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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

FOREWORD

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

This fifth edition cancels and replaces the fourth edition published in 2006, Amendment 1:2009 and Amendment 2:2013. This edition constitutes a technical revision.

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

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

The text of this standard is based on the following documents:

FDIS	Report on voting
121A/71/FDIS	121A/83/RVD

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

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

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

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

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

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

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- withdrawn,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

The contents of the corrigendum of November 2016 have been included in this copy.

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

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

~~The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1, for example, 1.2.3 of IEC 60947-1, Table 4 of IEC 60947-1, or Annex A of IEC 60947-1.~~

1.1 Scope and object

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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) particular or additional requirements may be necessary.

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

The object of this standard is to state:

a) the characteristics of circuit-breakers;

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

1) operation and behaviour in normal service;
2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (~~discrimination~~ selectivity and back-up protection);
3) dielectric properties;

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

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

1.2 Normative references

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

~~IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~
~~Amendment 1 (2000)~~

~~IEC 60051 (all parts) *Direct acting indicating analogue electrical measuring instruments and their accessories*~~

IEC 60068-2-14~~:1984~~, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*
~~Amendment 1 (1986)~~

IEC 60068-2-30~~:2005~~, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

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

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

~~IEC 60364-4-41:2001, *Electrical installations of buildings – Part 4-41: Protection for safety – Protection against shock*~~

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

~~IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*~~

~~IEC 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*~~

~~IEC 60695-2-12:2000, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability test method for materials*~~

~~IEC 60695-2-13:2000, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignitability test method for materials*~~

~~IEC 60755:1983, *General requirements for residual current operated protective devices*~~
~~Amendment 1 (1988)~~
~~Amendment 2 (1992)~~

~~IEC 60898, *Circuit-breakers for over-current protection for household and similar installations*~~

~~IEC 60934, *Circuit-breakers for equipment (CBE)*~~

IEC 60947-1:~~2004~~ 2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
IEC 60947-1:2007/AMD1:2010
IEC 60947-1:2007/AMD2:2014

IEC 60947-4-1~~:2000~~, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*
~~Amendment 1 (2002)~~

IEC 61000-3-2~~:2000~~, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*
~~Amendment 1 (2001)~~
~~Amendment 2 (2004)~~

IEC 61000-3-3~~:1994~~, *Electromagnetic compatibility (EMC) – Part 3: Limits –~~ Section 3:~~ Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*
~~Amendment 1 (2001)~~

IEC 61000-4-2~~:1995~~, *Electromagnetic compatibility(EMC) – Part 4-2: Testing and measurement techniques –~~ Section 2:~~ Electrostatic discharge immunity test*
~~Amendment 1 (1998)~~
~~Amendment 2 (2000)~~

IEC 61000-4-3:~~2002~~ 2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
IEC 61000-4-3:2006/AMD1:~~2002~~ 2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:~~1995~~ 2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques –~~ Section 4:~~ Electrical fast transient/burst immunity test*
~~Amendment 1 (2000)~~
~~Amendment 2 (2001)~~

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IEC 61000-4-5:~~1995~~ 2014, *Electromagnetic compatibility(EMC) – Part 4-5: Testing and measurement techniques –~~ Section 5:~~ Surge immunity test*
~~Amendment 1 (2000)~~

IEC 61000-4-6:~~2003~~ 2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio frequency fields*
~~Amendment 1 (2004)~~

IEC 61000-4-11~~:2004~~, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

~~IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*~~

~~IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*~~

~~IEC 61008-1:1996, *Residual current operated circuit-breakers without integral over-current protection for household and similar uses (RCCBs) – Part 1: General rules*~~
~~Amendment 1 (2002)~~

~~IEC 61009-1:1996, *Residual current operated circuit-breakers with integral over-current protection for household and similar uses (RCBOs) – Part 1: General rules*~~
~~Amendment 1 (2002)~~

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

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

CISPR 11~~:2003~~, *Industrial, scientific and medical~~ (ISM) radio-frequency~~ equipment – ~~Electromagnetic~~ Radio-frequency disturbance characteristics – Limits and methods of measurement*
~~Amendment 1 (2004)~~

CISPR 22~~:2005~~, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*
~~Amendment 1 (2005)~~

2 Terms and definitions

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

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

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

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

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

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

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

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

2.1.2
construction break
a significant difference in construction between circuit-breakers of a given frame size, requiring additional type testing ~~(see 7.1.5)~~

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

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

2.3
current-limiting circuit-breaker
~~circuit-breaker with a break-time short enough to prevent the short-circuit current reaching its otherwise attainable peak value~~
circuit-breaker that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t) to a value less than the let-through energy of a half-cycle wave of the symmetrical prospective current

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

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

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

~~[IEV 441-14-21]~~

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

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

2.5
withdrawable circuit-breaker
circuit-breaker which, in addition to its interrupting contacts, has a set of isolating contacts which enable the circuit-breaker to be ~~disconnected~~ withdrawn from the main circuit, and, in the ~~withdrawn~~ 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

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[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

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

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

2.12
short-time delay short-circuit release
an over-current release intended to operate at the end of the short-time delay ~~(see 2.5.26 of IEC 60947-1)~~

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

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

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

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

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

2.16
opening time
~~subclause 2.5.39 of IEC 60947-1 applies, with the following additions:~~
interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry:

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

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

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

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

2.17
over-current protective co-ordination
~~subclause 2.5.22 of IEC 60947-1 applies~~

~~**2.17.1**~~
~~**over-current discrimination**~~
~~subclause 2.5.23 of IEC 60947-1 applies~~

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

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

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

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– 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**~~
~~**back-up protection**~~
~~subclause 2.5.24 of IEC 60947-1 applies~~

2.17.5
take-over current
***I*B**
~~subclause 2.5.25 of IEC 60947-1 is amplified as follows:~~

~~For the purpose of this standard, 2.5.25 of IEC 60947-1 applies to two over-current protective devices in series for operating times ≥0,05 s. For operating times <0,05 s the two over-current devices in series are considered as an association, see Annex A.~~

~~NOTE The take-over current is the~~ current co-ordinate of the intersection between the maximum break time current characteristics of two over-current protective devices in series

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

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

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

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

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

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

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

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

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3 Classification

Circuit-breakers may be classified:

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

3.2 According to the interrupting medium, for example:

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

3.3 According to the design, for example:

– open construction;
– moulded case.

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

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

3.5 According to the suitability for isolation:

– suitable for isolation;
– not suitable for isolation.

3.6 According to the provision for maintenance:

– maintainable;
– non-maintainable.

3.7 According to the method of installation, for example:

– fixed;
– plug-in;
– withdrawable.

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

4 Characteristics of circuit-breakers

4.1 Summary of characteristics

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

– type of circuit-breaker (4.2);
– rated and limiting values of the main circuit (4.3);
– ~~utilization~~ selectivity categories (4.4);
– control circuits (4.5);
– auxiliary circuits (4.6);

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– releases (4.7);
– integral fuses (integrally fused circuit-breakers) (4.8).

4.2 Type of circuit-breaker

The following shall be stated:

~~4.2.1~~ – number of poles;

~~4.2.2~~ – kind of current (a.c. or d.c.) and, in the case of a.c., number of phases and rated frequency.

4.3 Rated and limiting values of the main circuit

4.3.1 General

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

4.3.2 Rated voltages

~~A circuit-breaker is defined by the following rated voltages:~~

4.3.2.1 Rated operational voltage (U_e)

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

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

U_e is generally stated as the voltage between phases.

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

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

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

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

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

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

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

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

4.3.2.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

4.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

4.3.3 Currents

~~A circuit-breaker is defined by the following currents:~~

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

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

4.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

4.3.3.3 Rated current (I_n)

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

4.3.3.4 Current rating for four-pole circuit-breakers

Subclause 7.1.9 of IEC 60947-1:2007 applies.

4.3.4 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

4.3.5 Rated duty

The rated duties considered as normal are ~~as follows~~:

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

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

4.3.6 Short-circuit characteristics

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

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

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

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

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

4.3.6.2 Rated short-circuit breaking capacities

4.3.6.2.1 General

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

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

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– for a.c., at any power factor not less than that of Table 11 (see 8.3.2.2.4);
– for d.c., with any time constant not greater than that of Table 11 (see 8.3.2.2.5).

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

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

The rated short-circuit breaking capacities are stated as:

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

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

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

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

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 2.15.2) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 8.3.4. It is expressed as a value of prospective breaking current, in kA, ~~corresponding to one of the specified percentages of the rated ultimate short-circuit breaking capacity, in accordance with Table 1, and rounded up to the nearest whole number. It may be expressed~~ 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}.

~~Alternatively, when the rated service short-circuit breaking capacity is equal to the rated short-time withstand current (see 4.3.5.4), it may be stated as that value, in kA, provided that it is not less than the relevant minimum value of Table 1.~~

~~Where I_{cu} exceeds 200 kA for utilization category A (see 4.4), or 100 kA for utilization category B, the manufacturer may declare a value I_{cs} of 50 kA.~~

Table 1 ~~– Standard ratios between I_{cs} and I_{cu}~~ (void)

~~Utilization category A~~ ~~% of I_{cu}~~	~~Utilization category B~~ ~~% of I_{cu}~~
~~25~~	~~50~~
~~50~~	~~75~~
~~75~~	~~100~~
~~100~~	

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

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

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

Short-circuit breaking capacity kA r.m.s.	Power factor	Minimum value required for *n* $n = \frac{\text{short - circuit making capacity}}{\text{short - circuit breaking capacity}}$
$I \leq 1{,}5$	0,95	1,41
$1{,}5 < I \leq 3$	0,9	1,42
$3 < I \leq 4{,}5$	0,8	1,47
$4{,}5 < I \leq 6$	0,7	~~1,5~~ 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
~~NOTE For values of breaking capacity lower than 4,5 kA, for certain applications, see Table 11 for the power factor~~		

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

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

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

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

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

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

0,05 s – 0,1 s – 0,25 s – 0,5 s – 1 s

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

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

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

4.4 ~~Utilization~~ Selectivity categories

~~The utilization category of a circuit-breaker shall be stated with reference to whether or not it is specifically intended for selectivity by means of an intentional time delay with respect to other circuit-breakers in series on the load side, under short-circuit conditions (see Figure A.3).~~

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

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

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

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

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

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

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

~~Utilization categories are defined in Table 4.~~

Table 4 ~~– Utilization categories~~ (void)

~~Utilization category~~	~~Application with respect to selectivity~~
~~A~~	~~Circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions, and therefore without a short-time withstand current rating according to 4.3.5.4.~~
~~B~~	~~Circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable), provided for selectivity under short-circuit conditions. Such circuit-breakers have a short-time withstand current rating according to 4.3.5.4.~~ ~~NOTE Selectivity is not necessarily ensured up to the ultimate short-circuit breaking capacity of the circuit-breakers (for example in the case of operation of an instantaneous release) but at least up to the value specified in Table 3.~~

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~~NOTE 1 The power factor or time constant associated with each value of rated short-circuit current is given in Table 11 (see 8.3.2.2.4 and 8.3.2.2.5).~~

~~NOTE 2 Attention is drawn to the different requirements for the minimum required percentage of I_{cs} for utilization categories A and B, in accordance with Table 1.~~

~~NOTE 3 A circuit-breaker of utilization category A may have an intentional short-time delay provided for selectivity under conditions other than those of short circuit, with a short-time withstand current less than that according to Table 3. In that case, the tests include test sequence IV (see 8.3.6) at the assigned short-time withstand current.~~

4.5 Control circuits

4.5.1 Electrical control circuits

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

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

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

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

~~NOTE The manufacturer should be prepared to state the value or values of the current taken by the control circuits at the rated control supply voltage.~~

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

Subclause 4.5.2 of IEC 60947-1:2007 applies.

4.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

4.7 Releases

4.7.1 Types

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

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

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

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

3) undervoltage release (for opening);

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4) other releases.

4.7.2 Characteristics

The following characteristics shall be considered:

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

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

4.7.3 Current setting of over-current releases

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

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

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

Unless otherwise specified

- the operating value of overload releases other than those of the thermal type is independent of the ambient air temperature within the limits of –5 °C to +40 °C;
- for releases of the thermal type, the values stated are for a reference temperature of +30 °C ± 2 °C. The manufacturer shall be prepared to state the influence of variations in the ambient air temperature (see 7.2.1.2.4, item b)).

4.7.4 Tripping time setting of over-current releases

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

1) Definite time-delay over-current releases

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

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2) Inverse time-delay over-current releases

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

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

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

~~NOTE~~ It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006~~ and in Figures 4(I), 3(II) and 4(II) of IEC 60269-2-1~~.

4.8 Integral fuses (integrally fused circuit-breakers)

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

The manufacturer shall provide the necessary information.

5 Product information

5.1 Nature of the information

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

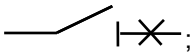
In addition the manufacturer shall make available, upon request, information concerning typical power losses for the various frame sizes (see 2.1.1). See Annex G.

5.2 Marking

Each circuit-breaker shall be marked in a durable manner.

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

– rated current (I_n);

– suitability for isolation, if applicable, with the symbol  ;

– indication of the open and closed positions, with and respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007).

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

– manufacturer's name or trade mark;

– type designation or serial number;

– IEC 60947-2 if the manufacturer claims compliance with this standard;

– ~~utilization~~ selectivity category;

– rated operational voltage(s) U_e (see 4.3.2.1 and, where applicable, Annex H);

– rated impulse withstand voltage (U_{imp});

– value (or range) of the rated frequency (for example 50 Hz), and/or the indication "d.c." (or the symbol ⎓);

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- rated service short-circuit breaking capacity (I_{cs}) at the corresponding rated voltage (U_e);
- rated ultimate short-circuit breaking capacity (I_{cu}) at the corresponding rated voltage (U_e);
- rated short-time withstand current (I_{cw}), and associated short-time delay, for ~~utilization~~ selectivity category B;
- line and load terminals, unless their connection is immaterial;
- neutral pole terminals, if applicable, by the letter N;
- protective earth terminal, where applicable, by the symbol ⏚ (see 7.1.10.3 of IEC 60947-1:2007);
- reference temperature for non-compensated thermal releases, if different from 30 °C;
- range of the current setting (I_r) of adjustable overload release;
- range of the rated instantaneous short-circuit current setting (I_i), for ajustable releases.

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

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

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

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

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

e) Terminal marking

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

5.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007/AMD2:2014 applies.

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6 Normal service, mounting and transport conditions

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

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

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

7 Constructional and performance requirements

7.1 Constructional requirements

7.1.1 General

~~Subclause 7.1 of IEC 60947-1 applies except that the text of 7.1.1.1 is replaced by the following:~~

~~Parts of insulating materials which might be exposed to thermal stresses due to electrical effects and the deterioration of which might impair the safety of the equipment shall not be adversely affected by abnormal heat and fire.~~

~~Tests on equipment shall be made by the glow-wire tests of IEC 60695-2-10, IEC 60695-2-11, IEC 60695-2-12 and IEC 60695-2-13.~~

~~Parts of insulating materials necessary to retain in position current-carrying parts of the main circuit in service shall conform to the glow-wire test of 8.2.1.1.1 of IEC 60947-1, at a temperature of 960 °C.~~

~~Parts of insulating materials other than those specified in the previous paragraph shall conform to the requirements of the glow-wire tests of 8.2.1.1.1 of IEC 60947-1 at a temperature of 650 °C.~~

Subclause 7.1 of IEC 60947-1:2007/AMD1:2010/AMD2:2014 applies. Where, in 7.1.2.2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, the test temperature is to be specified, the test temperature required by this standard is 960 °C.

7.1.2 Withdrawable circuit-breakers

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

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

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

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

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

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

7.1.3 Additional requirements for circuit-breakers suitable for isolation

For additional requirements concerning performance, see 7.2.7.

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

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

~~The indicated open position is the only position in which the specified isolating distance between the contacts is ensured.~~

7.1.4 Clearances and creepage distances

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

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

7.1.5 Requirements for the safety of the operator

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

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

7.1.6 List of construction breaks

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

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

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.

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

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

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

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

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

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

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

7.2 Performance requirements

7.2.1 Operating conditions

7.2.1.1 Closing

7.2.1.1.1 General

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

7.2.1.1.2 Dependent manual closing

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

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

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

7.2.1.1.3 Independent manual closing

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

7.2.1.1.4 Dependent power closing

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

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

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

7.2.1.1.5 Independent power closing

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

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

7.2.1.1.6 Stored energy closing

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

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

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

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

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

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

7.2.1.2 Opening

7.2.1.2.1 General

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

7.2.1.2.2 Opening by undervoltage releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies.

7.2.1.2.3 Opening by shunt releases

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

7.2.1.2.4 Opening by over-current releases

a) Opening under short-circuit conditions

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

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

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

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

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

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

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

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

2) Inverse time-delay operation

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

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

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

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

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

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

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

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

7.2.2 Temperature-rise

7.2.2.1 Temperature-rise limits

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

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7.2.2.2 Ambient air temperature

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

7.2.2.3 Main circuit

The main circuit of a circuit-breaker, including the over-current releases which may be associated with it, shall be capable of carrying ~~the conventional thermal current (I_{th} or I_{the}, as applicable, see 4.3.2.1 and 4.3.2.2)~~ its rated current I_n, under the conditions of Clause 8, without the temperature-rises exceeding the limits specified in Table 7.

7.2.2.4 Control circuits

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

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

7.2.2.5 Auxiliary circuits

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

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

Description of part [a]	Temperature-rise limits [b] K
– Terminals for external connections	80
– Manual operating means:	
Metallic	25
non-metallic	35
– Parts intended to be touched but not hand-held:	
Metallic	40
non-metallic	50
– Parts which need not be touched for normal operation:	
Metallic	50
non-metallic	60

[a] No value is specified for parts other than those listed but no damage should be caused to adjacent parts of insulating materials.

[b] The temperature-rise limits specified are not intended to apply to a new sample, but are those applicable to the temperature-rise verifications during the appropriate test sequences specified in Clause 8.

7.2.3 Dielectric properties

7.2.3.1 General

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

Type tests shall be made in accordance with 8.3.3.3.

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

Routine tests shall be made in accordance with 8.4.6.

7.2.3.2 Impulse withstand voltage

Subclause 7.2.3.1 of IEC 60947-1:2007 applies.

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

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

Power-frequency tests are used in the following cases:

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

7.2.3.4 Clearances

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

7.2.3.5 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

7.2.3.6 Solid insulation

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

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

7.2.3.7 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

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

7.2.4.1 Overload performance

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

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

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

7.2.4.2 Operational performance capability

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

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

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

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

Table 8 – Number of operating cycles

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

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

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

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

7.2.5 Ability to make and break under short-circuit conditions

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

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

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

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

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

7.2.6 Vacant

7.2.7 Additional requirements for circuit-breakers suitable for isolation

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

7.2.8 Specific requirements for integrally fused circuit-breakers

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

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

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

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

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

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

7.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

8 Tests

8.1 Kind of tests

8.1.1 General

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

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

– type tests (see 8.3);
– routine tests (see 8.4);
– special tests (see 8.5).

8.1.2 Type tests

Type tests include the following tests:

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

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

8.1.3 Routine tests

Routine tests comprise the tests listed in 8.4.

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8.2 Compliance with constructional requirements

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

8.3 Type tests

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

– test conditions applicable to all sequences (8.3.3 to 8.3.8);
– test conditions applicable to temperature-rise tests (8.3.2.5);
– test conditions applicable to short-circuit tests (8.3.2.6).

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

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

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

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

8.3.1 Test sequences

8.3.1.1 General

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

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

8.3.1.2 Tests omitted from sequence I and made separately

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

– tripping limits and characteristics (8.3.3.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 8.3.3.2.3 only on the phase poles at the maximum setting ~~only~~, at room temperature and without the additional test of item b) to verify the time-current characteristic;
– test of dielectric properties (8.3.3.3);
– test of under-voltage releases of 8.3.3.4.2.3 and 8.3.3.4.3 to verify the requirements of 7.2.1.3 of IEC 60947-1:2007, and tests of under-voltage releases at alternative frequencies (see 8.3.2.1);
– test of shunt ~~trip~~ releases of 8.3.3.4.2.4 and 8.3.3.4.3 to verify the requirements of 7.2.1.4 of IEC 60947-1:2007/AMD2:2014, and tests of shunt releases at alternative frequencies (see 8.3.2.1);
– additional tests for operational performance capability without current for withdrawable circuit-breakers (8.3.3.4.5).

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

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

Alphabetical index of tests

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

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Table 9 – Overall schema of test sequences[a]

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

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a For the selection of circuit-breakers for tests and the applicability of the various test sequences according to the relationship between I_{cs} , I_{cu} and I_{cw}, see Table 9a.

b Except where ~~the combined test~~ Sequence VI is applied.

c Except

- where I_{cs} = I_{cu} (but see 8.3.5),
- where ~~the combined test~~ sequence VI is applied,
- for integrally fused circuit-breakers.

~~*~~ d See note to 8.3.5.1

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

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

[a] This table applies to any one value of U_e. For multiple U_e ratings, the table applies to each U_e rating. The applicability of a test sequence is indicated by X in the relevant space.

[b] Test applicable only if $I_{cu} > I_{cw}$.

[c] At the discretion of, or in agreement with the manufacturer, this sequence may be applied to circuit-breakers of selectivity category B, in which case it replaces test sequences II and IV.

[d] Test sequence IV applies only ~~in the case of circuit-breakers covered by note 3 of Table 4~~ to circuit-breakers with a rated short-time withstand current (see 4.4).

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

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

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

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

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

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

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