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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

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

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

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

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

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

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

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

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

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

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

This International Standard is to be used in conjunction with IEC 60947-1:2020.

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

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

- reconfirmed,
- withdrawn, or
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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

~~1 General~~

1 Scope ~~and object~~

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

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

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

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

Circuit-breakers per this document are suitable for isolation.

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

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

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

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

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

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

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

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

The requirements for instantaneous trip circuit-breakers are contained in Annex O.

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

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

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

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

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

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

NOTE 1 Circuit-breakers can have dedicated accessories.

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

The object of this document is to state:

a) the characteristics of circuit-breakers;

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

   1) operation and behaviour in normal service;

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

   3) dielectric properties;

   4) requirements on electromagnetic compatibility, where applicable;

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

d) information to be marked on or given with the ~~apparatus~~ circuit-breakers.

NOTE 3 For cybersecurity requirements, see IEC TS 63208.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

IEC 60228, *Conductors of insulated cables*

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

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

IEC 60947-1:~~2007~~2020, *Low-voltage switchgear and controlgear – Part 1: General rules*
~~IEC 60947-1:2007/AMD1:2010~~
~~IEC 60947-1:2007/AMD2:2014~~

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

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

IEC 61000-4-3:~~2006~~2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
~~IEC 61000-4-3:2006/AMD1:2007~~
~~IEC 61000-4-3:2006/AMD2:2010~~

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

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*
IEC 61000-4-5:2014/AMD1:2017

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

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

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

IEC 61545:1996, *Connecting devices – Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units*

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

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

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

3 Terms and definitions

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

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

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

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

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

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

3.1.1
frame size
term designating a group of circuit-breakers, the external physical dimensions of which are common to a range of current ratings

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

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

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

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

3.2
integrally fused circuit-breaker
combination, in a single device, of a circuit-breaker and fuses, one fuse being placed in series with each pole of the circuit-breaker intended to be connected to a ~~phase~~ line conductor

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

3.3
current-limiting circuit-breaker
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

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

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

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

3.4
plug-in circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of contacts which enable the circuit-breaker to be removed

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

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3.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be withdrawn from the main circuit, and, in the disconnected position, to achieve an isolating distance in accordance with specified requirements

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

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

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

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

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

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

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

3.6
making-current release
release which permits a circuit-breaker to open, without any intentional time-delay, during a closing operation, if the making current exceeds a predetermined value, and which is rendered inoperative when the circuit-breaker is in the closed position

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

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

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

3.10
circuit-breaker with lock-out device preventing closing
circuit-breaker in which each of the moving contacts is prevented from closing sufficiently to be capable of passing current if the closing command is initiated while specified conditions remain established

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

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3.11.1
ultimate short-circuit breaking capacity
breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the circuit-breaker to carry its rated current continuously

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

3.11.3
service short-circuit breaking capacity
breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the circuit-breaker to carry its rated current continuously

3.12
opening time
<of a mechanical switching device> interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

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

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

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

[SOURCE: ~~IEC 60947-1:2007, 2.5.39, modified – addition of Notes to entry.~~ IEC 60947-1:2020, 3.7.39, modified – modification of Note 1 to entry and addition of Note 2 to entry.]

~~**2.17**~~
~~**over-current protective co-ordination**~~

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

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

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

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

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

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

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

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

3.13
I^2t characteristic of a circuit-breaker
information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (RMS symmetrical for AC) up to the maximum prospective current corresponding to the rated short-circuit breaking capacity and associated voltage

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

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

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

Note 1 to entry: I_i can be non-adjustable

3.16
overload current setting
I_r
current setting of an adjustable overload release

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

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

3.18
programmable logic controller
PLC
digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analogue inputs and outputs, various types of machines or processes

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Note 1 to entry: Both the PLC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions.

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

3.19
closing release
closing coil
release, energized by a source of voltage, which triggers the closing of the circuit-breaker

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

4 Classification

~~Circuit-breakers may be classified:~~

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

~~3.2 According to the interrupting medium, for example:~~

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

~~3.3 According to the design, for example:~~

~~– open construction;~~
~~– moulded case.~~

4.2 According to the method of controlling the operating mechanism:

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

~~3.5 According to the suitability for isolation:~~

~~– suitable for isolation;~~
~~– not suitable for isolation.~~

4.3 According to the provision for maintenance:

– maintainable;
– non-maintainable.

4.4 According to the method of installation:

– fixed;
– plug-in;
– withdrawable.

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

5 Characteristics of circuit-breakers

5.1 Summary of characteristics

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

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

5.2 Type of circuit-breaker

The following shall be stated:

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

5.3 Rated and limiting values of the main circuit

5.3.1 General

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

5.3.2 Rated voltages

5.3.2.1 Rated operational voltage (U_e)

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

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

U_e is generally stated as the voltage between phases.

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

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

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

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

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

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

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

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by 5.3.1.1 item b) of IEC 60947-1:~~2007~~2020 are identified by the voltage between phases only.

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5.3.2.2 Rated insulation voltage (U_i)

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

5.3.2.3 Rated impulse withstand voltage (U_{imp})

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

5.3.3 Currents

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

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

5.3.3.2 Conventional enclosed thermal current (I_{the})

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

5.3.3.3 Rated current (I_n)

For circuit-breakers, the rated current is the rated uninterrupted current (I_u) (see 5.3.2.4 of IEC 60947-1:~~2007~~2020) and is equal to the conventional free-air thermal current (I_{th}).

~~**4.3.3.4 Current rating for four-pole circuit-breakers**~~

~~Subclause 7.1.9 of IEC 60947-1:2007 applies.~~

5.3.4 Rated frequency

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

5.3.5 Rated duty

The rated duties considered as normal are:

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

5.3.6 Short-circuit characteristics

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

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

For AC, the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor n of Table 1 (see 5.3.6.3).

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

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

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5.3.6.2 Rated short-circuit breaking capacities

5.3.6.2.1 General

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

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

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

– for AC, at any power factor not less than ~~that of Table 11~~ those required in 9.3.3.2.4;
– for DC, with any time constant not greater than ~~that of Table 11~~ those required in 9.3.3.2.5.

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

For AC, the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in ~~Table 11~~ 9.3.3.2.4, irrespective of the value of the inherent DC component, on the assumption that the RMS value of the AC component of the prospective current is constant.

The rated short-circuit breaking capacities are stated as:

– rated ultimate short-circuit breaking capacity;
– rated service short-circuit breaking capacity.

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

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

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

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

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

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 3.11.3) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.5. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example I_{cs} = 25 % I_{cu}).

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

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~~Table 1 (void)~~

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

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

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

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

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

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

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

The rated short-time withstand current of a circuit-breaker is the value of short-time withstand current assigned to that circuit-breaker by the manufacturer under the test conditions specified in 9.3.7.3.

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

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

For AC, the value of this current is the RMS value of the AC component of the prospective short-circuit current, assumed constant during the short-time delay.

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

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

The rated short-time withstand current shall be not less than the appropriate values shown in Table 2.

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Table 2 – Minimum values of rated short-time withstand current

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

5.4 Selectivity categories

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

– **Selectivity category B** comprises circuit-breakers providing selectivity by having a short-time withstand current rating and an associated short-time delay according to 5.3.6.4.

Selectivity of circuit-breakers of selectivity category B is not necessarily ensured up to the ultimate short-circuit breaking capacity (e.g. in the case of operation of an instantaneous release) but at least up to the value specified in Table 2.

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

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

A circuit-breaker of selectivity category A may have an intentional short-time delay with a short-time withstand current less than that according to 5.3.6.4. In that case, the tests shall include test sequence IV (see 9.3.7) at the assigned short-time withstand current.

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

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

5.5 Control circuits

5.5.1 Electrical control circuits

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

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

Table 3 – Preferred values of the rated control circuit supply voltage, if different from that of the main circuit

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

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

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

5.6 Auxiliary circuits

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

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5.7 Releases

5.7.1 Types

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

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

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

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

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

5.7.2 Characteristics

The following characteristics shall be considered:

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

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

5.7.3 Current setting of overcurrent releases

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

For circuit-breakers fitted with adjustable releases (see Note 2 to 5.7.1, item 2), the current settings shall be marked on the release, or displayed on the release's display, or displayed on an external device's display connectable to the release. The settings may be either directly in

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

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 5, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

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

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

Unless otherwise specified:

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

– for releases of the thermal type, the values stated are for a reference temperature of +30 °C ±2 °C. The manufacturer shall ~~be prepared to~~ state the influence of ~~variations in the~~ ambient ~~air~~ temperature in the literature (see 8.2.1.2.4, item b)).

5.7.4 Tripping time setting of overcurrent releases

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

1) Definite time-delay overcurrent releases

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

2) Inverse time-delay overcurrent releases

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

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

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

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

5.8 Integral fuses (integrally fused circuit-breakers)

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

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

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6 Product information

6.1 Nature of the information

Subclause 6.1 of IEC 60947-1:~~2007~~2020 applies, as far as appropriate for a particular design.

In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 3.1.1). See Annex G.

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

6.2 Marking

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

Table 4 – Product information

Item	Information	~~Marking~~ Location
1.1	rated current (I_n)	Visible
1.2	suitability for isolation~~, if applicable,~~ with the symbol  (IEC 60617-~~S00288~~S00287:2001-07 combined with IEC 60617-~~S00219~~S00220:2001-07)	Visible
1.3	indication of the open and closed position with O (IEC 60417-5008:2002-10) and I (IEC 60417-5007:2002-10) respectively, if symbols are used (see 8.1.6.1 of IEC 60947-1:~~2007~~2020)	Visible
2.1	manufacturer's name or trade mark	Marked
2.2	type designation or catalogue reference	Marked
2.3	IEC 60947-2, if the manufacturer claims compliance with this document	Marked
2.4	selectivity category A or B	Marked
2.5	rated operational voltage(s) U_e (see 5.3.2.1 and, where applicable, Annex H)	Marked
2.6	~~unsuitability for IT systems, if applicable, with the symbol~~  ~~(IEC 60417-6363:2016-07)~~ Indication that the circuit-breaker is not suitable for IT systems at all rated voltages with the symbol  (IEC 60417-6363:2016-07). For any exception for specific rated voltages, see H.5.	Marked
2.7	rated impulse withstand voltage (U_{imp})	Marked
2.8	value (or range) of the rated frequency, and/or the indication "DC" (or the symbol ⎓ (IEC 60417-5031:2002-10))	Marked
2.9	rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e)	Marked
2.10	rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e)	Marked
2.11	rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}), at the corresponding rated voltage (U_e), if different from I_{cu}	Marked
2.12	rated short-time withstand current (I_{cw}), and associated short-time delay, for selectivity category B	Marked
2.13	range of the current setting (I_r) of the adjustable overload release	Marked [a]
2.14	value or range (when adjustable) of the short-time pick-up current setting (I_{sd}) of the release and its intended time-delay (t_{sd}), when applicable	Marked [a]
2.15	range of the ground-fault current (I_g) of the adjustable release, when applicable	Marked [a]
2.16	range of the ~~rated~~ instantaneous short-circuit current setting (I_i), for adjustable releases	Marked [a]

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Item	Information	~~Marking~~ Location
2.17	reference temperature for non-compensated thermal releases, if different from 30 °C	Marked
2.18	terminals identification, according to 8.1.8.4 of IEC 60947-1:~~2007~~2020	Marked
2.19	Identification of line and load terminals, if applicable	Marked
2.20	neutral pole terminals, if applicable, by the letter N	Marked
2.21	protective earth terminal, where applicable, by the symbol (IEC 60417-5019:2006-08)  (see 8.1.10.3 of IEC 60947-1:~~2007~~2020)	Marked
3.1	rated short-circuit making capacity (I_{cm}) at the corresponding rated voltage (U_e), if higher than the minimum values specified in 5.3.6.1	Literature
3.2	rated insulation voltage (U_i), if higher than the maximum rated operational voltage	Literature
3.3	pollution degree if other than 3 (see 7.1.3.2 of IEC 60947-1:2020)	Literature
3.4	conventional enclosed thermal current (I_{the}) if different from the rated current	Literature
3.5	IP code, where applicable (see Annex C of IEC 60947-1:~~2007/AMD1:2010~~2020)	Literature
3.6	when applicable, minimum enclosure size and ventilation data (if any) to which marked ratings apply	Literature
3.7	details of minimum distance between circuit-breaker and earthed metal parts for circuit-breakers intended for use without enclosures	Literature
3.8	suitability for environment A or environment B per Annex J, as applicable	Literature
3.9	RMS sensing, if applicable, in accordance with F.4.1.1	Literature
3.10	minimum cable cross-section, if different from Table 9 of IEC 60947-1:~~2007~~2020, for ratings ≤ 20 A according to rated ultimate short-circuit breaking capacity I_{cu}	Literature
3.11	values of tightening torque for the circuit-breaker terminals	Literature
3.12	current derating, when applicable, for temperatures higher than the reference temperature	Literature
3.13	influence of ambient temperature, if applicable, on the tripping performance of the overcurrent release (see 5.7.3)	Literature
3.14	current derating for terminals and connections, if applicable	Literature
3.15	method and diagram of series connection of poles (as necessary for each rating) for DC circuit-breakers	Literature
3.16	type of ground-fault detection function (see T.4 of IEC 60947-1:2020)	Literature
3.17	value of the instantaneous short-circuit current setting (I_i), for non-adjustable releases	Literature
3.18	number of poles	Literature
3.19	further information concerning aluminum conductors (see D.5.2)	Literature
4.1	for closing releases (see 3.19) and/or motor-operators, rated control circuit voltage, kind of current and rated frequency for AC	Aux
4.2	rated control circuit voltage of the shunt release and/or of the undervoltage release (or of the no-voltage release), kind of current and rated frequency for AC	Aux
4.3	rated current of indirect overcurrent releases (see 5.7.3)	Aux
4.4	number and type of auxiliary contacts, rated operational currents at the rated operational voltages, and rated frequency for AC	Aux

Key

Visible: visible from the front when the circuit-breaker is installed as in service and the actuator is accessible

Marked: marked on the circuit-breaker

Literature: provided in the manufacturer's literature

Aux: marked on the auxiliaries or on the circuit-breaker, if marking space is sufficient; additionally, data shall be made available in the manufacturer's literature

[a] ~~Where applicable, I_r and I_i ranges may be displayed instead of being marked on the circuit-breaker.~~ Where applicable, settings of I_r, I_i, I_{sd} and I_g may be displayed on the display of the release or of an external device instead of being marked (see 5.7.3).

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6.3 Instructions for installation, operation and maintenance

Subclause 6.3 of IEC 60947-1:~~2007/AMD2:2014~~2020 applies with the following addition:

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

7 Normal service, mounting and transport conditions

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

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

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

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

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

a) Where, in 8.1.2.2 of IEC 60947-1:2020, the test temperature is to be specified, the value required by this document for the parts necessary to retain in position current-carrying parts is 960 °C for the main circuit and 850 °C for the other circuits.

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

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

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

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

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

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

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

~~– 960 °C for the main circuit;~~

~~– 850 °C for the other circuits.~~

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8.1.2 Withdrawable circuit-breakers

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

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

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

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

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

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

8.1.3 ~~Additional requirements for circuit-breakers suitable for~~ Isolation

~~For additional requirements concerning performance, see 7.2.7.~~

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

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

Subclause 8.1.7 of IEC 60947-1:2020 applies.

For additional requirements concerning performance, see 8.2.6.

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

8.1.4 Clearances and creepage distances

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

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

8.1.5 Requirements for the safety of the operator

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

Compliance is checked by the provisions of 9.3.3.6.1, item b).

8.1.6 List of construction breaks

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

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– material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
– size, material, configuration and method of attachment of the main contacts;
– any integral manual operating mechanism, its materials and physical characteristics;
– moulding and insulating materials;
– the principle of operation, materials and construction of the arc extinction device;
– the basic design of the overcurrent tripping devices, admitting, however, the variations detailed in a), b) and c) below.

Variations in the following do not constitute a construction break:

a) dimensions of terminals, provided that creepage and clearance distances are not reduced;
b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;
c) secondary windings of current transformer operated releases;
d) external operating means, additional to the integral operating means;
e) type designation and/or purely aesthetic features (e.g. labels);
f) in the case of the 2-pole and 4-pole variants, replacement of the trip unit in one pole by a link, to provide an unprotected neutral;
g) creating a 2-pole breaker from a 3-pole breaker by removing the centre current path, or rendering the central pole inaccessible;
h) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;
i) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

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

Subclause 8.1.9 of IEC 60947-1:~~2007~~2020 applies ~~with the following addition:~~.

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

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

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

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 Closing

8.2.1.1.1 General

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

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8.2.1.1.2 Dependent manual closing

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

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

However, this does not apply in the case of a circuit-breaker having a dependent manual closing mechanism and incorporating an integral fast-acting opening release which causes the circuit-breaker to break safely, irrespective of the speed and firmness with which it is closed on to prospective peak currents exceeding 10 kA; in this case, a rated short-circuit making capacity can be assigned.

8.2.1.1.3 Independent manual closing

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

8.2.1.1.4 Dependent power closing

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

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

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

8.2.1.1.5 Independent power closing

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

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

8.2.1.1.6 Stored energy closing

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

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

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

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

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

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

8.2.1.2 Opening

8.2.1.2.1 General

Circuit-breakers which open automatically shall be trip-free (see 3.6.24 of IEC 60947-1:~~2007~~2020) and~~, unless otherwise agreed between manufacturer and user, circuit-breakers~~ shall have their energy for the tripping operation stored automatically prior to the completion of the closing operation.

8.2.1.2.2 Opening by undervoltage releases

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

8.2.1.2.3 Opening by shunt releases

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

8.2.1.2.4 Opening by overcurrent releases

a) Opening under short-circuit conditions

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

Where necessary for overcurrent coordination, the manufacturer shall provide information (usually curves) showing:

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

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

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

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

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

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

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 5.

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

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see

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3.7.31 of IEC 60947-1:~~2007~~2020), tripping shall then occur in less than the conventional time later.

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

Table 5 – Characteristics of the opening operation of inverse time-delay overcurrent opening releases at the reference temperature

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

If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 5 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 %/K.

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

c) Opening under ground-fault conditions

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

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

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

8.2.2 Temperature-rise

8.2.2.1 Temperature-rise limits

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

8.2.2.2 Ambient air temperature

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

8.2.2.3 Main circuit

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

8.2.2.4 Control circuits

The control circuits, including control circuit devices, used for the closing and opening operations of a circuit-breaker, shall permit the rated duty, as specified in 5.3.5, and also the temperature-rise tests under the test conditions specified in 9.3.3.5, to be made without the temperature-rises exceeding the limits specified in Table 6.

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

8.2.2.5 Auxiliary circuits

Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional thermal current without the temperature-rises exceeding the limits specified in Table 6 when tested in accordance with 9.3.3.5.

Table 6 – Temperature-rise limits for terminals and accessible parts

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which ~~need~~ shall not be touched for normal operation:	
Metallic	50
non-metallic	60
[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.	
[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 9.	

8.2.3 Dielectric properties

8.2.3.1 General

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

Type tests shall be made in accordance with 9.3.4.3.

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

Routine tests shall be made in accordance with 9.4.6.

8.2.3.2 Impulse withstand voltage

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

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

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

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8.2.3.3 Power-frequency or DC withstand voltage of the main, auxiliary and control circuits

Power-frequency tests are used in the following cases:

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

8.2.3.4 Clearances

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

8.2.3.5 Creepage distances

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

8.2.3.6 Solid insulation

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

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

8.2.3.7 Spacing between separate circuits

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

8.2.3.8 Requirements for circuits with protective separation

Annex N of IEC 60947-1:2020 applies.

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

8.2.4.1 Overload performance

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

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 9.3.4.5.

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

8.2.4.2 Operational performance capability

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

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

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

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

Table 7 – Number of operating cycles

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

[a] This means the maximum rated current for a given frame size.

[b] Column 2 gives the minimum operating rate. This rate may be increased with the consent of the manufacturer; in this case the rate used shall be stated in the test report.

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

8.2.5 Ability to make and break under short-circuit conditions

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

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

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

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

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

~~**7.2.6 Vacant**~~

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

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

8.2.7 Specific requirements for integrally fused circuit-breakers

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

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

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

For all overcurrents up to and including the rated ultimate short-circuit breaking capacity assigned to the composite unit, the circuit-breaker shall open when one or more fuses operate (in order to prevent single-phasing). If the circuit-breaker is stated by the manufacturer to be

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circuit-breaker with lock-out device preventing closing (see 3.10), it shall not be possible to reclose the circuit-breaker until either the melted fuse-links or any missing fuse-links have been replaced or the lock-out means has been reset.

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

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

8.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

9 Tests

9.1 Kind of tests

9.1.1 General

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

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

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

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

9.1.2 Type tests

Type tests include the tests listed in Table 8.

Table 8 – Type tests

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

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

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9.1.3 Routine tests

Routine tests comprise the tests listed in 9.4.

9.1.4 Special tests

Special tests comprise the tests listed in 9.5.

9.2 Compliance with constructional requirements

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

9.3 Type tests

9.3.1 General

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

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

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

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

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

In order to facilitate locating a particular test condition or test, an alphabetical index is given in Table 9, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

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Table 9 – Alphabetical index of tests

General test conditions	Subclause
Arrangement of circuit-breakers, general	9.3.3.1
Arrangement of circuit-breakers for short-circuit tests	9.3.3.6.1
Frequency	9.3.3.2.3
Power factor	9.3.3.2.4
Records (interpretation of)	9.3.3.6.6
Recovery voltage	9.3.3.2.6
Short-circuit test circuits	9.3.3.6.2
Short-circuit test procedure	9.3.3.6.4
Temperature-rise test	9.3.3.5
Time constant	9.3.3.2.5
Tolerances	9.3.3.2.2
Tests (for overall schema of test sequences, see Table 10)	**Subclause**
Critical DC load current	9.3.10
Dielectric properties	9.3.4.3
Dielectric withstand (verification)	9.3.4.6 – 9.3.5.4 – 9.3.6.4 – 9.3.7.6 – 9.3.8.4 – 9.3.8.8 – 9.3.9.6
Individual pole short-circuit test (for phase-earthed systems)	Annex C
Individual pole short-circuit test (for IT systems)	Annex H – see H.2
Indication of main contact position	9.3.4.10
Integrally fused circuit-breakers (short-circuit tests)	9.3.8.2 – 9.3.8.6 – 9.3.8.7
Operational performance capability	9.3.4.4 – 9.3.5.3 – 9.3.5.5
Overload performance	9.3.4.5
Overload releases (verification)	9.3.4.8 – 9.3.5.6 – 9.3.6.2 – 9.3.6.5 – 9.3.7.2 – 9.3.7.7 – 9.3.8.5 – 9.3.8.9 – 9.3.9.2 – 9.3.9.8
Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage	9.3.11
Service short-circuit breaking capacity	9.3.5.2 – 9.3.9.4
Short-circuit breaking capacity test at maximum short-time withstand current	9.3.7.5
Short-time withstand current	9.3.7.3 – 9.3.9.3
Temperature-rise (verification)	9.3.4.7 – 9.3.5.5 – 9.3.7.4 – 9.3.8.3 – 9.3.9.7
Tripping limits and characteristics	9.3.4.2
Ultimate short-circuit breaking capacity	9.3.6.3
Withdrawable circuit-breakers (additional tests)	9.3.4.4.5

9.3.2 Test sequences

9.3.2.1 General

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

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

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9.3.2.2 Tests omitted from sequence I and made separately

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

– tripping limits and characteristics (9.3.4.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 9.3.4.2.3 only on the phase poles at the maximum setting, at room temperature and without the additional test of item b) to verify the time-current characteristic;

– test of dielectric properties (9.3.4.3);

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

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

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

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

The applicability of test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw} is given in Table 11.

Table 10 – Overall schema of test sequences[a]

Test sequence	Applicable to	Tests
I General performance characteristics (9.3.4)	All circuit-breakers	Tripping limits and characteristics Dielectric properties Mechanical operation and operational performance capability Overload performance (where applicable) Verification of dielectric withstand Verification of temperature-rise Verification of overload releases Verification of undervoltage and shunt releases (where applicable) Verification of main contact position ~~(where applicable)~~
II Rated service short-circuit breaking capacity (9.3.5)	All circuit-breakers [b]	Rated service short-circuit breaking capacity Verification of operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
III Rated ultimate short-circuit breaking capacity (9.3.6)	All circuit-breakers [c] of selectivity category A and circuit-breakers of selectivity category B with instantaneous override[d]	Verification of overload releases Rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases

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Test sequence	Applicable to	Tests
IV Rated short-time withstand current (9.3.7)	Circuit-breakers of selectivity category B [b] and circuit-breakers of selectivity category A with an assigned short-time withstand current (see 5.4)	Verification of overload releases Rated short-time withstand current Verification of temperature-rise Short-circuit breaking capacity at maximum short-time withstand current Verification of dielectric withstand Verification of overload releases
V Performance of integrally fused circuit-breakers (9.3.8)	Stage 1 Integrally fused circuit-breakers Stage 2	Short-circuit at the selectivity limit current Verification of temperature-rise Verification of dielectric withstand Verification of overload releases Short-circuit at 1,1 times the take-over current Short-circuit at rated ultimate short-circuit breaking capacity Verification of dielectric withstand Verification of overload releases
VI Combined test sequence (9.3.9)	Circuit-breakers of selectivity category B: when $I_{cw} = I_{cs}$ (replaces test sequences II and IV) when $I_{cw} = I_{cs} = I_{cu}$ (replaces test sequences II, III and IV)	Verification of overload releases Rated short-time withstand current Rated service short-circuit breaking capacity Operational performance capability Verification of dielectric withstand Verification of temperature-rise Verification of overload releases
VII Critical DC load current (9.3.10)	Circuit-breakers with DC ratings	Critical DC load current tests
VIII Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (9.3.11)	AC circuit-breakers, when applicable (see 9.3.11.1)	Verification of overload releases Rated individual pole ultimate short-circuit breaking capacity at phase-to-neutral AC voltage (I_{cu1}) Verification of dielectric withstand Verification of overload releases
Individual pole short-circuit test sequence (Annex C)	Circuit-breakers for use on phase-earthed systems	Individual pole short-circuit breaking capacity (I_{su}) Verification of dielectric withstand Verification of overload releases
Test sequence for circuit-breakers for IT systems (Annex H)	Circuit-breakers for use in IT systems	Individual pole short-circuit breaking capacity (I_{IT}) Verification of dielectric withstand Verification of overload releases

[a] For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs}, I_{cu} and I_{cw}, see Table 11.

[b] Except where Sequence VI is applied.

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

[d] See note to 9.3.6.1

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