

INTERNATIONAL STANDARD



**Railway Applications – Electric equipment for rolling stock –
Part 3: Electrotechnical components – Rules for DC circuit-breakers**

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INTERNATIONAL STANDARD



**Railway Applications – Electric equipment for rolling stock –
Part 3: Electrotechnical components – Rules for DC circuit-breakers**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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CONTENTS

FOREWORD	4
1 Scope ~~and object~~	6
2 Normative references	7
3 Terms, definitions and abbreviated terms	7
3.1 Components	8
3.2 Component parts	8
3.3 Operational features	10
3.4 Breaking characteristics	10
3.5 Abbreviated terms	13
4 Classification	13
5 Characteristics	13
5.1 List of characteristics	13
5.2 Type of circuit-breaker	13
5.3 Rated values and limiting values for the main circuit	13
5.3.1 General	13
5.3.2 Rated voltages	14
5.3.3 Rated currents	14
5.3.4 Rated time constants	14
5.3.5 ~~Short-circuit characteristics (see also annex B)~~ Rated short-circuit making and breaking capacity	15
5.4 Operational frequencies	15
5.5 Electric and pneumatic control circuits	15
5.6 Electric and pneumatic auxiliary circuits	15
5.7 Overcurrent release	15
5.8 Peak arc voltages	16
6 Product information	16
6.1 Component documentation	16
6.2 Marking	16
7 Normal service conditions	16
8 Constructional and performance requirements	16
8.1 Constructional requirements	16
8.2 Performance requirements	16
8.2.1 Operating conditions	16
8.2.2 Temperature ~~rise~~ limits	16
8.2.3 Operation following inactivity	16
8.2.4 Electromagnetic compatibility (EMC)	16
8.2.5 Acoustic noise emission	16
8.2.6 ~~Dielectric properties~~ Clearances	17
8.2.7 Creepage distances	17
8.2.8 Switching overvoltages	17
8.2.9 Operational performance capability	17
8.2.10 Ability to withstand vibration and shock	18
8.2.11 Ability to make and break under short-circuit conditions	18
9 Tests	19
9.1 Kinds of tests	19

9.1.1	General	19
9.1.2	Type tests.....	19
9.1.3	Routine tests	19
9.1.4	~~Investigatory~~ Investigation tests.....	19
9.2	Verification of constructional requirements.....	19
9.2.1	General	19
9.2.2	Type tests.....	19
9.2.3	Routine tests	20
9.3	Type tests for verification of performance requirements	20
9.3.1	Test sequences	20
9.3.2	General test conditions	21
9.3.3	Test sequence I: General performance characteristics.....	22
9.3.4	Test sequence II: Rated short-circuit making and breaking capacities.....	23
9.3.5	Test sequence III: ~~capability~~ Ability to withstand vibration and shock.....	25
9.3.6	Test sequence IV: Searching for critical currents	26
9.3.7	Test sequence V: Climatic conditions	26
9.3.8	Test sequence VI: Other tests.....	26
9.4	Routine tests for verification of performance requirements.....	27
9.4.1	General	27
9.4.2	~~Mechanical operation~~ Functional test.....	27
9.4.3	Measurement of resistance.....	27
9.4.4	Calibration of releases.....	27
9.4.5	Air-tightness (for pneumatic circuit-breaker)	27
9.4.6	Dielectric withstand	27
Annex A (normative)	Test circuit to verify the making and breaking capacities	28
Annex B (informative)	Verification of short-circuit making and breaking capacities	29
Bibliography		31
Figure A.1	– Diagram of the test circuit	28
Figure B.1	– Calibration of the circuit to obtain the prospective peak making current	29
Figure B.2	– Oscillogram corresponding to a break after the current has passed its maximum value.....	30
Figure B.3	– Oscillogram corresponding to a break before the current has reached its maximum value (current-limiting circuit-breaker)	30
Table 1	– Rated time constants.....	14
Table 2	– Operational performance capability	18
Table 3	– List of type test sequences for performance requirements	20
Table 4	– Tolerances on test values.....	21

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ELECTRIC EQUIPMENT FOR ROLLING STOCK –****Part 3: Electrotechnical components –
Rules for DC circuit-breakers**

FOREWORD

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International Standard IEC 60077-3 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 2001. It constitutes a technical revision.

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

- a) procedure of verification of temperature rise is changed;
- b) 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
9/2537/FDIS	9/2553/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
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RAILWAY APPLICATIONS – ELECTRIC EQUIPMENT FOR ROLLING STOCK –

Part 3: Electrotechnical components – Rules for DC circuit-breakers

1 Scope ~~and object~~

In addition to the general requirements of IEC 60077-2, this part of IEC 60077 gives the rules for circuit-breakers, the main contacts of which are ~~to be~~ connected to DC power and/or auxiliary circuits. The nominal voltage of these circuits does not exceed 3 000 V DC according to IEC 60850.

This part of IEC 60077, 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~~ **complies** with reference to:
 - operation and behaviour in normal service;
 - operation and behaviour in the case of 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 predetermined conditions other than those of overcurrent, for example, under-voltage 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 circuit-breakers ~~should~~ **comply** with the relevant document 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 ~~may~~ **can** be necessary.

This document does not cover:

- a) multi-connection of electro-technical components to achieve a particular duty;
- b) industrial circuit-breakers which ~~have to comply~~ **complies** with IEC 60947-2;
- c) DC circuit-breakers for fixed installations which ~~have to comply~~ **complies** with IEC 61992-2.

For b) and c), 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 or fixed installations circuits breakers ~~are to~~ **comply**, for example:

- either to be adapted (for example, for control voltage, environmental conditions, etc.);

- or to be installed and used in such a way 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 – Switchgear, controlgear and fuses~~

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 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

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

~~IEC 60850:2000, Railway applications – Supply voltage of traction systems~~

~~IEC/TR3 60943:1998, Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals~~

~~IEC 60947-2:1989, Low-voltage switchgear and controlgear – Part 2: Circuit-breakers~~

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

~~IEC 61992-2:2001, Railway applications – Fixed installations – DC switchgear – Part 2: Circuit-breakers~~

3 Terms, definitions and abbreviated terms

~~For the purpose of this part of IEC 60077, the definitions given in clauses 3 of IEC 60077-1 and 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:

- 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

polarized circuit-breaker

circuit-breaker for which the breaking characteristics are defined for only one prescribed direction of current in the main circuit

3.1.2

bi-directional circuit-breaker

circuit-breaker for which the breaking characteristics are the same for both directions of current in the main circuit

3.1.3

air circuit-breaker

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

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-27]

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

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]

3.1.6

hybrid circuit-breaker

circuit-breaker with mechanical contacts for isolation associated with a semiconductor for switching

Note 1 to entry: Semiconductor circuit-breakers without mechanical isolation are not used on rolling stock.

3.2 Component parts

3.2.1

release, <for a circuit-breaker>

device, ~~mechanically connected to a mechanical switching device,~~ which releases the holding means and permits the opening or closing of the circuit-breaker

~~[IEV 441-15-17, modified]~~

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

Note 2 to entry: ~~A release may include mechanical, electromechanical or electronic parts.~~ These releases 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

direct overcurrent release

overcurrent release directly energized 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~~]

3.2.4

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 ~~(shunt 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".]

3.2.5

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.]

3.2.6

enclosure, <of an assembly>

part of an assembly providing a specified degree of protection of ~~the circuit-breaker~~ 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.]

3.2.7

integral enclosure

enclosure forming an integral part of the circuit-breaker

3.3 Operational features

3.3.1

current-limiting circuit-breaker

circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-21]

3.3.2

trip-free circuit-breaker

circuit-breaker in which 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 proper breaking of the current which may have been established, it may be necessary that the contacts momentarily reach the closed position.

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.4.11]

3.3.3

current setting, <of an overcurrent release>

~~value of the current in the main circuit to which the operating characteristics of the overcurrent 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.]

3.3.4

current setting range, <of an overcurrent release>

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

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

3.3.5

tripping operation

opening operation of a circuit-breaker initiated by a release

3.4 Breaking characteristics

~~NOTE – Some of the terms defined in this clause are used in the examples of 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

overcurrent opening time

interval of time between the instant when the current in the main circuit reaches the current setting value of the overcurrent release and the instant when the arcing contacts have separated

3.4.3

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.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modified – Note has been replaced.]

3.4.4

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.]

3.4.5

prospective breaking current, <for a pole of a switching device or a fuse>

prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

Note 1 to entry: The instant of initiation of the breaking process is usually defined as the beginning of the arc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-06, modified – Note 1 to entry has been replaced.]

3.4.6

cut-off current

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-12, modified – In note 1 to entry "is" has been added between "concept" and "of particular".]

3.4.7

recovery voltage

voltage which appears across the terminals of ~~each~~ a pole of a ~~circuit-breaker~~ 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.]

3.4.8

arcing time, <of a pole or a fuse>

interval of time between the instant of the initiation of the arc ~~between the arcing contacts~~ in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-37, ~~modified~~]

3.4.9

break-time

interval of time between the beginning of the opening time of a ~~circuit-breaker~~ mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-39, ~~modified~~]

3.4.10

joule integral, <for a circuit-breaker>

I^2t

integral of the square of the current in a circuit-breaker during a breaking process, over the break-time

$$I^2t = \int_{t_1}^{t_2} i^2 dt$$

~~t_1 = beginning of the opening time~~

~~t_2 = end of the arcing time~~

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

t_0 = beginning of the opening time

t_1 = end of the arcing time

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-23, modified – "in a circuit-breaker during a breaking process," has been added. "a given time interval" has been replaced with "the break-time". Notes have been deleted, keys for t_0 and t_1 have been added.]

3.4.11

I^2t characteristic, <for a circuit-breaker>

information (generally a curve) giving the value of I^2t as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-24, modified – "information (generally a curve) giving" has been added. "under prescribed conditions" has been deleted. "prospective current and/or voltage" has been replaced with "the prospective peak current ...". Note has been deleted.]

3.4.12

break-time – current characteristic

curve giving the break-time as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

3.4.13

cut-off current characteristic, <for a circuit-breaker>

curve giving the cut-off current as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

[SOURCE: IEC 60050-811:2017, 811-29-43, modified – "peak", "such" and ", etc." have been added.]

3.4.14

initial current rate of rise

di/dt

rate of rise at the beginning of the current flow

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.2.27, modified – "current" has been added in the term and symbol has been added.]

3.5 Abbreviated terms

DC Direct Current

EMC Electromagnetic Compatibility

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:

- a) according to their operational frequency C1, C2 or C3. The characteristics of these operational frequencies are given in 5.4;
- b) according to the type of design:
 - open construction;
 - construction with an integral enclosure;
- c) according to the degree of protection provided by the enclosure (see IEC 60529).

5 Characteristics

5.1 List of characteristics

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

- type of circuit-breaker (5.2);
- rated values and limiting values ~~of~~ 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 arc voltages (5.8).

5.2 Type of circuit-breaker

It is necessary to state:

- the kind of device (for example, air ~~circuit-breaker~~, vacuum circuit-breaker, hybrid circuit-breaker, bi-directional or polarized circuit-breaker);
- the type of design (see Clause 4);
- the degree of protection provided by the enclosure (see Clause 4);
- operational features (for example, current-limiting circuit-breaker, trip-free circuit-breaker).

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 Certain types of circuit-breakers ~~may~~ have several rated operational voltages or ~~may~~ have 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 for 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 time constant $T2$ (see 5.3.4);

NOTE Certain types of circuit-breakers ~~may~~ have several rated operational currents or ~~may~~ have a rated operational current range.

- conventional free air thermal current (I_{th}) ~~(see 5.3.3 of IEC 60077-2);~~
- ~~– rated short time withstand current (I_{cw}) (see 5.3.2 of IEC 60077-1).~~
- conventional enclosed thermal current (I_{the}).

5.3.4 Rated time constants

The time constants for the circuit-breaker are dependent on the electrical characteristics of the substation, the line and the load.

The four time constants given in Table 1 shall be used by the manufacturer to determine the short-circuit breaking and making capacities stated in 5.3.5.

If necessary the time constant values may be defined by agreement between the manufacturer and the user.

Table 1 – Rated time constants

Rated operational voltage ~~U_e~~ U_r V		900	1 800	3 600
Time constant $T1$ (minimum)	ms	0	0	0
Time constant $T2$	ms	15	15	15
Time constant $T3$	ms	50	40	30
Time constant $T4$	ms	150	100	50
NOTE A time constant of 0 ms signifies that for the tests the load is made up of resistors without any voluntary adding of inductance.				

5.3.5 ~~Short-circuit characteristics (see also annex B)~~ Rated short-circuit making and breaking capacity

5.3.5.1 ~~Rated short-circuit making capacity~~

~~The rated short-circuit making capacity of a circuit-breaker is the value of the making current corresponding to the rated operational voltage and is assigned by the manufacturer. The circuit-breaker shall satisfy the rated short-circuit test conditions specified in 9.3.4 and shall be capable of subsequent operation.~~

5.3.5.2 ~~Rated short-circuit breaking capacity~~

The rated short-circuit making and breaking capacities of a circuit-breaker are the values of the ~~breaking~~ prospective peak current corresponding to the rated operational voltage for the rated time constants and ~~is~~ are assigned by the manufacturer. The circuit-breaker shall satisfy the rated short-circuit test conditions specified in 9.3.4 and shall be capable of subsequent operation.

NOTE See also Annex B.

5.4 Operational frequencies

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

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

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

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 (for example, direct overcurrent release and/or indirect overcurrent release, with or without an anti-pumping device);
- current setting (or setting range) for each direction of the current in the main circuit;
- characteristics of the opening time as a function of the quantities which influence the release (for example, as a function of the rate of rise of current).

5.8 Peak arc voltages

The manufacturer shall specify the maximum value of the peak arc voltages caused by operation of the circuit-breaker when it is tested in accordance with the provisions of the making and breaking tests of sequences I, II and IV of Table 3.

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 and is supplemented by the following:

- rated operational voltage of the control circuit of the indirect overcurrent release and/or under-voltage release (or no voltage release) and its rated frequency, if applicable;
- current setting or current setting range of overcurrent releases;
- opening time, break-time – current characteristic;
- cut-off current characteristic;
- I^2t characteristic.

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

8.2.8 of IEC 60077-1:2017 applies with the following additional requirement:

- the switching of DC circuit-breakers for which the rated insulation voltage (U_i , U_{Nm}) is between 660 V and 4 800 V shall not generate peak arc voltages higher than 3 times U_i , U_{Nm} .

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).

Each sequence shall consist of performing a number of operating cycles without current, specified in Table 2 column 3, followed by a number of operating cycles with current, specified in Table 2 column 4.

Each sequence shall be repeated a number of times as specified in Table 2 column 2 to obtain the total number of operating cycles stated in Table 2, columns 5 and 6.

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 should be mentioned in the test report.

A different number of sequences may be adopted under the following conditions:

- the proportion of operating cycles with and without current in each cycle is equal to that specified in Table 2;
- the total number of operating cycles with and without current is equal to those specified in columns 5 and 6 of Table 2.

Table 2 – Operational performance capability

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Operational frequency	Number of sequences	Number of operating cycles per sequence		Total number of operating cycles	
		Without current	With current	Without current	With current
C1	1	20 000	100	20 000	100
C2	2	50 000	200	100 000	400
C3	4	50 000	200	200 000	800

~~NOTE 1 The rate of operating cycles is chosen to keep all parts of the circuit-breaker within acceptable limits of temperature-rise.~~

~~NOTE 2 The rate of operating cycles selected by mutual agreement between the manufacturer and the user should be mentioned in the test report.~~

~~NOTE 3 The operating cycles with current are applicable at the end of each sequence and the following rates are recommended:~~

~~— 30 cycles per hour for rated operational current less than or equal to 2 000 A;~~

~~— 15 cycles per hour for rated operational current greater than 2 000 A.~~

~~NOTE 4 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.~~

~~NOTE 5 A different number of sequences may be adopted under the following conditions:~~

~~— the proportion of operating cycles with and without current in each cycle is equal to that specified in this table;~~

~~— the total number of operating cycles with and without current is equal to those specified in columns 5 and 6 of this table.~~

The operating cycles with current are applicable at the end of each sequence and the following rates are recommended:

- 30 cycles per hour for rated operational current less than or equal to 2 000 A with a maximum of 2 s in the closed position for each operating cycle;
- 15 cycles per hour for rated operational current greater than 2 000 A with a maximum of 2 s in the closed position for each operating cycle.

8.2.10 Ability to withstand vibration and shock

The circuit-breaker shall be capable of withstanding the vibration and shocks 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;
- ~~rated short-circuit~~ prospective peak currents at the rated operational voltage for the corresponding rated ~~short-circuit~~ time constant;
- recovery voltage equal to the rated operational voltage;
- four time constants in accordance with the values of 5.3.4;
- a sequence of operations O – t_1 – CO – t_2 – CO for each time constant;
 - O represents a breaking operation;
 - CO represents a making operation followed by a breaking operation after the appropriate opening time;
 - t_1 is the time interval between the first opening and the first closing and is equal to 20 s;

- t_2 is the time interval between the second opening and the second closing and is equal to 60 s.

9 Tests

9.1 Kinds 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:

- the 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 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 (for example, 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).

~~— measurement of resistance. The tests required in 9.2.3 of IEC 60077-1 shall be applied. The measured values for main and control circuits shall be recorded in the routine test report.~~

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 the 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 circuits	9.3.4.2
	Ability to make and break under short-circuit conditions at time constant T_2	9.3.4.4
	Ability to make and break under short-circuit conditions at time constant T_3	9.3.4.5
	Ability to make and break under short-circuit conditions at time constant T_4	9.3.4.6
	Ability to make and break under short-circuit conditions at minimum time constant T_1	9.3.4.7
	Verification of dielectric withstand	9.3.4.8
	Verification of temperature rise	9.3.4.9
	Verification of tripping operation	9.3.4.10
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 – Critical currents	Searching for critical currents	9.3.6
V – Climatic conditions (if required)	Environmental tests (dry heat, damp heat, cold, etc.)	9.3.7

Test sequences	Tests	Subclause
VI – Other tests (if required)	Electromagnetic compatibility (EMC)	9.3.8
	Acoustic noise emission	9.3.8

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 except for that specified for operational performance capability (see 9.3.3.6).

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). For bi-directional circuit-breakers, testing shall be carried out with both directions of current if necessary.

The tests shall be performed at the rated operational values (current, voltage, 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: $+5\%$ 0%	Main circuit Current: $+5\%$ 0% Time constant: $+15\%$ 0%	Main circuit Current: $+10\%$ 0% Time constant: $+25\%$ 0%
Control and auxiliary circuit Current: $\pm 5\%$ Voltage: $\pm 5\%$ Air pressure: $\pm 5\%$		
NOTE 1 For T_1 time constant refer to NOTE in Table 1. NOTE 2 For tripping limits, the current tolerance is also 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:

- either 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.

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 MΩ by a megohmmeter applying a DC voltage of at least 500 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, with the sequences corresponding to the operational frequency.

The operations of making and breaking shall be carried out at the rated operational current, the rated operational voltage and for time constant T_2 (15 ms) using a test circuit as in Annex A.

Between the sequences of Table 2, inspection and maintenance operations are permitted in accordance with instructions specified in the maintenance documents (see 6.3 of IEC 60077-1:2017). During these operations, the parts replaced shall be limited to the contacts (and other parts exposed to arcing) of the main circuit. The list of the replaced parts and the maintenance operations carried out during this test shall be declared by the manufacturer. The replaceable parts should be found in the maintenance manual.

NOTE 1 Maintenance manual describes conditions based on service conditions. The test cycles and maintenance intervals of this test are for test conditions.

NOTE 2 A single sequence of Table 2 includes operation both without and with current.

At the end of the last sequence, 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.

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 dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

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

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 9.4.4.

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 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.

9.3.4.3 General test conditions

9.3.4.3.1 General

The schematic diagram of the test circuit shall be as given in Annex A, Figure A.1.

9.3.4.3.2 General rules for the calibration of the test circuit

The calibration of the test circuit shall be carried out by placing temporary connection C of negligible impedance as close as reasonably possible to the terminals provided for connecting the circuit-breaker under test.

The resistor R and inductor X shall be adjusted to obtain at the rated operational voltage the values of the rated short-circuit making and breaking capacities defined in 5.3.5.1 and 5.3.5.2 at the different rated short-circuit time constants defined in 5.3.4.

NOTE Saturation of the inductor ~~may~~ can be avoided by the use of an air cored inductor.

A calibration test shall then be carried out to measure these values and to check that they are within the tolerances indicated in Table 4.

The di/dt value of the test circuits calibration should be recorded in the test report.

9.3.4.3.3 General rules for the making and breaking tests

The releases shall be set to their highest value.

All parts of the circuit-breaker normally connected to the vehicle body, including the enclosure or the screens, shall be insulated from earth and connected to a point as indicated in Annex A.

This connection shall comprise a fusible element F with a recommended value of 10 A for the detection of the fault current.

The prospective fault current in the fusible element circuit may be limited by a resistor R_L .

NOTE In addition, a measurement of the fault current may be made.

9.3.4.3.4 General evaluation of the tests

During the tests,

- no part of the circuit-breaker shall be broken;
- the fusible element F shall be undamaged.

The measurements carried out during each of these tests shall demonstrate the correct operation of the circuit-breaker and verify the making and the breaking characteristics:

- overcurrent opening time;
- cut off current;
- arcing time;
- peak arc voltages.

For each breaking operation (as far as possible) a thermal stress calculation shall be made to produce a I^2t characteristic (Joule integral).

NOTE Examples of measuring records of calibration and waveforms of making and breaking currents can be found in Annex B.

9.3.4.3.5 General rules of maintenance during the tests

A limited maintenance operation of cleaning and replacement of main contacts and other parts exposed to arcing may only be carried out before the final sequence of operations $O - t_1 - CO - t_2 - CO$ at the minimum time constant $T1$. The list of the replaced parts and the maintenance operations carried out during this test shall be declared by the manufacturer. The replaceable parts should be found in the maintenance manual.

NOTE Maintenance manual describes conditions based on service conditions. The test cycles and maintenance intervals of this test are for test conditions.

9.3.4.4 ~~Capability~~ Ability to make and break under short-circuit conditions at time constant T_2

After the calibration of the test circuit, the short-circuit test sequence at time constant T_2 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.5 ~~Capability~~ Ability to make and break under short-circuit conditions at time constant T_3

After the calibration of the test circuit, the short-circuit test sequence at time constant T_3 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.6 ~~Capability~~ Ability to make and break under short-circuit conditions at time constant T_4

After the calibration of the test circuit, the short-circuit test sequence at time constant T_4 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.7 ~~Capability~~ Ability to make and break under short-circuit conditions at minimum time constant T_1

After the calibration of the test circuit, the short-circuit test sequence at the minimum time constant T_1 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.8 Verification of dielectric withstand

After the test described in 9.3.4.7, the circuit-breaker shall be capable of withstanding the dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

9.3.4.9 Verification of temperature rise

~~After the verification described in 9.3.4.6 a temperature rise test shall be carried out on the main circuit in accordance with 9.3.3.2.~~

The verification described in 9.3.3.8 shall be carried out.

9.3.4.10 Verification of tripping operation

After the verification described in 9.3.4.9, the current settings of the releases shall be checked in accordance with 9.4.4.

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

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 duration shall be distributed in such a way that:

- both operational states are tested;
- the distribution of these states represents the expected service.

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 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

After the verification described in 9.3.5.4, the current settings of the releases shall be checked in accordance with 9.4.4.

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

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 dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

9.3.6 Test sequence IV: Searching for critical currents

This test shall be carried out only for circuit-breakers of categories C2 and C3, according to 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 time constant $T2$ according to 5.3.4 using the circuit as in Annex A.

Minimum five operations at each value of current shall be carried out. The exact values of current are not important, provided that each current is approximately half of the previous current.

Lower time constants at $T2$ are accepted provided that the circuit load inductance has a minimum value of 50 mH.

NOTE The test enables the manufacturer to supply curves of the arcing time as a function of the current broken.

9.3.7 Test sequence V: Climatic conditions

When tests are required, 9.3.7 of IEC 60077-2:2017 shall be applied.

9.3.8 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);
- measurement of resistance (see 9.4.3);
- calibration of releases (see 9.4.4);
- air tightness, if applicable (see 9.4.5);
- dielectric withstand (see 9.4.6).

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 Measurement of resistance

The test required in 9.4.3 of IEC 60077-2:2017 shall be applied. The ambient temperature shall be recorded in the routine test report.

9.4.4 Calibration of releases

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

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

NOTE 2 Steady-state current means less than 200 A/s rise.

9.4.5 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.

9.4.6 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.

Annex A (normative)

Test circuit to verify the making and breaking capacities

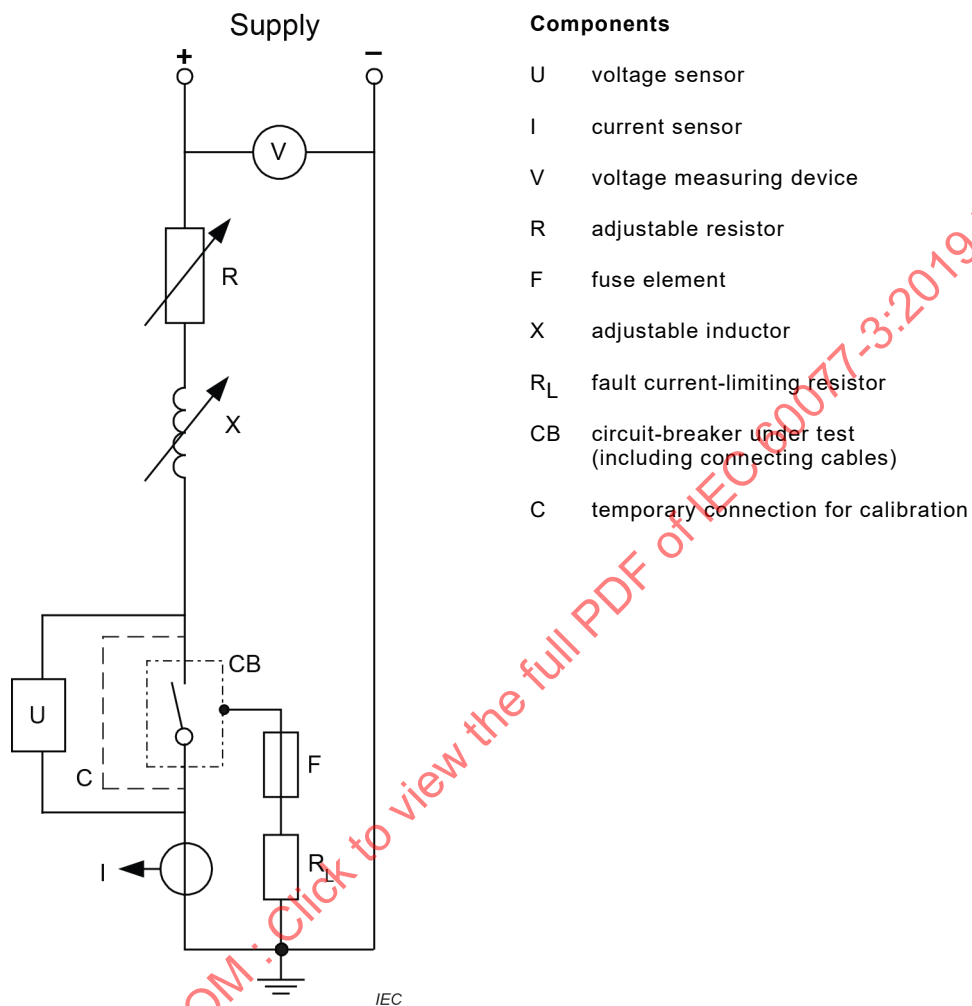


Figure A.1 – Diagram of the test circuit

Annex B (informative)

Verification of short-circuit making and breaking capacities

This annex gives examples of oscillograms which are recorded during the calibration of the circuit, making and breaking of a circuit-breaker.

The key for Figure B.1, Figure B.2 and Figure B.3 is the following:

- A_0 Current setting
- A_1 Breaking current
- A_2 Prospective peak current
- A_3 Prospective breaking current
- A_4 Cut-off current
- T Time constant
- V_0 Rated operational voltage
- V_1 Recovery voltage
- V_2 Peak arc voltage
- t_1 Opening time
- t_2 Arcing time
- t_3 Break-time

~~In figures B.2 and B.3:~~

- ~~— the short-circuit making capacity is equal to the current A_2 at the applied voltage V_0 ;~~
- ~~— the short-circuit breaking capacity is equal to the current A_3 at the recovery voltage V_1 .~~

In Figure B.2 and Figure B.3, the short-circuit making and breaking capacity is equal to the current A_2 at the applied voltage V_0 .

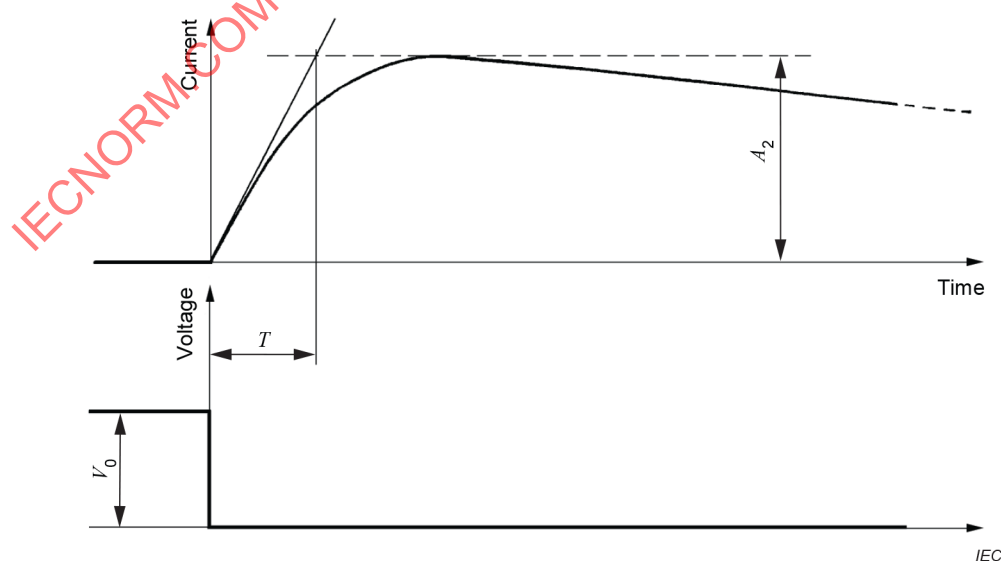
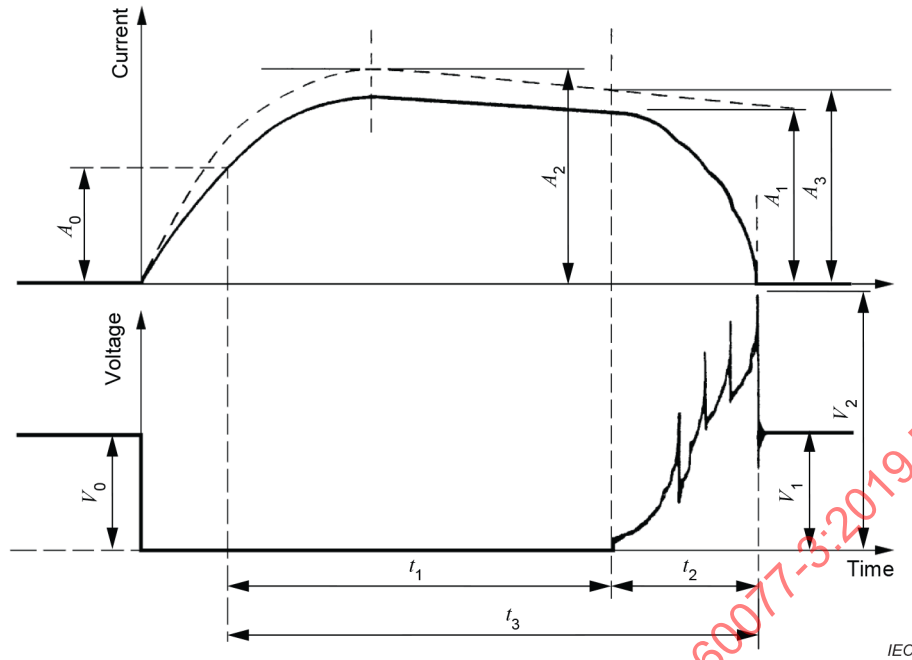
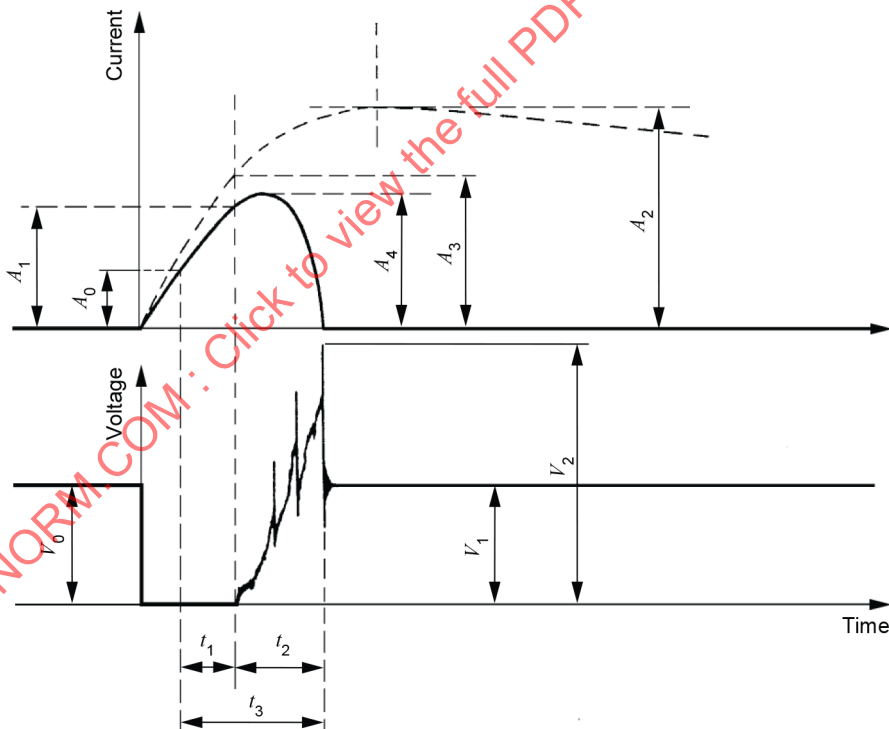


Figure B.1 – Calibration of the circuit to obtain the prospective peak making current



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Figure B.2 – Oscillogram corresponding to a break after the current has passed its maximum value



IEC

Figure B.3 – Oscillogram corresponding to a break before the current has reached its maximum value (current-limiting circuit-breaker)

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IEC 61992-1:2006/AMD1:2014

IEC 61992-2, *Railway applications – Fixed installations – DC switchgear – Part 2: Circuit-breakers*

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Railway Applications – Electric equipment for rolling stock –
Part 3: Electrotechnical components – Rules for DC circuit-breakers**

**Applications ferroviaires – Équipements électriques du matériel roulant –
Partie 3: Composants électrotechniques – Règles pour disjoncteurs
à courant continu**

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CONTENTS

FOREWORD	4
1 Scope	6
2 Normative references	7
3 Terms, definitions and abbreviated terms	7
3.1 Components	7
3.2 Component parts	8
3.3 Operational features	9
3.4 Breaking characteristics	10
3.5 Abbreviated terms	12
4 Classification	12
5 Characteristics	12
5.1 List of characteristics	12
5.2 Type of circuit-breaker	12
5.3 Rated values and limiting values for the main circuit	13
5.3.1 General	13
5.3.2 Rated voltages	13
5.3.3 Rated currents	13
5.3.4 Rated time constants	13
5.3.5 Rated short-circuit making and breaking capacity	14
5.4 Operational frequencies	14
5.5 Electric and pneumatic control circuits	14
5.6 Electric and pneumatic auxiliary circuits	14
5.7 Overcurrent release	14
5.8 Peak arc voltages	14
6 Product information	14
6.1 Component documentation	14
6.2 Marking	15
7 Normal service conditions	15
8 Constructional and performance requirements	15
8.1 Constructional requirements	15
8.2 Performance requirements	15
8.2.1 Operating conditions	15
8.2.2 Temperature limits	15
8.2.3 Operation following inactivity	15
8.2.4 Electromagnetic compatibility (EMC)	15
8.2.5 Acoustic noise emission	15
8.2.6 Clearances	15
8.2.7 Creepage distances	15
8.2.8 Switching overvoltages	15
8.2.9 Operational performance capability	16
8.2.10 Ability to withstand vibration and shock	16
8.2.11 Ability to make and break under short-circuit conditions	17
9 Tests	17
9.1 Kinds of tests	17
9.1.1 General	17

9.1.2	Type tests.....	17
9.1.3	Routine tests	17
9.1.4	Investigation tests.....	17
9.2	Verification of constructional requirements.....	18
9.2.1	General	18
9.2.2	Type tests.....	18
9.2.3	Routine tests	18
9.3	Type tests for verification of performance requirements	18
9.3.1	Test sequences	18
9.3.2	General test conditions	19
9.3.3	Test sequence I: General performance characteristics.....	20
9.3.4	Test sequence II: Rated short-circuit making and breaking capacities.....	21
9.3.5	Test sequence III: Ability to withstand vibration and shock.....	23
9.3.6	Test sequence IV: Searching for critical currents	24
9.3.7	Test sequence V: Climatic conditions	24
9.3.8	Test sequence VI: Other tests.....	24
9.4	Routine tests for verification of performance requirements.....	25
9.4.1	General	25
9.4.2	Functional test.....	25
9.4.3	Measurement of resistance.....	25
9.4.4	Calibration of releases.....	25
9.4.5	Air-tightness (for pneumatic circuit-breaker)	25
9.4.6	Dielectric withstand	25
Annex A	(normative) Test circuit to verify the making and breaking capacities	26
Annex B	(informative) Verification of short-circuit making and breaking capacities	27
Bibliography		29
Figure A.1	– Diagram of the test circuit	26
Figure B.1	– Calibration of the circuit to obtain the prospective peak making current	27
Figure B.2	– Oscillogram corresponding to a break after the current has passed its maximum value.....	28
Figure B.3	– Oscillogram corresponding to a break before the current has reached its maximum value (current-limiting circuit-breaker)	28
Table 1	– Rated time constants.....	13
Table 2	– Operational performance capability	16
Table 3	– List of type test sequences for performance requirements	18
Table 4	– Tolerances on test values.....	19

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ELECTRIC EQUIPMENT FOR ROLLING STOCK –****Part 3: Electrotechnical components –
Rules for DC circuit-breakers**

FOREWORD

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International Standard IEC 60077-3 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 2001. It constitutes a technical revision.

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

- a) procedure of verification of temperature rise is changed;
- b) 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
9/2537/FDIS	9/2553/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 3: Electrotechnical components – Rules for DC circuit-breakers

1 Scope

In addition to the general requirements of IEC 60077-2, this part of IEC 60077 gives the rules for circuit-breakers, the main contacts of which are connected to DC power and/or auxiliary circuits. The nominal voltage of these circuits does not exceed 3 000 V DC according to IEC 60850.

This part of IEC 60077, together with IEC 60077-2, states specifically:

- a) the characteristics of the circuit-breakers;
- b) the service conditions with which circuit-breakers complies with reference to:
 - operation and behaviour in normal service;
 - operation and behaviour in the case of 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 predetermined conditions other than those of overcurrent, for example, under-voltage 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 circuit-breakers comply with the relevant document for electronics (IEC 60571).

NOTE 3 Certain of these rules, after agreement between the user and the manufacturer, are used for electro-technical 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:

- e) multi-connection of electro-technical components to achieve a particular duty;
- f) industrial circuit-breakers which complies with IEC 60947-2;
- g) DC circuit-breakers for fixed installations which complies with IEC 61992-2.

For f) and g), 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 or fixed installations circuits breakers comply, for example:

- either to be adapted (for example, for control voltage, environmental conditions, etc.);
- or to be installed and used in such a way 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 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*

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

polarized circuit-breaker

circuit-breaker for which the breaking characteristics are defined for only one prescribed direction of current in the main circuit

3.1.2

bi-directional circuit-breaker

circuit-breaker for which the breaking characteristics are the same for both directions of current in the main circuit

3.1.3

air circuit-breaker

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

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-27]

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

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]

3.1.6

hybrid circuit-breaker

circuit-breaker with mechanical contacts for isolation associated with a semiconductor for switching

Note 1 to entry: Semiconductor circuit-breakers without mechanical isolation are not used on rolling stock.

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

direct overcurrent release

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

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

3.2.4

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".]

3.2.5

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.]

3.2.6

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.]

3.2.7

integral enclosure

enclosure forming an integral part of the circuit-breaker

3.3 Operational features

3.3.1

current-limiting circuit-breaker

circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-21]

3.3.2

trip-free circuit-breaker

circuit-breaker in which the moving contacts return to and remain in the open position when the 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.

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.4.11]

3.3.3

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.]

3.3.4

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]

3.3.5

tripping operation

opening operation of a circuit-breaker initiated by a release

3.4 Breaking characteristics

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

overcurrent opening time

interval of time between the instant when the current in the main circuit reaches the current setting value of the overcurrent release and the instant when the arcing contacts have separated

3.4.3

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.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modified – Note has been replaced.]

3.4.4

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.]

3.4.5

prospective breaking current, <for a pole of a switching device or a fuse>

prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

Note 1 to entry: The instant of initiation of the breaking process is usually defined as the beginning of the arc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-06, modified – Note 1 to entry has been replaced.]

3.4.6

cut-off current

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-12, modified – In note 1 to entry "is" has been added between "concept" and "of particular".]

3.4.7**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.]

3.4.8**arcing time, <of a pole or a fuse>**

interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-37]

3.4.9**break-time**

interval of time between the beginning of the opening time of a mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-39]

3.4.10**joule integral, <for a circuit-breaker>**

I^2t

integral of the square of the current in a circuit-breaker during a breaking process, over the break-time

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

t_0 = beginning of the opening time

t_1 = end of the arcing time

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-23, modified – "in a circuit-breaker during a breaking process," has been added. "a given time interval" has been replaced with "the break-time". Notes have been deleted, keys for t_0 and t_1 have been added.]

3.4.11 **I^2t characteristic, <for a circuit-breaker>**

information (generally a curve) giving the value of I^2t as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-24, modified – "information (generally a curve) giving" has been added. "under prescribed conditions" has been deleted. "prospective current and/or voltage" has been replaced with "the prospective peak current ...". Note has been deleted.]

3.4.12**break-time – current characteristic**

curve giving the break-time as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

3.4.13**cut-off current characteristic, <for a circuit-breaker>**

curve giving the cut-off current as a function of the prospective peak current for specified conditions such as the current setting of the release, the time constant of the test circuit, etc.

[SOURCE: IEC 60050-811:2017, 811-29-43, modified – "peak", "such" and ", etc." have been added.]

3.4.14

initial current rate of rise

di/dt

rate of rise at the beginning of the current flow

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.2.27, modified – "current" has been added in the term and symbol has been added.]

3.5 Abbreviated terms

DC Direct Current

EMC Electromagnetic Compatibility

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:

- a) according to their operational frequency C1, C2 or C3. The characteristics of these operational frequencies are given in 5.4;
- b) according to the type of design:
 - open construction;
 - construction with an integral enclosure;
- c) according to the degree of protection provided by the enclosure (see IEC 60529).

5 Characteristics

5.1 List of characteristics

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

- 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 arc voltages (5.8).

5.2 Type of circuit-breaker

It is necessary to state:

- the kind of device (for example, air circuit-breaker, vacuum circuit-breaker, hybrid circuit-breaker, bi-directional or polarized circuit-breaker);
- the type of design (see Clause 4);
- the degree of protection provided by the enclosure (see Clause 4);
- operational features (for example, current-limiting circuit-breaker, trip-free circuit-breaker).

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 Certain types of circuit-breakers have several rated operational voltages or have 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 time constant T_2 (see 5.3.4);

NOTE Certain types of circuit-breakers have several rated operational currents or have a rated operational current range.

- conventional free air thermal current (I_{th});
- conventional enclosed thermal current (I_{the}).

5.3.4 Rated time constants

The time constants for the circuit-breaker are dependent on the electrical characteristics of the substation, the line and the load.

The four time constants given in Table 1 shall be used by the manufacturer to determine the short-circuit breaking and making capacities stated in 5.3.5.

If necessary the time constant values may be defined by agreement between the manufacturer and the user.

Table 1 – Rated time constants

Rated operational voltage U_r V		900	1 800	3 600
Time constant T_1 (minimum)	ms	0	0	0
Time constant T_2	ms	15	15	15
Time constant T_3	ms	50	40	30
Time constant T_4	ms	150	100	50
NOTE A time constant of 0 ms signifies that for the tests the load is made up of resistors without any voluntary adding of inductance.				

5.3.5 Rated short-circuit making and breaking capacity

The rated short-circuit making and breaking capacities of a circuit-breaker are the values of the prospective peak current corresponding to the rated operational voltage for the rated time constants and are assigned by the manufacturer. The circuit-breaker shall satisfy the rated short-circuit test conditions specified in 9.3.4 and shall be capable of subsequent operation.

NOTE See also Annex B.

5.4 Operational frequencies

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

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

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

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 (for example, direct overcurrent release and/or indirect overcurrent release, with or without an anti-pumping device);
- current setting (or setting range) for each direction of the current in the main circuit;
- characteristics of the opening time as a function of the quantities which influence the release (for example, as a function of the rate of rise of current).

5.8 Peak arc voltages

The manufacturer shall specify the maximum value of the peak arc voltages caused by operation of the circuit-breaker when it is tested in accordance with the provisions of the making and breaking tests of sequences I, II and IV of Table 3.

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 and is supplemented by the following:

- rated operational voltage of the control circuit of the indirect overcurrent release and/or under-voltage release (or no voltage release) and its rated frequency, if applicable;
- current setting or current setting range of overcurrent releases;
- opening time, break-time – current characteristic;
- cut-off current characteristic;
- I^2t characteristic.

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

8.2.8 of IEC 60077-1:2017 applies with the following additional requirement:

- the switching of DC circuit-breakers for which the rated insulation voltage (U_{Nm}) is between 660 V and 4 800 V shall not generate peak arc voltages higher than 3 times U_{Nm} .

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).

Each sequence shall consist of performing a number of operating cycles without current, specified in Table 2 column 3, followed by a number of operating cycles with current, specified in Table 2 column 4.

Each sequence shall be repeated a number of times as specified in Table 2 column 2 to obtain the total number of operating cycles stated in Table 2, columns 5 and 6.

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 should be mentioned in the test report.

A different number of sequences may be adopted under the following conditions:

- the proportion of operating cycles with and without current in each cycle is equal to that specified in Table 2;
- the total number of operating cycles with and without current is equal to those specified in columns 5 and 6 of Table 2.

Table 2 – Operational performance capability

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Operational frequency	Number of sequences	Number of operating cycles per sequence		Total number of operating cycles	
		Without current	With current	Without current	With current
C1	1	20 000	100	20 000	100
C2	2	50 000	200	100 000	400
C3	4	50 000	200	200 000	800
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.					

The operating cycles with current are applicable at the end of each sequence and the following rates are recommended:

- 30 cycles per hour for rated operational current less than or equal to 2 000 A with a maximum of 2 s in the closed position for each operating cycle;
- 15 cycles per hour for rated operational current greater than 2 000 A with a maximum of 2 s in the closed position for each operating cycle.

8.2.10 Ability to withstand vibration and shock

The circuit-breaker shall be capable of withstanding the vibration and shocks 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;
- prospective peak currents at the rated operational voltage for the corresponding rated time constant;
- recovery voltage equal to the rated operational voltage;
- four time constants in accordance with the values of 5.3.4;
- a sequence of operations $O - t_1 - CO - t_2 - CO$ for each time constant;
 - O represents a breaking operation;
 - CO represents a making operation followed by a breaking operation after the appropriate opening time;
 - t_1 is the time interval between the first opening and the first closing and is equal to 20 s;
 - t_2 is the time interval between the second opening and the second closing and is equal to 60 s.

9 Tests

9.1 Kinds 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:

- the 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 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 (for example, 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).

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 the 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 circuits	9.3.4.2
	Ability to make and break under short-circuit conditions at time constant T_2	9.3.4.4
	Ability to make and break under short-circuit conditions at time constant T_3	9.3.4.5
	Ability to make and break under short-circuit conditions at time constant T_4	9.3.4.6

Test sequences	Tests	Subclause
	Ability to make and break under short-circuit conditions at minimum time constant T_1	9.3.4.7
	Verification of dielectric withstand	9.3.4.8
	Verification of temperature rise	9.3.4.9
	Verification of tripping operation	9.3.4.10
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 – Critical currents	Searching for critical currents	9.3.6
V – Climatic conditions (if required)	Environmental tests (dry heat, damp heat, cold, etc.)	9.3.7
VI – Other tests (if required)	Electromagnetic compatibility (EMC)	9.3.8
	Acoustic noise emission	9.3.8

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 except for that specified for operational performance capability (see 9.3.3.6).

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). For bi-directional circuit-breakers, testing shall be carried out with both directions of current if necessary.

The tests shall be performed at the rated operational values (current, voltage, 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: $+5\%$ 0%	Main circuit Current: $+5\%$ 0% Time constant: $+15\%$ 0%	Main circuit Current: $+10\%$ 0% Time constant: $+25\%$ 0%
Control and auxiliary circuit Current: $\pm 5\%$ Voltage: $\pm 5\%$ Air pressure: $\pm 5\%$		
NOTE 1 For T_1 time constant refer to NOTE in Table 1.		
NOTE 2 For tripping limits, the current tolerance is also 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:

- either 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.

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 MΩ by a megohmmeter applying a DC voltage of at least 500 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, with the sequences corresponding to the operational frequency.

The operations of making and breaking shall be carried out at the rated operational current, the rated operational voltage and for time constant T_2 (15 ms) using a test circuit as in Annex A.

Between the sequences of Table 2, inspection and maintenance operations are permitted in accordance with instructions specified in the maintenance documents (see 6.3 of IEC 60077-1:2017). During these operations, the parts replaced shall be limited to the contacts (and other parts exposed to arcing) of the main circuit. The list of the replaced parts and the

maintenance operations carried out during this test shall be declared by the manufacturer. The replaceable parts should be found in the maintenance manual.

NOTE 1 Maintenance manual describes conditions based on service conditions. The test cycles and maintenance intervals of this test are for test conditions.

NOTE 2 A single sequence of Table 2 includes operation both without and with current.

At the end of the last sequence, 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.

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 dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

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 9.4.4.

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 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.

9.3.4.3 General test conditions

9.3.4.3.1 General

The schematic diagram of the test circuit shall be as given in Annex A, Figure A.1.

9.3.4.3.2 General rules for the calibration of the test circuit

The calibration of the test circuit shall be carried out by placing temporary connection C of negligible impedance as close as reasonably possible to the terminals provided for connecting the circuit-breaker under test.

The resistor R and inductor X shall be adjusted to obtain at the rated operational voltage the values of the rated short-circuit making and breaking capacities defined in 5.3.5 at the different rated short-circuit time constants defined in 5.3.4.

NOTE Saturation of the inductor can be avoided by the use of an air cored inductor.

A calibration test shall then be carried out to measure these values and to check that they are within the tolerances indicated in Table 4.

The di/dt value of the test circuits calibration should be recorded in the test report.

9.3.4.3.3 General rules for the making and breaking tests

The releases shall be set to their highest value.

All parts of the circuit-breaker normally connected to the vehicle body, including the enclosure or the screens, shall be insulated from earth and connected to a point as indicated in Annex A.

This connection shall comprise a fusible element F with a recommended value of 10 A for the detection of the fault current.

The prospective fault current in the fusible element circuit may be limited by a resistor R_L .

In addition, a measurement of the fault current may be made.

9.3.4.3.4 General evaluation of the tests

During the tests,

- no part of the circuit-breaker shall be broken;
- the fusible element F shall be undamaged.

The measurements carried out during each of these tests shall demonstrate the correct operation of the circuit-breaker and verify the making and the breaking characteristics:

- overcurrent opening time;
- cut off current;
- arcing time;
- peak arc voltages.

For each breaking operation (as far as possible) a thermal stress calculation shall be made to produce a I^2t characteristic (Joule integral).

NOTE Examples of measuring records of calibration and waveforms of making and breaking currents can be found in Annex B.

9.3.4.3.5 General rules of maintenance during the tests

A limited maintenance operation of cleaning and replacement of main contacts and other parts exposed to arcing may only be carried out before the final sequence of operations $O - t_1 - CO - t_2 - CO$ at the minimum time constant $T1$. The list of the replaced parts and the maintenance operations carried out during this test shall be declared by the manufacturer. The replaceable parts should be found in the maintenance manual.

NOTE Maintenance manual describes conditions based on service conditions. The test cycles and maintenance intervals of this test are for test conditions.

9.3.4.4 Ability to make and break under short-circuit conditions at time constant T_2

After the calibration of the test circuit, the short-circuit test sequence at time constant T_2 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.5 Ability to make and break under short-circuit conditions at time constant T_3

After the calibration of the test circuit, the short-circuit test sequence at time constant T_3 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.6 Ability to make and break under short-circuit conditions at time constant T_4

After the calibration of the test circuit, the short-circuit test sequence at time constant T_4 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.7 Ability to make and break under short-circuit conditions at minimum time constant T_1

After the calibration of the test circuit, the short-circuit test sequence at the minimum time constant T_1 shall be carried out under the general conditions of 9.3.2 in accordance with the requirements of 8.2.11.

9.3.4.8 Verification of dielectric withstand

After the test described in 9.3.4.7, the circuit-breaker shall be capable of withstanding the dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

9.3.4.9 Verification of temperature rise

The verification described in 9.3.3.8 shall be carried out.

9.3.4.10 Verification of tripping operation

After the verification described in 9.3.4.9, the current settings of the releases shall be checked in accordance with 9.4.4.

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

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 duration shall be distributed in such a way that:

- both operational states are tested;
- the distribution of these states represents the expected service.

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 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

After the verification described in 9.3.5.4, the current settings of the releases shall be checked in accordance with 9.4.4.

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

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 dielectric test voltages reduced to 75 % of the values required in 9.3.3.5.

9.3.6 Test sequence IV: Searching for critical currents

This test shall be carried out only for circuit-breakers of categories C2 and C3, according to 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 time constant T_2 according to 5.3.4 using the circuit as in Annex A.

Minimum five operations at each value of current shall be carried out. The exact values of current are not important, provided that each current is approximately half of the previous current.

Lower time constants at T_2 are accepted provided that the circuit load inductance has a minimum value of 50 mH.

NOTE The test enables the manufacturer to supply curves of the arcing time as a function of the current broken.

9.3.7 Test sequence V: Climatic conditions

When tests are required, 9.3.7 of IEC 60077-2:2017 shall be applied.

9.3.8 Test sequence VI: 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);
- measurement of resistance (see 9.4.3);
- calibration of releases (see 9.4.4);
- air tightness, if applicable (see 9.4.5);
- dielectric withstand (see 9.4.6).

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 Measurement of resistance

The test required in 9.4.3 of IEC 60077-2:2017 shall be applied. The ambient temperature shall be recorded in the routine test report.

9.4.4 Calibration of 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 less than 200 A/s rise.

9.4.5 Air-tightness (for pneumatic circuit-breaker)

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

9.4.6 Dielectric withstand

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

Annex A (normative)

Test circuit to verify the making and breaking capacities

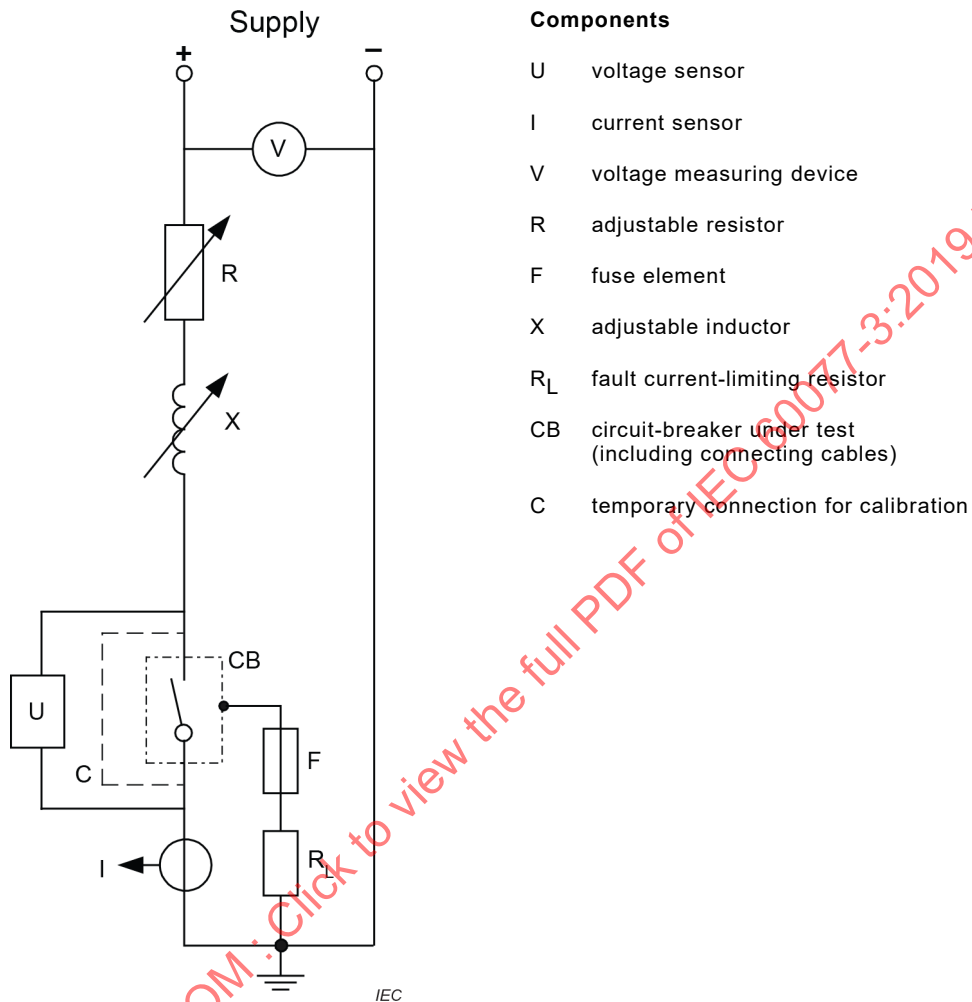


Figure A.1 – Diagram of the test circuit

Annex B (informative)

Verification of short-circuit making and breaking capacities

This annex gives examples of oscillograms which are recorded during the calibration of the circuit, making and breaking of a circuit-breaker.

The key for Figure B.1, Figure B.2 and Figure B.3 is the following:

- A_0 Current setting
- A_1 Breaking current
- A_2 Prospective peak current
- A_3 Prospective breaking current
- A_4 Cut-off current
- T Time constant
- V_0 Rated operational voltage
- V_1 Recovery voltage
- V_2 Peak arc voltage
- t_1 Opening time
- t_2 Arcing time
- t_3 Break-time

In Figure B.2 and Figure B.3, the short-circuit making and breaking capacity is equal to the current A_2 at the applied voltage V_0 .

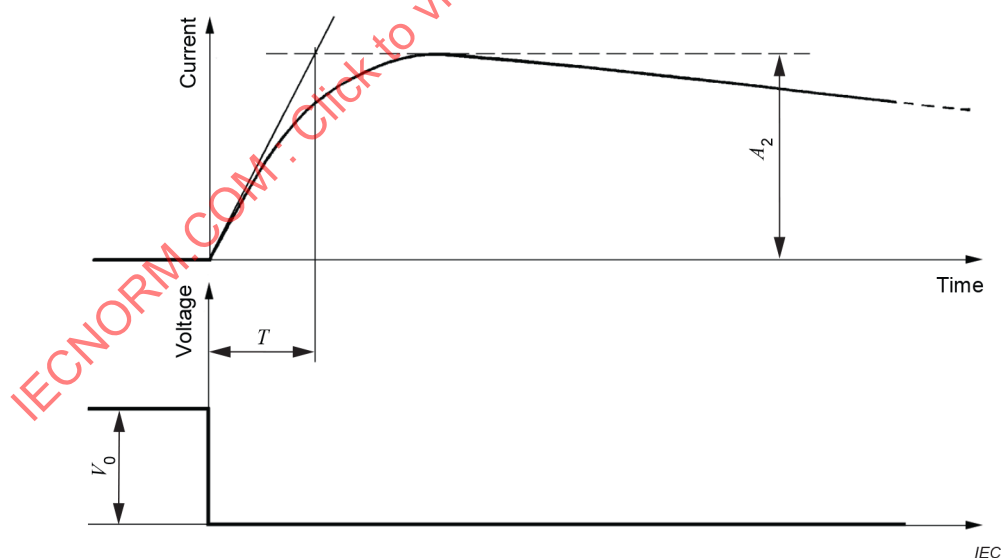
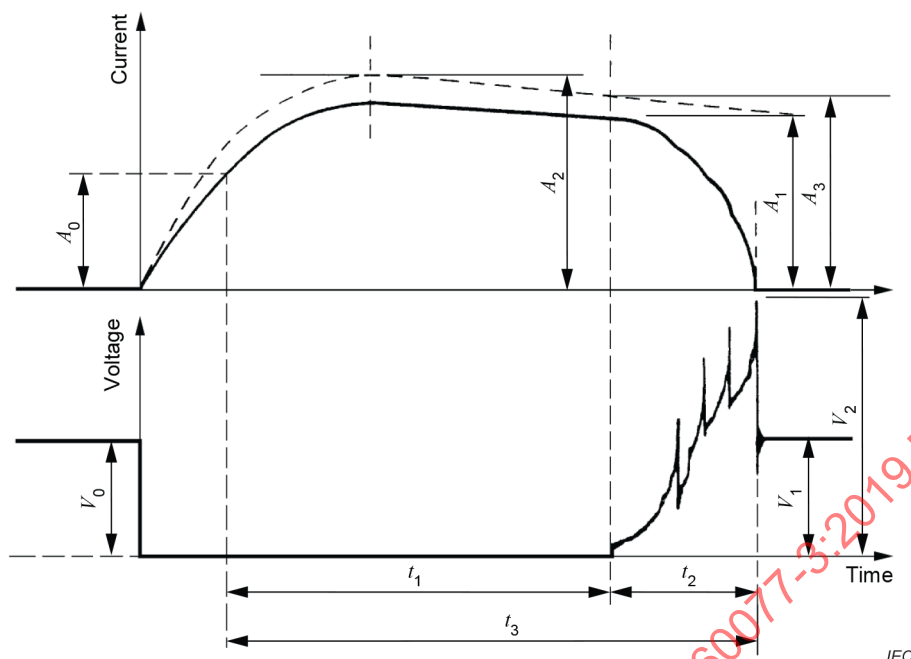
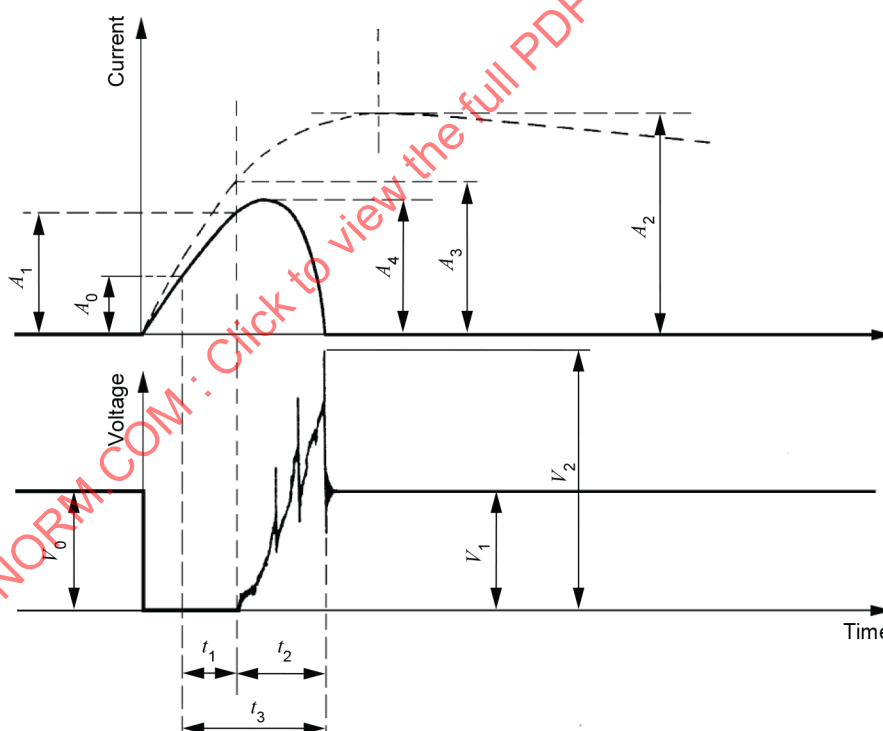


Figure B.1 – Calibration of the circuit to obtain the prospective peak making current



IEC

Figure B.2 – Oscillogram corresponding to a break after the current has passed its maximum value



IEC

Figure B.3 – Oscillogram corresponding to a break before the current has reached its maximum value (current-limiting circuit-breaker)

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SOMMAIRE

AVANT-PROPOS	32
1 Domaine d'application	34
2 Références normatives	35
3 Termes, définitions et termes abrégés	35
3.1 Composants	35
3.2 Parties de composant	36
3.3 Caractéristiques de fonctionnement	37
3.4 Caractéristiques de coupure	38
3.5 Termes abrégés	40
4 Classification	40
5 Caractéristiques	40
5.1 Liste des caractéristiques	40
5.2 Type de disjoncteur	40
5.3 Valeurs limites et valeurs assignées du circuit principal	41
5.3.1 Généralités	41
5.3.2 Tensions assignées	41
5.3.3 Courants assignés	41
5.3.4 Constantes de temps assignées	41
5.3.5 Pouvoirs de fermeture et coupure assignés en court-circuit	42
5.4 Fréquences de fonctionnement	42
5.5 Circuits de commande électriques et pneumatiques	42
5.6 Circuits auxiliaires électriques et pneumatiques	42
5.7 Déclencheur à maximum de courant	42
5.8 Valeurs crêtes de la tension d'arc	43
6 Informations sur le produit	43
6.1 Documentation sur le composant	43
6.2 Marquage	43
7 Conditions normales de service	43
8 Exigences relatives à la construction et au fonctionnement	43
8.1 Exigences relatives à la construction	43
8.2 Exigences relatives au fonctionnement	43
8.2.1 Conditions de fonctionnement	43
8.2.2 Températures limites	43
8.2.3 Fonctionnement à la mise en service	43
8.2.4 Compatibilité électromagnétique (CEM)	43
8.2.5 Emission de bruit acoustique	44
8.2.6 Distances d'isolement dans l'air	44
8.2.7 Lignes de fuite	44
8.2.8 Surtensions de manœuvre	44
8.2.9 Aptitude au fonctionnement en service	44
8.2.10 Tenue aux vibrations et aux chocs	45
8.2.11 Aptitude à l'établissement et à la coupure en court-circuit	45
9 Essais	45
9.1 Types des essais	45
9.1.1 Généralités	45

9.1.2	Essais de type	46
9.1.3	Essais individuels de série.....	46
9.1.4	Essais d'investigation	46
9.2	Vérification des exigences relatives à la construction.....	46
9.2.1	Généralités	46
9.2.2	Essais de type	46
9.2.3	Essais individuels de série.....	46
9.3	Essais de type pour la vérification des exigences relatives au fonctionnement	47
9.3.1	Séquences d'essais	47
9.3.2	Conditions générales d'essais	48
9.3.3	Séquence d'essais I: Caractéristiques générales de fonctionnement.....	48
9.3.4	Séquence d'essais II: Pouvoirs de fermeture et de coupure assignés en court-circuit	50
9.3.5	Séquence d'essais III: Tenue aux vibrations et aux chocs.....	52
9.3.6	Séquence d'essais IV: Recherche des courants critiques.....	53
9.3.7	Séquence d'essais V: Conditions climatiques	53
9.3.8	Séquence d'essais VI: Autres essais	53
9.4	Essais individuels de série pour la vérification des exigences relatives au fonctionnement	53
9.4.1	Généralités	53
9.4.2	Essai fonctionnel	54
9.4.3	Mesure de la résistance.....	54
9.4.4	Etalonnage des déclencheurs	54
9.4.5	Étanchéité (pour les disjoncteurs à air comprimé).....	54
9.4.6	Tenue diélectrique	54
Annexe A (normative)	Circuit d'essai pour la vérification des pouvoirs de fermeture et de coupure.....	55
Annexe B (informative)	Vérification des pouvoirs de fermeture et de coupure en court-circuit.....	56
Bibliographie.....		58
Figure A.1 – Schéma du circuit d'essai		55
Figure B.1 – Etalonnage du circuit pour obtenir la valeur de crête du courant établi présumé		56
Figure B.2 – Oscillogramme correspondant à une coupure du courant après le passage de sa valeur maximale		57
Figure B.3 – Oscillogramme correspondant à la coupure du courant avant sa valeur maximale (disjoncteur limiteur de courant)		57
Tableau 1 – Constantes de temps assignées		41
Tableau 2 – Aptitude au fonctionnement		45
Tableau 3 – Liste des séquences d'essais de type pour les exigences relatives au fonctionnement		47
Tableau 4 – Tolérances des grandeurs d'essai		48

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 3: Composants électrotechniques – Règles pour disjoncteurs à courant continu

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La Norme internationale IEC 60077-3 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 2001. Elle constitue une révision technique.

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

- a) modification de la procédure de vérification de l'échauffement;

- b) ajout de l'essai d'étanchéité comme essai de type et de la mesure de la résistance d'isolement.

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

FDIS	Rapport de vote
9/2537/FDIS	9/2553/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.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous «<http://webstore.iec.ch>» dans les données relatives au document recherché. A cette date, le document sera

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APPLICATIONS FERROVIAIRES – ÉQUIPEMENTS ÉLECTRIQUES DU MATÉRIEL ROULANT –

Partie 3: Composants électrotechniques – Règles pour disjoncteurs à courant continu

1 Domaine d'application

La présente partie de l'IEC 60077 donne, en complément des règles générales de l'IEC 60077-2, les règles relatives aux disjoncteurs dont les contacts sont connectés aux circuits à courant continu de traction et/ou aux circuits des auxiliaires. La tension continue nominale de ces circuits n'excède pas 3 000 V CC, conformément à l'IEC 60850.

En complément de l'IEC 60077-2, la présente partie de l'IEC 60077 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 au document correspondant 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 électrotechniques installés dans des véhicules autres que ceux du matériel roulant ferroviaire tels que les locomotives de mine, les trolleybus, etc. Dans ce cas particulier, des exigences complémentaires peuvent être nécessaires.

Le présent document ne couvre pas:

- e) l'assemblage de composants électrotechniques destinés à des fonctions particulières;
- f) les disjoncteurs industriels conformes à l'IEC 60947-2;
- g) les disjoncteurs à courant continu des installations fixes conformes à l'IEC 61992-2.

Pour f) et g), dans le but d'obtenir un fonctionnement satisfaisant, le présent document est employé uniquement pour spécifier les exigences particulières relatives à l'application ferroviaire. Dans de tels cas, un document spécifique indique les exigences complémentaires auxquelles les disjoncteurs industriels ou les disjoncteurs pour installations fixes se conforment, par exemple:

- pour être adaptés (tension de commande, conditions d'environnement, etc.);

- 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 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*

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 polarisé

disjoncteur pour lequel les caractéristiques de coupure ne sont définies que pour une direction du courant dans le circuit principal

3.1.2

disjoncteur bidirectionnel

disjoncteur pour lequel les caractéristiques de coupure sont les mêmes dans les deux sens de circulation du courant dans le circuit principal

3.1.3

disjoncteur à air

disjoncteur dont les contacts s'ouvrent et se ferment dans l'air à la pression atmosphérique

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-27]

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 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]

3.1.6

disjoncteur hybride

disjoncteur muni de contacts mécaniques pour l'isolement associés à un semiconducteur pour la coupure

Note 1 à l'article: Les disjoncteurs à semiconducteur sans contact mécanique pour l'isolement ne sont pas utilisés sur le matériel roulant.

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 direct à maximum de courant

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

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

3.2.4

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».]

3.2.5

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.]

3.2.6

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 procurer 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.]

3.2.7

enveloppe intégrée

enveloppe faisant partie intégrante du disjoncteur

3.3 Caractéristiques de fonctionnement

3.3.1

disjoncteur limiteur de courant

disjoncteur dont la durée de coupure est particulièrement brève en vue d'obtenir que le courant de court-circuit ne puisse atteindre son amplitude maximale

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-14-21]

3.3.2

disjoncteur à déclenchement libre

disjoncteur dans lequel les contacts mobiles reviennent en position d'ouverture et y demeurent quand la manœuvre de déclenchement 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.

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.4.11]

3.3.3

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.]

3.3.4

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]

3.3.5

manœuvre de déclenchement

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

3.4 Caractéristiques de coupure

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

durée d'ouverture par maximum de courant

intervalle de temps entre l'instant où le courant atteint la valeur de réglage du déclencheur à maximum de courant et l'instant où les contacts de coupure sont séparés

3.4.3

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.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-01, modifié – La NOTE a été remplacée.]

3.4.4

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.]

3.4.5

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

courant présumé évalué à l'instant correspondant au début du phénomène de coupure

Note 1 à l'article: L'instant du début du phénomène de coupure est habituellement choisi comme le moment du début de l'arc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-06, modifié – La NOTE 1 à l'article a été remplacée.]

3.4.6

courant coupé limité

valeur instantanée maximale du courant atteinte au cours de la coupure effectuée par un appareil de connexion ou un fusible

Note 1 à l'article: Cette notion est d'importance particulière si l'appareil de connexion ou le fusible fonctionne de telle manière que la valeur de crête du courant présumé du circuit n'est pas atteinte.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-12]

3.4.7

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.]

3.4.8

durée d'arc, <d'un pôle ou d'un fusible>

intervalle de temps entre l'instant de début de l'arc sur un pôle ou sur un fusible et l'instant de l'extinction finale de l'arc sur ce pôle ou ce fusible

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-37]

3.4.9

durée de coupure

intervalle de temps entre le début de la durée d'ouverture d'un appareil mécanique de connexion, ou le début de la durée de préarc d'un fusible, et la fin de la durée d'arc

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-17-39]

3.4.10

intégrale de Joule, <pour un disjoncteur>

I^2t

intégrale du carré de la valeur du courant dans un disjoncteur dans l'intervalle de la durée de coupure lors de la manœuvre d'ouverture

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

t_0 = début de la durée d'ouverture

t_1 = fin de la durée d'arc

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-23, modifié – «dans un disjoncteur dans l'intervalle de la durée de coupure» a été ajouté; «pour un intervalle de temps donné» a été remplacé par «lors de la manœuvre d'ouverture». Les NOTES ont été supprimées, les légendes pour t_0 et t_1 ont été ajoutées.]

3.4.11

caractéristique I^2t , <pour un disjoncteur>

information (généralement une courbe) donnant la valeur de I^2t en fonction de la valeur de crête du courant présumé dans des conditions spécifiées comme le courant de réglage du déclencheur, la constante de temps du circuit d'essai, etc.

[SOURCE: IEC 60050-441:1984/AMD1:2000, 441-18-24, modifié – «information (généralement une courbe) donnant la» a été ajouté; «dans des conditions prescrites» a été supprimé; «courant présumé ou de la tension ou des deux à la fois» a été remplacé par «la valeur de crête du courant présumé...». La NOTE a été supprimée.]

3.4.12

caractéristique durée de coupure-courant

courbe donnant la durée de coupure en fonction de la valeur de crête du courant présumé dans les conditions spécifiées comme le courant de réglage du déclencheur, la constante de temps du circuit d'essai, etc.

3.4.13

caractéristique de coupure courant, <pour un disjoncteur>

courbe donnant le courant coupé en fonction de la valeur de crête du courant présumé dans les conditions spécifiées comme le réglage du déclencheur, la constante de temps du circuit d'essai, etc.

[SOURCE: IEC 60050-811:2017, 811-29-43, modifié – "de la valeur de crête", "comme" et ", etc." ont été ajoutés.]

3.4.14

vitesse de montée du courant initiale

di/dt

vitesse de montée au début du passage du courant

[SOURCE: IEC 61992-1:2006/AMD1:2014, 3.2.27, modifié – "courant" a été ajouté dans le terme et le symbole a été ajouté.]

3.5 Termes abrégés

CEM Compatibilité électromagnétique

4 Classification

Cet article est destiné à énumérer les caractéristiques d'un disjoncteur sur lequel le constructeur donne des informations, et qui doivent être vérifiées par des essais si nécessaire.

Les disjoncteurs sont classés:

- a) selon leur fréquence de fonctionnement C1, C2 ou C3. Les caractéristiques de ces fréquences de fonctionnement sont données en 5.4;
- b) selon le type de conception:
 - construction ouverte;
 - construction sous enveloppe intégrée;
- c) selon le degré de protection fourni par l'enveloppe (voir l'IEC 60529).

5 Caractéristiques

5.1 Liste des caractéristiques

Les caractéristiques d'un disjoncteur doivent être celles de la liste suivante lorsqu'elles sont appropriées:

- type de disjoncteur (5.2);
- valeurs limites et valeurs assignées pour le circuit principal (5.3);
- fréquences de fonctionnement (5.4);
- circuits de commande électriques et pneumatiques (5.5);
- circuits auxiliaires électriques et pneumatiques (5.6);
- déclencheur à maximum de courant (5.7);
- valeurs crêtes de la tension d'arc (5.8).

5.2 Type de disjoncteur

Il est nécessaire d'indiquer:

- le type d'appareil (par exemple disjoncteur à air, disjoncteur à vide, disjoncteur hybride, disjoncteur bidirectionnel ou polarisé);

- le type de conception (voir Article 4);
- le degré de protection fourni par l'enveloppe (voir Article 4);
- caractéristiques de fonctionnement (par exemple disjoncteur limiteur de courant, disjoncteur à déclenchement libre).

5.3 Valeurs limites et valeurs assignées du circuit principal

5.3.1 Généralités

Les valeurs assignées sont choisies par le constructeur; il n'est toutefois pas nécessaire d'établir toutes les valeurs caractéristiques énumérées.

5.3.2 Tensions assignées

Un composant est défini par les tensions assignées suivantes, définies en 5.2 de l'IEC 60077-1:2017:

- tension assignée d'emploi (U_r);

NOTE 1 Certains types de disjoncteurs ont plusieurs valeurs de tensions assignées d'emploi ou un domaine assigné de tensions d'emploi.

- tension d'isolement assignée (U_{Nm});

NOTE 2 Lorsqu'aucune tension d'isolement assignée n'a été assignée à un disjoncteur, la tension d'isolement assignée est considérée comme étant égale à la valeur de tension assignée d'emploi la plus élevée.

- tension assignée de choc (U_{Ni});
- tension d'essai à la fréquence industrielle (U_a).

5.3.3 Courants assignés

Un composant est défini par les tensions assignées suivantes, définies en 5.4 de l'IEC 60077-1:2017 et en 5.3.3 de l'IEC 60077-2:2017:

- courant assigné d'emploi (I_r) à la constante de temps assignée T_2 (voir 5.3.4);

NOTE Certains types de disjoncteurs ont plusieurs valeurs de courants assignés d'emploi ou une plage de courants assignés d'emploi.

- courant thermique conventionnel à l'air libre (I_{th});
- courant thermique conventionnel sous enveloppe (I_{the}).

5.3.4 Constantes de temps assignées

Les constantes de temps pour le disjoncteur dépendent des caractéristiques électriques de la sous-station, de la ligne et de la charge.

Les quatre constantes de temps données dans le Tableau 1 doivent être utilisées par le constructeur pour déterminer les pouvoirs de coupure et de fermeture en court-circuit mentionnés en 5.3.5.

Si nécessaire, les valeurs des constantes de temps peuvent être définies par accord entre le constructeur et l'utilisateur.

Tableau 1 – Constantes de temps assignées

Tension assignée d'emploi U_r V		900	1 800	3 600
Constante de temps T_1 (minimum)	ms	0	0	0
Constante de temps T_2	ms	15	15	15
Constante de temps T_3	ms	50	40	30