRIC EQUIPMENT FOR ROLLING STOCK –****Part 4: Electrotechnical components –
Rules for AC circuit-breakers**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60077-4 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition, issued in 2003. It constitutes a technical revision.

This edition includes the following main technical changes with regard to the previous edition:

- a) standard values of transient recovery voltages and test procedure are reviewed;
- b) procedure of verification of temperature rise is changed;
- c) air-tightness test as type test, insulation resistance measurement are added.

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

FDIS	Report on voting
9/2538/FDIS	9/2554/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

This document should be read in conjunction with IEC 60077-1 and IEC 60077-2.

A list of all parts in the IEC 60077 series, published under the general title *Railway applications – Electric equipment for rolling stock*, can be found on the IEC website.

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

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

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RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 4: Electrotechnical components – Rules for AC circuit-breakers

1 Scope

In addition to the general requirements of IEC 60077-2, this part of IEC 60077 gives rules for AC circuit-breakers, the main contacts of which are connected to AC overhead contact lines; the nominal voltage of these circuits being in accordance with IEC 60850.

This document, together with IEC 60077-2, states specifically:

- a) the characteristics of the circuit-breakers;
- b) the service conditions with which circuit-breakers comply with reference to:
 - operation and behaviour in normal service;
 - operation and behaviour in short-circuit;
 - dielectric properties;
- c) the tests for confirming the compliance of the components with the characteristics under the service conditions and the methods to be adopted for these tests;
- d) the information to be marked on, or given with the circuit-breaker.

NOTE 1 Circuit-breakers which are dealt with in this document can be provided with devices for automatic opening under pre-determined conditions other than those of overcurrent, for example, undervoltage and reversal of power flow direction. This document does not deal with the verification of operation under such predetermined conditions.

NOTE 2 The incorporation of electronic components or electronic sub-assemblies into electrotechnical components is now common practice.

Although this document is not applicable to electronic equipment, the presence of electronic components does not provide a reason to exclude such electrotechnical components from the scope.

Electronic sub-assemblies included in the circuit-breakers comply with the relevant standard for electronics (IEC 60571).

NOTE 3 Certain of these rules, after agreement between the user and the manufacturer, are used for electrotechnical components installed on vehicles other than rail rolling stock such as mine locomotives, trolleybuses, etc. In this case, particular additional requirements can be necessary.

This document does not cover industrial circuit-breakers which comply with IEC 62271-100. For these, in order to ensure satisfactory operation, this document is used to specify only the particular requirements for rolling stock. In such cases, a specific document states the additional requirements with which the industrial circuit-breakers comply, for example:

- either to be adapted (e.g. for control voltage, environmental conditions, etc.);
- or to be installed and used so that they do not have to endure specific rolling stock conditions;
- or to be additionally tested to prove that these components can withstand satisfactorily the rolling stock conditions.

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 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60077-1:2017, *Railway applications – Electric equipment for rolling stock. – Part 1: General service conditions and general rules*

IEC 60077-2:2017, *Railway applications – Electric equipment for rolling stock. – Part 2: Electrotechnical components – General rules*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and Vibration tests*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in Clause 3 of IEC 60077-1:2017 and Clause 3 of IEC 60077-2:2017, and the following apply.

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

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

3.1 Components

3.1.1

indoor circuit-breaker

circuit-breaker designed solely for protected installation against wind, rain, snow, abnormal dirt deposits, abnormal conditions, ice and hoarfrost

3.1.2

outdoor circuit-breaker

circuit-breaker suitable for installation in open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoarfrost

3.1.3

oil circuit-breaker

circuit-breaker in which the contacts open and close in oil

Note 1 to entry: Typical examples of oil circuit-breakers are live tank minimum oil circuit-breakers and dead tank bulk oil circuit-breakers.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-28]

3.1.4

vacuum circuit-breaker

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

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-29]

3.1.5

air-blast circuit-breaker, <for rolling stock>

circuit-breaker in which the contacts open in a blast of air

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-32, modified – “gas-blast” has been deleted. “the gas used is air” has been replaced with “the contacts open in a blast of air”.]

3.1.6

air circuit-breaker

circuit-breaker in which the contacts open and close in air

3.1.7

gas circuit-breaker

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

Note 1 to entry: An example of a gas circuit-breaker is the sulphur hexafluoride circuit-breaker.

3.1.8

semiconductor circuit-breaker

circuit-breaker designed to make and break the current in an electric circuit by means of the controlled conductivity of a semiconductor

Note 1 to entry: There can be mechanical contacts associated with these semiconductor devices.

[SOURCE: IEC 60050-811:2017, 811-29-42]

3.2 Component parts

3.2.1

release, <for a circuit breaker>

device which releases the holding means and permits the opening or closing of the circuit-breaker

Note 1 to entry: A circuit-breaker can be activated by several releases each becoming operational according to specified conditions.

Note 2 to entry: These releases can be mechanically or electrically connected to the switching device.

[SOURCE: IEC 60050-811:2017, 811-29-44]

3.2.2

overcurrent release

release which permits a mechanical switching device to open with or without time-delay when the current in the release exceeds a predetermined value

Note 1 to entry: This value can in some cases depend upon the rate-of-rise of current.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-33]

3.2.3

definite time-delay overcurrent release

overcurrent release which operates with a definite time-delay, which may be adjustable, but is independent of the value of the overcurrent

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-34]

3.2.4

direct overcurrent release

overcurrent release directly energised by the current in the main circuit of a mechanical switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000,441-16-36]

3.2.5

indirect overcurrent release, <for a circuit-breaker>

overcurrent release initiated by the current in the main circuit of a mechanical switching device through a current sensor

[SOURCE: IEC 60050-441:1984/AMD1:2000,441-16-37, modified – “energized” and “a current transformer or a shunt” have been replaced with “initiated” and “a current sensor”.]

3.2.6

anti-pumping device

device which prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing

Note 1 to entry: The opening operation may be either an opening command or a tripping operation.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-48, modified – Note 1 to entry has been added.]

3.2.7

enclosure, <of an assembly>

part of an assembly providing a specified degree of protection of equipment against external influences and a specified degree of protection against approach to or contact with live parts and against contact with moving parts

Note 1 to entry: The enclosure may also provide a protection of adjacent parts against the influence of the circuit-breaker (for example, arcing).

[SOURCE: IEC 60050-441:1984/AMD1:2000,441-13-01, modified – Note 1 to entry has been added.]

3.2.8

integral enclosure

enclosure forming an integral part of the circuit-breaker

3.3 Operational features

3.3.1

trip-free circuit-breaker

circuit-breaker, the moving main contacts of which return to and remain in the open position when the opening (i.e. tripping) operation is initiated after the initiation of the closing operation even if the closing command is maintained

Note 1 to entry: To ensure proper breaking of the current which may have been established, it may be necessary that the contacts momentarily reach the closed position.

Note 2 to entry: The trip free operation may require an anti-pumping device.

3.3.2 **current setting**, <of an overcurrent release>

value of the operating current for which the release is adjusted and in accordance with which its operating conditions are defined

Note 1 to entry: A release may have more than one current setting.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-46, modified – Note 1 to entry has been added.]

3.3.3 **current setting range**, <of an overcurrent release>

range between the minimum and maximum values over which the current setting of the release can be adjusted

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-47]

3.3.4 **tripping operation**

opening operation of a circuit-breaker initiated by a release

3.4 Making and breaking characteristics

NOTE See Annex B.

3.4.1 **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: The instant of initiation of the opening operation is specified by the manufacturer for all the opening commands other than overcurrent.

Note 2 to entry: The opening time includes the operating time of any auxiliary equipment necessary to open the circuit-breaker and forming an integral part of the circuit-breaker.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-36, modified – Note 1 to entry has been modified and Note 2 to entry has been added.]

3.4.2 **prospective current**, <of a circuit and with respect to a switching device or a fuse>

current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: This term is commonly associated with fault conditions.

Note 2 to entry: The prospective current is composed of an RMS AC value plus a DC component (if any).

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modified – Notes to entry have been replaced.]

3.4.3 **prospective peak current**

peak value of a prospective current during the transient period following initiation

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-02, modified – Note has been deleted.]

3.4.4**prospective symmetrical current**, <of an AC circuit>

prospective current when it is initiated at such an instant that no transient phenomenon follows the initiation

Note 1 to entry: The prospective symmetrical current is expressed by its RMS value.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-03, modified – Note 1 has been deleted.]

3.4.5**breaking current**, <of a switching device or a fuse >

current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-07]

3.4.6**breaking capacity**, <of a switching device or a fuse>

value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-08, modified – Notes have been deleted.]

3.4.7**making capacity**, <of a switching device or a fuse>

value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-09, modified – Note has been deleted.]

3.4.8**short-circuit making capacity**

making capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-10]

3.4.9**short-circuit breaking capacity**

breaking capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-11]

3.4.10**short-time withstand current**

current that a circuit or a switching device in the closed position can carry during a specified short time under specified conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-17]

3.4.11**peak withstand current**

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-18]

3.4.12**recovery voltage**

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-25, modified – Note has been deleted.]

3.4.13**transient recovery voltage**

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: The transient recovery voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and the switching device.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-26, modified – The second sentence of Note 1 to entry has been deleted. Note 2 to entry has been deleted.]

3.4.14**prospective transient recovery voltage**, <of a circuit>

transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

Note 1 to entry: The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-29]

3.4.15**power-frequency recovery voltage**

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-27]

3.5 Abbreviated terms

AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
RMS	Root Mean Square (value)
RRRV	Rate of Rise of Recovery Voltage
TRV	Transient Recovery Voltage

4 Classification

This clause is intended to list the characteristics of a circuit-breaker on which information is given by the manufacturer and which shall be verified by testing where relevant.

The circuit-breakers are classified:

- according to their operational frequency C1, C2 or C3. The characteristics of these operational frequencies are given in 5.4;
- according to the type of design, i.e. outdoor or indoor circuit-breaker;
- according to the degree of protection provided by the enclosure (see IEC 60529).

5 Characteristics

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 values and limiting values for the main circuit (5.3);
- operational frequencies (5.4);
- electric and pneumatic control circuits (5.5);
- electric and pneumatic auxiliary circuits (5.6);
- overcurrent release (5.7);
- peak value of the recovery voltage (5.8).

5.2 Type of circuit-breaker

It is necessary to state:

- the kind of device (e.g. air-blast circuit-breaker, air circuit-breaker, vacuum circuit-breaker, gas circuit-breaker, oil circuit-breaker, semiconductor circuit-breaker, etc.);
- the type of design (see Clause 4);
- the degree of protection provided by the enclosure (see Clause 4);
- operational features (e.g. trip-free circuit-breaker direct or indirect overcurrent release, time-delay overcurrent release).

5.3 Rated values and limiting values for the main circuit

5.3.1 General

Rated values are assigned by the manufacturer but it is not necessary to establish all the ratings listed.

5.3.2 Rated voltages

A component is defined by the following rated voltages given in 5.2 of IEC 60077-1:2017:

- rated operational voltage (U_r);

NOTE 1 A circuit-breaker has more than one rated operational voltage or has a rated operational voltage range.

- rated insulation voltage (U_{Nm});

NOTE 2 When no rated insulation voltage has been assigned to a circuit-breaker, the rated insulation voltage is considered to be equal to the highest value of the rated operational voltage.

- rated impulse voltage (U_{Ni});
- power-frequency test voltage (U_a).

5.3.3 Rated currents

A component is defined by the following rated currents given in 5.4 of IEC 60077-1:2017 and 5.3.3 of IEC 60077-2:2017:

- rated operational current (I_r) at the rated power factor $T2$ (see 5.3.5);

NOTE 1 A circuit-breaker can have more than one rated operational current or can have a rated operational current range.

- conventional free air thermal current (I_{th});
- conventional free air thermal current for DC (I_{th_DC});

NOTE 2 The conventional free air thermal current for DC is the maximum value of the DC test current to be used for temperature rise tests of equipment in free air at the maximum ambient air temperature.

NOTE 3 AC circuit-breaker used for AC-DC dual system electric rolling stock can have a different thermal current for DC. For DC system only conducting performance is relevant.

- conventional enclosed thermal current (I_{the});
- rated short-time withstand current (I_{CW});
- rated peak withstand current (I_P).

NOTE 4 Where the circuit-breaker is used to energize and protect a transformer or an inductor or a reactive filter circuit, the inrush of current on energization can contain a large and prolonged DC component.

5.3.4 Rated operational frequency

The rated operational frequency (f_r) of a circuit-breaker is the frequency relevant to the rated operational voltage (see 5.5 of IEC 60077-1:2017).

A circuit-breaker may have more than one rated operational frequency.

5.3.5 Rated power factors

The rated power factors are used to characterize the performance as follows:

- 0,1 for short-circuit conditions ($T1$);
- 0,8 for normal service conditions ($T2$).

The rated power factor for the short-circuit is dependent on the electrical characteristics of the sub-station, the supply lines to the vehicle and the load.

If necessary, other power factor values may be defined by agreement between the manufacturer and the user.

5.3.6 Short-circuit characteristics

5.3.6.1 Rated peak withstand current

The rated peak withstand current (I_P) is the peak current associated with the first major loop of the rated short-time withstand current that the switchgear and controlgear can carry in the closed position under its service conditions.

The rated peak withstand current is obtained by multiplying the RMS value of the rated short-time withstand current with a peak factor. This peak factor is a function of the DC time constant of the network and the rated frequency. The preferred value of the peak factor is 2,5.

5.3.6.2 Rated short-circuit making capacity

The manufacturer shall declare the rated short-circuit making current corresponding to the power factor $T1$.

The rated short-circuit making capacity of a circuit-breaker is the peak value (I_P) of the making current corresponding to the rated operational voltage. The circuit-breaker shall satisfy the rated short-circuit making test specified in 9.3.4 and shall be capable of subsequent operation.

5.3.6.3 Rated short-circuit breaking capacity

The manufacturer shall declare the rated short-circuit breaking current corresponding to the power factor $T1$.

It is the highest short-circuit current which the circuit-breaker shall be capable of breaking under the conditions of test specified in this document in a circuit having a power-frequency recovery voltage corresponding to the rated operational voltage and having a transient recovery voltage equal to the rated value specified in 5.3.6.4.

The rated short-circuit breaking current is characterized by two values:

- the RMS value of its AC component, termed “rated short-circuit current”;
- and the percentage DC component.

NOTE If the DC component does not exceed 20 %, the rated short-circuit breaking capacity is characterized only by the RMS value of its AC component. See also Annex B.

The circuit-breaker shall be capable of breaking any short-circuit current up to its rated short-circuit breaking current containing any AC component up to the rated value and associated with it any percentage DC component up to that specified, under the conditions mentioned above.

The circuit-breaker shall satisfy the rated short-circuit breaking test specified in 9.3.4 and shall be capable of subsequent operation.

At voltages below the rated operational voltage, it shall be capable of breaking its rated short-circuit breaking current.

5.3.6.4 Rated transient recovery voltage

The rated transient recovery voltage for a short-circuit is related to the rated short-circuit breaking capacity in accordance with 5.3.6.3. It is the reference voltage which constitutes the limit of the prospective transient recovery voltage of circuits which the circuit-breaker shall be capable of breaking in the event of a short-circuit.

Standard values of transient recovery voltage (TRV) are given in Table 1.

Table 1 also indicate values of rate of rise of recovery voltage (RRRV), taken as u_c/t_3 , which together with TRV peak values u_c may be used for purposes of specification of TRV.

The values given in Table 1 are prospective values. They apply to railway on board circuit-breakers in traction systems consisting of transformers, lines and cables.

Where a circuit-breaker has to operate under more severe conditions of TRV than those in Table 1, these shall be identified in the purchaser's specification.

Table 1 – Standard values of transient recovery voltage – Representation by two parameters

Nominal voltage	Maximum permanent voltage	First- pole-to-clear factor	Amplitude factor	TRV peak value	Time	Time delay	Voltage	Time	RRRV
U_n kV	U_{max1}^a kV	k_{pp} p.u.	k_{af} p.u.	u_c kV	t_3 μs	t_d μs	u' kV	t' μs	u_c/t_3 kV/μs
12 also 12,5	N/A ^b	1	1,4	25	73	11	8	35	0,34
15	17,25	1	1,4	34	80	15	11	39	0,42
20	22,0	1	1,4	44	92	14	15	45	0,47
25	27.5	1	1,4	54	95	14	18	46	0,57
25	30,0	1	1,4	62	103	15,5	21	50	0,60

where:

$$u_c = \sqrt{2} \times k_{pp} \times k_{af} \times U_{max1};$$

$$u_c = u_c / 3;$$

$$t_d = 0,15 \times t_3.$$

NOTE $k_{pp} = 1$ is used for a single phase system.

^a See IEC 60850.

^b N/A not applicable.

5.3.6.5 Rated duration of short-circuit

The rated duration of short-circuit is the interval of time for which a circuit-breaker shall be capable of carrying, in the closed position, a current equal to its rated short-time withstand current.

The standard value of rated duration of short-circuit is 1 s.

If it is necessary, a value lower or higher than 1 s may be chosen. The recommended values are 0,5 s, 2 s and 3 s.

5.4 Operational frequencies

The operational frequencies are used to characterize the performance capability as given in Table 2.

The operational frequencies C1, C2 and C3 are defined as:

- C1: light operational frequency (e.g. the circuit-breaker opens only when a short-circuit is detected);
- C2: medium operational frequency (e.g. in addition to C1 the circuit-breaker opens by a command produced by exceeding a predetermined limiting value, for example due to overload conditions, etc.);
- C3 heavy operational frequency (e.g. in addition to C2, the circuit-breaker opens for other reasons, for example at each gap section, each sectioning point, each end of service, etc.).

5.5 Electric and pneumatic control circuits

The characteristics of the electric and pneumatic control circuits are given in 5.6 and 5.7 of IEC 60077-2:2017.

5.6 Electric and pneumatic auxiliary circuits

The characteristics of the auxiliary circuits are the number and nature of the contacts (“a” contact, “b” contact, etc.) of each of these circuits and their rated characteristics. These characteristics are given in 5.9 and 5.10 of IEC 60077-2:2017.

5.7 Overcurrent release

The following characteristics shall be declared by the manufacturer for each overcurrent release:

- type of overcurrent release (e.g. direct, indirect, time-delay, etc.);
- an anti-pumping device may be included.
- current setting (or setting range);
- characteristics of the opening time as a function of the quantities which influence the release.

5.8 Recovery voltages

The manufacturer shall specify the peak value of the recovery voltage when it is tested in accordance with the provisions of the making and breaking tests of sequences I and II of Table 3.

Under no circumstances shall this value exceed that of the rated impulse withstand voltage of the circuit-breaker.

6 Product information

6.1 Component documentation

This information shall be given in the manufacturer's catalogue or manual.

6.1 of IEC 60077-2:2017 applies supplemented by the following:

- rated operational voltage of the control circuit of built-in releases and rated frequency if applicable;
- current setting or current setting range of the relevant overcurrent releases (e.g. direct or indirect overcurrent release, definite time-delay overcurrent release, etc.);
- opening time.

6.2 Marking

The data or identification shall be marked in accordance with 6.2 of IEC 60077-2:2017.

7 Normal service conditions

These conditions are given in Clause 7 of IEC 60077-1:2017.

8 Constructional and performance requirements

8.1 Constructional requirements

These requirements are given in 8.1 of IEC 60077-2:2017.

8.2 Performance requirements

8.2.1 Operating conditions

These requirements are given in 8.2.1 of IEC 60077-2:2017.

8.2.2 Temperature limits

These requirements are given in 8.2.2 of IEC 60077-2:2017.

8.2.3 Operation following inactivity

These requirements are given in 8.2.3 of IEC 60077-1:2017.

8.2.4 Electromagnetic compatibility (EMC)

These requirements are given in 8.2.4 of IEC 60077-1:2017.

8.2.5 Acoustic noise emission

These requirements are given in 8.2.5 of IEC 60077-1:2017.

8.2.6 Clearances

These requirements are given in 8.2.6 of IEC 60077-1:2017.

8.2.7 Creepage distances

These requirements are given in 8.2.7 of IEC 60077-1:2017.

8.2.8 Switching overvoltages

These requirements are given in 8.2.8 of IEC 60077-1:2017.

In addition the manufacturer shall declare recovery voltages generated by the breaking tests of sequences I and II of Table 3.

8.2.9 Operational performance capability

The circuit-breaker shall be capable of complying (as a function of the operational frequency) with the provisions of Table 2 under the test conditions stated in 9.3.3.6.

Each operating cycle shall consist either of a closing operation followed by an opening operation (cycle without current), or a making operation followed by a breaking operation (cycle with current).

The total number of operating cycles shall consist of performing a number of operating cycles without current, specified in Table 2, column 2, followed by a number of operating cycles with current, specified in Table 2, column 3.

The rate of operating cycles, selected by mutual agreement between the manufacturer and the user, is chosen to keep all parts of the circuit-breaker within acceptable limits of temperature rise and is to be mentioned in the test report.

Table 2 – Operational performance capability

Column 1	Column 2	Column 3
Operational frequency	Total number of operating cycles	
	Without current	With current
C1	10 000	0
C2	100 000	200
C3	200 000	200

NOTE During each operating cycle, the circuit-breaker remains in the closed position for a sufficient time to ensure that the current is fully established, but not exceeding 2 s.

8.2.10 Ability to withstand vibration and shock

The circuit-breaker shall be capable of withstanding the vibration and shock given by test requirements (see 9.3.5.2 and 9.3.5.3).

8.2.11 Ability to make and break under short-circuit conditions

The circuit-breaker shall be capable of satisfying the short-circuit tests under the following conditions:

- current setting of the overcurrent release equal to the maximum value of the current setting range, if applicable;
- rated short-circuit breaking current at the rated operational voltage as stated in 5.3.6.3;
- recovery voltage equal to the rated operational voltage;
- transient recovery voltage equal to the rated transient recovery voltage as stated in 5.3.6.4;
- a sequence of operations: O – t_1 – CO – t_2 – CO;
 - O representing a breaking operation;
 - CO representing a making operation followed by a breaking operation after the appropriate opening time;
 - t_1 representing the time interval between the first opening and the first closing;
 - t_2 representing the time interval between the second opening and the second closing.

Unless otherwise agreed between the manufacturer and the user, t_1 and t_2 are 180 s.

9 Tests

9.1 Kind of tests

9.1.1 General

9.1.1 of IEC 60077-1:2017 applies except that sampling tests are not permissible for circuit-breakers.

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

- type tests (see 9.1.2);
- routine tests (see 9.1.3);
- investigation tests (see 9.1.4).

9.1.2 Type tests

The type tests comprise the following:

- verification of constructional requirements (see 9.2.2);
- verification of performance requirements (see 9.3).

9.1.3 Routine tests

The routine tests comprise the following:

- verification of constructional requirements (see 9.2.3);
- verification of performance requirements (see 9.4).

9.1.4 Investigation tests

These are supplementary tests to the type tests for a special application. They form the subject of a programme agreed between the manufacturer and the user, and may concern:

- influence of harmonics on the temperature rise and breaking characteristics;
- temperature rise for temporary overload conditions.

9.2 Verification of constructional requirements

9.2.1 General

The compliance of the circuit-breaker with the constructional requirements given in the appropriate parts of 8.1 of IEC 60077-1:2017 shall be proven prior to verification of the performance requirements as detailed in 9.3 and 9.4. The compliance of properties where testing is not appropriate shall be by visual examination, measurements, etc.

9.2.2 Type tests

Verification of compliance with the constructional requirements for the type test concerns:

- physical properties; a check shall be made that the circuit-breaker conforms to the drawings (e.g. dimensions, materials, electrical risks, protective bonding, etc.);
- clearance and creepage distances (see 9.3.3.2.1 and 9.3.3.2.3 of IEC 60077-1:2017);
- terminals and connecting capacity (tested as part of performance requirements in accordance with 9.3.3.8).

9.2.3 Routine tests

Verification of compliance with the constructional requirements for the routine test concerns:

- visual examination (compliance of the manufacture and assembly with the drawings);
- measurements of resistances. The tests required in 9.2.3 of IEC 60077-1:2017 shall be applied. The measured values for main and control circuits and the ambient temperature shall be recorded in the routine test report.

NOTE For measurement of main circuit resistance see also 9.3.4.2.

9.3 Type tests for verification of performance requirements

9.3.1 Test sequences

Type tests are grouped together in a number of test sequences as shown in Table 3.

For each sequence, the tests shall be carried out in the order listed in Table 3.

A new sample may be used for each sequence.

A routine test (see 9.1.3) shall be carried out on every sample before type test.

Table 3 – List of type test sequences for performance requirements

Test sequences	Tests	Subclause
I – General performance characteristics (9.3.3)	Operating limits	9.3.3.2
	Measurement of the resistance of circuits	9.3.3.3
	Temperature rise	9.3.3.4
	Dielectric properties	9.3.3.5
	Operational performance capability	9.3.3.6
	Verification of dielectric withstand	9.3.3.7
	Verification of temperature rise	9.3.3.8
	Verification of tripping operation	9.3.3.9
II – Rated short-circuit making and breaking capacities (9.3.4)	Measurement of the resistance of the main circuit	9.3.4.2
	Short-time withstand current and peak withstand current	9.3.4.4
	Ability to make and break under short-circuit conditions	9.3.4.5
	Verification of dielectric withstand	9.3.4.6
	Verification of temperature rise	9.3.4.7
	Verification of tripping operation	9.3.4.8
III – Ability to withstand vibration and shock (9.3.5)	Vibration	9.3.5.2
	Shock	9.3.5.3
	Verification of mechanical operation	9.3.5.4
	Verification of tripping operation	9.3.5.5
	Verification of dielectric withstand	9.3.5.6
IV – Climatic conditions	Environmental tests (wet, dry heat, damp heat, cold, ice, etc.)	9.3.6
V – Other tests (if required)	Electromagnetic compatibility (EMC)	9.3.7
	Acoustic noise emission	9.3.7

9.3.2 General test conditions

The circuit-breakers to be tested shall comply in all details with the drawings of the type which they represent.

During a test sequence no maintenance or repair is permissible.

Each of the sequences (described in Table 3) shall be made on a circuit-breaker in a clean and new condition (or considered as such after a repair).

The tests shall be performed at the rated operational values (current, voltage, frequency, air pressure) for the circuits (main, control and auxiliary) and in accordance with the values indicated in 5.3, 5.5 and 5.6.

The test values shall be within the tolerances indicated in Table 4.

Table 4 – Tolerances on test values

All tests	Tests under normal load conditions	Tests under short-circuit conditions
Main circuit Voltage: $\begin{matrix} +5 \\ 0 \end{matrix}$ Frequency: $\pm 10 \%$	Main circuit Current: $\begin{matrix} +10 \\ 0 \end{matrix} \%$ Power factor: $\pm 0,05$	Main circuit Current: $\begin{matrix} +10 \\ 0 \end{matrix} \%$ Power factor: $\begin{matrix} 0 \\ -0,05 \end{matrix}$
Control and auxiliary circuit Current: $\pm 5 \%$ Voltage: $\pm 5 \%$ Air pressure: $\pm 5 \%$		

For all the tests, the ambient air temperature shall be measured and recorded in the test report.

The complete circuit-breaker under test shall be mounted together with its external associated over-voltage protection when appropriate:

- in its integral enclosure if it has one;
- or in an enclosure representing the conditions of installation when these are prescribed by the manufacturer;
- or under the conditions of installation envisaged on the rolling stock.

9.3.3 Test sequence I: General performance characteristics

9.3.3.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.3.2 Operating limits

The tests required in 9.3.3.2 of IEC 60077-2:2017 shall be carried out.

Air-tightness tests for pneumatic equipment required in 9.3.4.2 of IEC 60077-1:2017 shall be carried out. The test shall be done for all the temperature conditions, at least at the lowest and the highest ambient temperatures. For low temperature different criteria may be used.

9.3.3.3 Measurement of the resistance of circuits

The tests required in 9.3.3.3 of IEC 60077-2:2017 shall be carried out.

NOTE The value before the test can be taken from the routine test result.

9.3.3.4 Temperature rise

The tests required in 9.3.3.4 of IEC 60077-2:2017 shall be carried out at the conventional free air thermal current, and at the conventional free air thermal current for DC if applicable.

9.3.3.5 Dielectric properties

The tests required in 9.3.3.5 of IEC 60077-2:2017 shall be carried out.

The insulation resistance should be measured before starting the dielectric tests, if requested by the end user. Unless agreed between the user and the manufacturer about the specified value, the insulation resistance shall be not less than 100 M Ω by a megohmmeter applying a DC voltage of at least 1 000 V between the high voltage conductive parts and the earth and between open contacts.

9.3.3.6 Operational performance capability

The tests shall be performed to verify compliance with the requirements of 8.2.9.

The operations of making and breaking shall be carried out at the rated operational current, the rated operational voltage and for a power factor of 0,8. For details of a test circuit see Annex A.

At the end of the tests, no maintenance operation shall be carried out before the verifications required in 9.3.3.7, 9.3.3.8 and 9.3.3.9.

NOTE The total number of operating cycles includes operations without and with current as appropriate for the characteristics.

9.3.3.7 Verification of dielectric withstand

After the test described in 9.3.3.6, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

9.3.3.8 Verification of temperature rise

After the verification described in 9.3.3.7, resistance measurement shall be carried out according to 9.3.3.3 of IEC 60077-2:2017.

The verification of the temperature rise according to 9.3.3.4 is required only when the resistance of the main circuit (without maintenance) has increased by more than 50 % of the value before the test according to 9.3.3.3 of IEC 60077-2:2017. A small number of no-load operations are allowed in an endeavour to bring the resistance down below this figure; if the test has to be performed, then the temperature rise limits and temperature limits on the contacts mentioned in Table 2 of IEC 60077-2:2017 are allowed to be exceeded by 10 K.

NOTE The number of no-load operations is 10 as a maximum.

For the measurement points, refer to 9.3.2.2 of IEC 60077-1:2017.

9.3.3.9 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the verification described in 9.3.3.8, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.4 Test sequence II: Rated short-circuit making and breaking capacities

9.3.4.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.4.2 Measurement of the resistance of the main circuit

The tests required in 9.3.3.3 of IEC 60077-2:2017 shall be carried out.

NOTE The value before the test can be taken from the routine test result.

9.3.4.3 Circuit for making and breaking capacity tests

For details of a test circuit see Annex A.

9.3.4.4 Short-time withstand current and peak withstand current

This test shall be carried out according to 7.6 of IEC 62271-1:2017 using the standard value of rated duration of short-circuit.

9.3.4.5 Ability to make and break under short-circuit conditions

This test shall be carried out according to 6.106 of IEC 62271-100:2008/AMD1:2012/AMD2:2017 for test duties T10, T30, T60, T100s and T100a, but using the sequence of operation given in 8.2.11.

For test duties T100s and T100a, the specified TRV values are given by the standard values in Table 1.

For test duties T10, T30 and T60, the specified TRV values are given in Table 5.

Table 5 – Standard values of prospective transient recovery voltage – Representation by two parameters

Nominal voltage	Maximum permanent voltage	Test duty	TRV peak value	Time	Time delay	Voltage	Time	RRRV
U_n kV	U_{max1}^a kV		u_c kV	t_3 μs	t_d μs	u' kV	t' μs	u_c/t_3 kV/μs
12 and 12,5	N/A ^b	T60	27	31	5	9	15	0,85
		T30		16	2		8	1,69
		T10						
15	17,25	T60	36	35	5	12	17	1,03
		T30		17	3		8	2,13
		T10						
20	22,0	T60	47	40	6	16	19	1,16
		T30		20	3		10	2,32
		T10						
25	27,5	T60	58	40	6	19	20	1,43
		T30		20	3		10	2,87
		T10						
25	30,0	T60	62	51	5	21	22	1,22
		T30						
		T10						

Where:

$$u_c = \sqrt{2} \times 1,5 \times 1,0 \times U_{max1};$$

$$u' = u_c / 3;$$

$$t_d = t_3 \times 0,15.$$

^a See IEC 60850.

^b N/A not applicable.

NOTE 1 For definitions of test duties T10, T30, T60, T100s and T100a, refer to IEC 62271-100:2008/AMD1:2012/AMD2:2017, 6.104.5.

The prospective transient recovery voltage wave of the test circuit shall at no time have its envelope below the specified reference line.

For T10 and T30, it may be difficult to meet the small values of time t_3 . The shortest time that can be met should be used.

The transient recovery voltage during the test shall be recorded.

NOTE 2 The test transient recovery voltage will differ from the prospective transient recovery voltage wave of the test circuit upon which the performance requirements are based to a degree depending upon the characteristics of the circuit-breaker.

9.3.4.6 Verification of dielectric withstand

After the test described in 9.3.4.5, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

9.3.4.7 Verification of temperature rise

The resistance measurement and the verification of temperature rise described in 9.3.3.8 shall be carried out.

9.3.4.8 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the verification described in 9.3.4.7, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.5 Test sequence III: Ability to withstand vibration and shock

9.3.5.1 General

This sequence shall include the tests and verifications listed in Table 3.

9.3.5.2 Vibration

The vibration tests shall be carried out in accordance with the relevant method of IEC 61373.

The test shall be carried out so that:

- both operational states are tested;
- the distribution of these states shall be 50 % open and 50 % closed;
- the circuit-breaker shall not change state during the functional vibration test.

9.3.5.3 Shock

After the tests described in 9.3.5.2, the shock tests shall be carried out in accordance with the relevant method of IEC 61373. The test shall include both operational states and the circuit-breaker shall not change state during the test.

9.3.5.4 Verification of mechanical operation

After the test described in 9.3.5.3 the mechanical operation shall be checked in accordance with the requirements of 9.4.2 of IEC 60077-2:2017.

9.3.5.5 Verification of tripping operation

This test is only applicable when the circuit-breaker has built-in releases.

After the test described in 9.3.5.4, the current settings of the releases shall be checked in accordance with 9.4.3.

Each setting shall not differ by more than 10 % of its previous value measured during the routine test.

9.3.5.6 Verification of dielectric withstand

After the test described in 9.3.5.5, the circuit-breaker shall be capable of withstanding the power frequency test voltage reduced to 75 % of the value required in 9.4.5.

9.3.6 Test sequence IV: Climatic conditions

The external surfaces of insulation of outdoor circuit-breakers shall be subjected to wet tests under the standard test procedure given in 4.4 of IEC 60060-1:2010.

If by agreement between the user and the manufacturer other tests are required, these tests shall be selected from 9.3.7 of IEC 60077-2:2017.

The test under severe ice conditions is applicable only to outdoor circuit-breakers having moving external parts and for which a class of 10 mm or 20 mm of ice thickness is specified. The test shall be performed under the conditions described in IEC 62271-102.

9.3.7 Test sequence V: Other tests

This sequence may include supplementary tests such as:

- electromagnetic compatibility (EMC);
- acoustic noise emission.

When tests are required, 9.3.8 of IEC 60077-2:2017 shall be applied.

9.4 Routine tests for verification of performance requirements

9.4.1 General

The following routine tests shall be carried out on each circuit-breaker:

- mechanical operation (see 9.4.2);
- calibration of releases if applicable (see 9.4.3);
- air tightness, if applicable (see 9.4.4);
- dielectric withstand (see 9.4.5).

The measured values shall be recorded in the routine test report.

9.4.2 Functional test

The tests required in 9.4.2 of IEC 60077-2:2017 shall be applied.

9.4.3 Calibration of releases

This test is only applicable when the circuit-breaker has built-in releases.

A check shall be made that the current causing a tripping operation of the circuit-breaker is within a tolerance of $\pm 10\%$ for any marked value of the current range using a steady state current.

NOTE 1 The $\pm 10\%$ tolerance includes a $\pm 5\%$ allowance for the calibration marking in addition to the setting tolerance.

NOTE 2 Steady state current means an RMS current with a rise of less than 200 A/s.

9.4.4 Air-tightness (for pneumatic circuit-breaker)

The tests required in 9.4.4 of IEC 60077-2:2017 shall be applied.

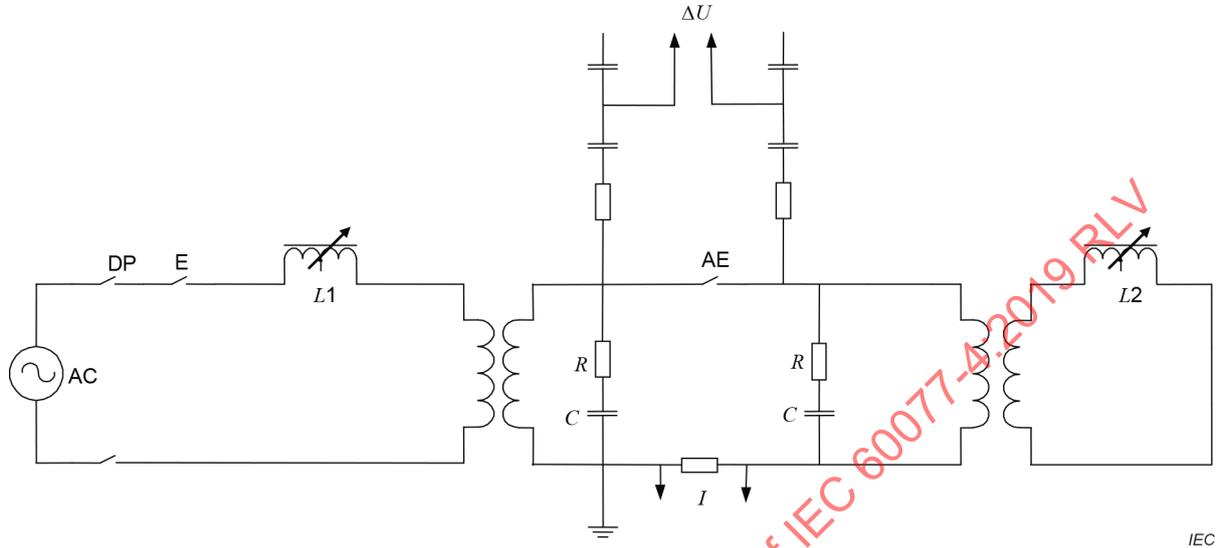
9.4.5 Dielectric withstand

The tests required in 9.4.5 of IEC 60077-2:2017 shall be applied.

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Annex A
(informative)

Test circuit to verify the making and breaking capacities



Key

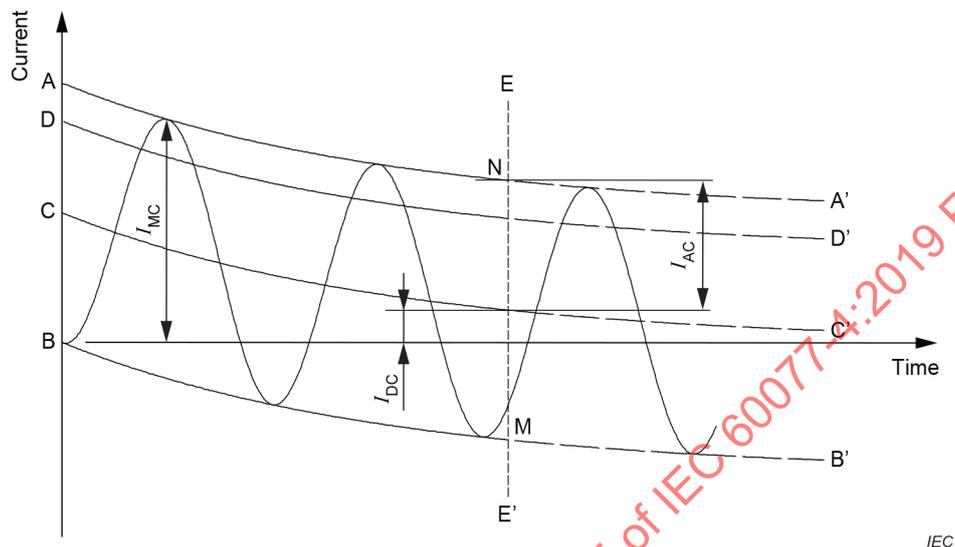
DP	Master breaker	R	Resistor for transient recovery voltage control
E	Making breaker	C	Capacitor for transient recovery voltage control
AE	Breaker being tested	$I, \Delta U$	Measurement of currents and voltages
AC	Test supply	$L1, L2$	Inductance

Figure A.1 – Diagram of the test circuit

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Annex B (informative)

Determination of short-circuit making and breaking currents, and of percentage DC component



IEC

Key

AA'; BB' Envelope of current-wave

CC' Displacement of current-wave zero line at any instant

DD' RMS value of the AC component of current at any instant measured from CC'

EE' Instant of contact separation (initiation of the arc)

I_{MC} Making current

I_{AC} Peak current of AC component at instant EE'

$I_{AC}/\sqrt{2}$ RMS value of the AC component of current at instant EE'

I_{DC} DC component of current at instant EE'

$\frac{I_{DC} \times 100}{I_{AC}}$ Percentage value of the DC component

**Figure B.1 – Determination of short-circuit making and breaking currents,
and of percentage DC components**

Bibliography

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60850, *Railway applications – Supply voltage of traction systems*

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 4: Composants électrotechniques – Règles pour disjoncteurs à courant monophasé

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La Norme internationale IEC 60077-4 a été établie par le comité d'études 9 de l'IEC: Matériels et systèmes électriques ferroviaires.

Cette deuxième édition annule et remplace la première édition, parue en 2003. Elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) les valeurs normalisées des tensions transitoires de rétablissement et la procédure d'essai sont revues;
- b) modification de la procédure de vérification de l'échauffement;

- c) ajout de l'essai d'étanchéité comme essai de type et du mesurage de la résistance d'isolement.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
9/2538/FDIS	9/2554/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Il convient qu'il soit lu conjointement avec l'IEC 60077-1 et l'IEC 60077-2.

Une liste de toutes les parties de la série IEC 60077, publiées sous le titre général *Applications ferroviaires – Équipements électriques du matériel roulant*, peut être consultée sur le site web de l'IEC.

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APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 4: Composants électrotechniques – Règles pour disjoncteurs à courant monophasé

1 Domaine d'application

En complément des exigences générales de l'IEC 60077-2, la présente partie de l'IEC 60077 donne les règles relatives aux disjoncteurs à courant monophasé dont les contacts principaux sont destinés à être raccordés à des lignes aériennes de contact à courant monophasé. La tension nominale de ces circuits est conforme à l'IEC 60850.

En complément de l'IEC 60077-2, le présent document précise particulièrement:

- a) les caractéristiques des disjoncteurs;
- b) les conditions de service que les disjoncteurs supportent du point de vue:
 - du fonctionnement et du comportement en service normal;
 - du fonctionnement et du comportement en cas de court-circuit;
 - des propriétés diélectriques;
- c) les essais de conformité des composants avec les caractéristiques dans les conditions de service ainsi que les méthodes d'essai correspondantes à utiliser;
- d) les informations à donner ou à marquer sur le disjoncteur.

NOTE 1 Les disjoncteurs qui font l'objet du présent document peuvent être équipés de dispositifs d'ouverture automatique dans des conditions prédéterminées autres que celles de la surcharge, comme une tension insuffisante ou l'inversion de la direction du flux de puissance, par exemple. Le présent document ne traite pas de la vérification de tels fonctionnements dans de telles conditions prédéterminées.

NOTE 2 L'incorporation de composants électroniques ou de sous-ensembles électroniques dans les composants électrotechniques est maintenant une pratique courante.

Bien que le présent document ne soit pas applicable aux matériels électroniques, la présence de composants électroniques n'est pas une raison suffisante pour exclure ces composants électrotechniques du domaine d'application du document.

Les sous-ensembles électroniques inclus dans les disjoncteurs sont conformes à la norme correspondante applicable à l'électronique (IEC 60571).

NOTE 3 Après accord entre l'utilisateur et le constructeur, certaines de ces règles sont utilisées pour les composants électriques installés dans des véhicules autres que ceux du matériel roulant ferroviaire, telles que les locomotives pour les mines, les trolleybus, etc. Dans ces cas, des exigences supplémentaires peuvent être nécessaires.

Le présent document ne couvre pas les disjoncteurs industriels conformes à l'IEC 62271-100. Pour ces derniers, dans le but d'obtenir un fonctionnement satisfaisant, le présent document est employé uniquement pour spécifier les exigences particulières relatives au matériel roulant. Dans de tels cas, un document spécifique indique les exigences complémentaires auxquelles les disjoncteurs industriels se conforment, par exemple:

- pour être adaptés (par exemple tension de commande, conditions d'environnement, etc.);
- ou pour être installés et utilisés de sorte qu'ils n'aient pas à subir les conditions particulières du matériel roulant;
- ou pour subir des essais complémentaires afin de montrer que ces composants peuvent supporter de façon satisfaisante les conditions du matériel roulant.

2 Références normatives

Les documents suivants cités dans le texte 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 60060-1:2010, *Technique des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60077-1:2017, *Applications ferroviaires – Equipements électriques du matériel roulant – Partie 1: Conditions générales de service et règles générales*

IEC 60077-2:2017, *Applications ferroviaires – Equipements électriques du matériel roulant – Partie 2: Composants électrotechniques – Règles générales*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 61373, *Applications ferroviaires – Matériel roulant – Essais de chocs et vibrations*

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-100:2008, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-102, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

3 Termes, définitions et termes abrégés

Pour les besoins du présent document, les termes et définitions donnés à l'Article 3 de l'IEC 60077-1:2017 et à l'Article 3 de l'IEC 60077-2:2017, ainsi que les suivants s'appliquent.

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 <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.1 Composants

3.1.1

disjoncteur pour l'intérieur

disjoncteur qui n'est conçu que pour être protégé par son installation contre le vent, la pluie, la neige, les pollutions, les conditions anormales, la glace et le givre

3.1.2

disjoncteur pour l'extérieur

disjoncteur convenant pour l'installation en plein air, c'est-à-dire capable de supporter le vent, la pluie, la neige, les pollutions, la condensation, la glace et le givre

3.1.3

disjoncteur à huile

disjoncteur dont les contacts s'ouvrent et se ferment dans l'huile

Note 1 à l'article: Les disjoncteurs à faible volume d'huile à cuve sous tension et les disjoncteurs à huile à cuve mise à la terre sont des exemples caractéristiques de disjoncteurs à huile.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-28]

3.1.4

disjoncteur à vide

disjoncteur dont les contacts s'ouvrent et se ferment dans une enceinte où règne un vide poussé

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-29]

3.1.5

disjoncteur à air comprimé, <pour matériel roulant>

disjoncteur dont les contacts s'ouvrent dans de l'air comprimé

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-32, modifié – "à gaz comprimé" a été supprimé. "dans lequel le gaz utilisé est l'air" a été remplacé par "dont les contacts s'ouvrent dans de l'air comprimé".]

3.1.6

disjoncteur à air

disjoncteur dont les contacts s'ouvrent et se ferment dans de l'air

3.1.7

disjoncteur à gaz

disjoncteur dont les contacts s'ouvrent et se ferment dans un gaz autre que l'air, sous pression ou à la pression atmosphérique

Note 1 à l'article: Le disjoncteur à l'hexafluorure de soufre est un exemple de disjoncteur à gaz.

3.1.8

disjoncteur à semiconducteur

disjoncteur conçu pour établir et interrompre le courant dans un circuit électrique au moyen de la conductivité contrôlée d'un semiconducteur

Note 1 à l'article: Des contacts mécaniques peuvent être associés à ces appareils à semiconducteur.

[SOURCE: IEC 60050-811:2017, 811-29-42]

3.2 Parties de composant

3.2.1

Déclencheur, <pour un disjoncteur>

dispositif qui libère les organes de retenue et qui permet l'ouverture ou la fermeture du disjoncteur

Note 1 à l'article: Un disjoncteur peut être activé par plusieurs déclencheurs, chacun d'eux fonctionnant dans des conditions spécifiées.

Note 2 à l'article: Ces déclencheurs peuvent être électriquement ou mécaniquement raccordés à un appareil de connexion.

[SOURCE: IEC 60050-811:2017, 811-29-44]

3.2.2

déclencheur à maximum de courant

déclencheur qui permet l'ouverture, avec ou sans retard, d'un appareil mécanique de connexion, lorsque le courant dans le déclencheur dépasse une valeur prédéterminée

Note 1 à l'article: Cette valeur peut, dans certains cas, dépendre de la vitesse d'accroissement du courant.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-33]

3.2.3

déclencheur à maximum de courant à retard indépendant

déclencheur à maximum de courant qui fonctionne avec un retard défini, qui peut être réglable, mais est indépendant de la valeur de la surintensité

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-34]

3.2.4

déclencheur direct à maximum de courant

déclencheur à maximum de courant alimenté directement par le courant dans le circuit principal d'un appareil mécanique de connexion

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-36]

3.2.5

déclencheur indirect à maximum de courant <pour un disjoncteur>

déclencheur à maximum de courant amorcé par le courant dans le circuit principal d'un appareil mécanique de connexion par l'intermédiaire d'un capteur de courant

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-37, modifié – "alimenté" et "un transformateur de courant ou d'un shunt" ont été remplacés par "amorcé" et "un capteur de courant".]

3.2.6

dispositif d'antipompage

dispositif qui empêche une refermeture après une manœuvre de fermeture-ouverture pendant toute la durée du maintien de l'ordre de fermeture

Note 1 à l'article: L'ouverture peut être une commande d'ouverture ou un déclenchement libre.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-48, modifié – La NOTE 1 à l'article a été ajoutée.]

3.2.7

Enveloppe, <d'un ensemble>

partie d'un ensemble procurant un degré de protection spécifié du matériel contre les influences externes et un degré de protection spécifié contre l'approche des parties actives ou le contact avec elles ou contre le contact avec des pièces en mouvement

Note 1 à l'article: L'enveloppe peut également fournir une protection des parties environnantes contre l'influence du disjoncteur (par exemple l'arc).

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-13-01, modifié – La NOTE 1 à l'article a été ajoutée.]

3.2.8

enveloppe intégrée

enveloppe faisant partie intégrante du disjoncteur

3.3 Caractéristiques de fonctionnement

3.3.1

disjoncteur à déclenchement libre

disjoncteur dont les contacts mobiles principaux reviennent en position d'ouverture et y demeurent quand la manœuvre (c'est-à-dire le déclenchement) d'ouverture est commandée après le début de la manœuvre de fermeture, même si l'ordre de fermeture est maintenu

Note 1 à l'article: Afin d'assurer une interruption correcte du courant qui peut avoir été établi, il peut être nécessaire que les contacts atteignent momentanément la position de fermeture.

Note 2 à l'article: L'exploitation du déclenchement libre peut nécessiter un dispositif d'antipompage.

3.3.2

courant de réglage <d'un déclencheur à maximum de courant>

valeur du courant de fonctionnement pour laquelle le déclencheur est réglé et par rapport à laquelle ses conditions de fonctionnement sont définies

Note 1 à l'article: Un déclencheur peut avoir plusieurs courants de réglage.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-46, modifié – La NOTE 1 à l'article a été ajoutée.]

3.3.3

domaine du courant de réglage, <d'un déclencheur à maximum de courant>

domaine limité par les valeurs minimale et maximale entre lesquelles on peut choisir la valeur du courant de réglage du déclencheur

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-16-47]

3.3.4

manœuvre de déclenchement

manœuvre d'ouverture d'un disjoncteur amorcée par un déclencheur

3.4 Caractéristiques de fermeture et de coupure

NOTE: Voir Annexe B.

3.4.1

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: Pour chacune des commandes d'ouverture autres que celle à maximum de courant, l'instant de l'origine de la manœuvre d'ouverture sera précisé par le constructeur.

Note 2 à l'article: La durée d'ouverture inclut le temps d'action de l'équipement auxiliaire nécessaire à l'ouverture du disjoncteur quand celui-ci est intégré au disjoncteur.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-36, modifié – La NOTE 1 à l'article a été modifiée et la NOTE 2 à l'article a été ajoutée.]

3.4.2

courant présumé, <d'un circuit et relatif à un appareil de connexion ou à un fusible>

courant qui circulerait dans le circuit si chaque pôle de l'appareil de connexion ou le fusible était remplacé par un conducteur d'impédance négligeable

Note 1 à l'article: Ce terme est communément associé aux conditions de défaut.

Note 2 à l'article: Le courant présumé est composé de la valeur efficace du courant alternatif plus une composante continue (si elle existe).

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modifié – Les NOTES à l'article ont été remplacées.]

3.4.3

valeur de crête du courant présumé

valeur de crête d'un courant présumé pendant la période transitoire qui suit son établissement

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-02, modifié – La NOTE a été supprimée.]

3.4.4

courant symétrique présumé, <d'un circuit à courant alternatif>

courant présumé lorsqu'il est établi à un instant tel qu'aucun phénomène transitoire ne suive l'établissement

Note 1 à l'article: Le courant présumé symétrique est exprimé par sa valeur efficace.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-03, modifié – La NOTE 1 a été supprimée.]

3.4.5

courant coupé, <d'un appareil de connexion ou d'un fusible>

courant dans un pôle d'un appareil de connexion ou dans un fusible évalué à l'instant de l'amorçage de l'arc au cours d'une coupure

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-07]

3.4.6

pouvoir de coupure <d'un appareil de connexion ou d'un fusible>

valeur de courant présumé qu'un appareil de connexion ou un fusible est capable d'interrompre sous une tension fixée dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-08, modifié – Les NOTES ont été supprimées.]

3.4.7

pouvoir de fermeture <d'un appareil de connexion ou d'un fusible>

valeur du courant présumé établi qu'un appareil de connexion est capable d'établir sous une tension donnée et dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-09, modifié – La NOTE a été supprimée.]

3.4.8

pouvoir de fermeture en court-circuit

pouvoir de fermeture pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-10]

3.4.9

pouvoir de coupure en court-circuit

pouvoir de coupure pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-11]

3.4.10

courant de courte durée admissible

courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter pendant un court intervalle de temps spécifié et dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-17]

3.4.11

valeur de crête du courant admissible

valeur de crête du courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-18]

3.4.12

tension de rétablissement

tension qui apparaît entre les bornes d'un appareil de connexion ou d'un fusible après l'interruption du courant

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-25, modifié – La NOTE a été supprimée.]

3.4.13

tension transitoire de rétablissement

tension de rétablissement pendant le temps où elle présente un caractère transitoire appréciable

Note 1 à l'article: La tension transitoire de rétablissement peut être oscillatoire ou non oscillatoire, ou être une combinaison de celles-ci selon les caractéristiques du circuit et de l'appareil de connexion.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-26, modifié – La seconde phrase de la NOTE 1 à l'article a été supprimée. La NOTE 2 à l'article a été supprimée.]

3.4.14

tension transitoire de rétablissement présumée <d'un circuit>

tension transitoire de rétablissement qui suit la coupure du courant présumé symétrique par un appareil de connexion idéal

Note 1 à l'article: La définition implique que l'appareil de connexion ou le fusible, pour lequel la tension transitoire de rétablissement est recherchée, est remplacé par un appareil de connexion idéal, c'est-à-dire dont l'impédance passe instantanément de la valeur zéro à la valeur infinie à l'instant du zéro de courant, c'est-à-dire au zéro "naturel". Pour des circuits ayant plusieurs voies, par exemple un circuit polyphasé, il est en outre admis par hypothèse que la coupure du courant par l'appareil de connexion idéal n'a lieu que sur le pôle considéré.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-29]

3.4.15

tension de rétablissement à fréquence industrielle

tension de rétablissement après la disparition des phénomènes transitoires de tension

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-27]

3.5 Termes abrégés

CEM Compatibilité électromagnétique

RRRV Vitesse d'accroissement de la tension de rétablissement

TRV Tension transitoire de rétablissement