

High-voltage alternating-current circuit-breakers —

(Implementation of CENELEC
HD 348 S7:1998)

ICS 29.120.50

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PEL/17, Switchgear, controlgear and high voltage/low-voltage co-ordination, upon which the following bodies were represented:

- ASTA Certification Services
- Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd.)
- British Railways Board
- Copper Development Association
- ERA Technology Ltd.
- Electricity Association
- GAMBICA (BEAMA Ltd.)
- Health and Safety Executive
- Ministry of Defence
- Transmission and Distribution Association (BEAMA Ltd.)

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Association of Consulting Engineers
- British Cable Makers Confederation
- Electrical Installation Equipment Manufacturers' Association (BEAMA Ltd.)
- Engineering Equipment and Materials Users' Association
- Institution of Incorporated Executive Engineers

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National foreword

This British Standard has been prepared by Technical Committee PEL/17. It implements HD 348 S7:1998 which supersedes HD 348 S6:1995, published by the European Committees for Electrotechnical Standardization (CENELEC). It was derived by CENELEC from IEC 56:1987, *High-voltage alternating-current circuit-breakers* and its amendments 1:1992, 2:1995 and 3:1996 published by the International Electrotechnical Commission (IEC).

CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by a sideline in the margin. Parts of the original IEC text that have been modified by CENELEC have been quoted in National annex NA.

This British Standard supersedes BS 5311:1988 which is withdrawn.

Cross-references

Publication referred to	Corresponding British Standard
	BS 4727 <i>Glossary of electrotechnical, power; telecommunication, electronics, lighting and colour terms</i> Part 1 <i>Terms common to power, telecommunications and electronics</i>
IEC 50(151):1978	Group 02:1980 <i>Electrical and magnetic devices terminology</i> (Technically equivalent) Part 2 <i>Terms particular to power engineering</i>
IEC 50(441):1974	Group 06:1985 <i>Switchgear and controlgear terminology (including fuse terminology)</i> (Technically equivalent)
HD 323.2.5 S1:1988 (IEC 68-2-5:1975)	BS 2011 <i>Environmental testing</i> Part 2.1 Sa:1977 Test Sa. <i>Simulated solar radiation at ground level</i>
HD 540.2 S1:1991 (IEC 71-2:1976)	BS 5622 <i>Guide for insulation co-ordination</i> Part 2:1979 <i>Application guide</i> (Identical)
IEC 77:1968	BS 2618:1975 <i>Specification for electric traction equipment</i> (Technically equivalent)
EN 60129:1994 (IEC 129:1984)	BS EN 60129:1994 <i>Specification for alternating current disconnectors and earthing switches</i> (Identical)
IEC 137:1984	BS 223:1985 <i>Specification for bushings for alternating voltages above 1 000 V</i> (Technically equivalent)
HD 553 S2:1993 (IEC 185:1987)	BS 7626:1993 <i>Specification for current transformers</i> (Technically equivalent)
HD 448 S2:1989 (IEC 694:1980)	BS 6581:1985 <i>Specification for common requirements for high-voltage switchgear and controlgear standards</i> (Technically equivalent)

IEC 60-1:1973 has been superseded by IEC 601:1989. An identical British Standard to IEC 60-1:1989 is BS 923-1:1990, which implements HD 588.1 S1.

IEC 68-2-17:1978 has been superseded by IEC 68-2-17:1994 which has been adopted by CENELEC as EN 60068-2-17:1994 and published as BS EN 60068-2-17:1995.

IEC 427:1973 has been superseded by IEC 427:1989 which has been adopted by CENELEC as EN 60427:1992 and published as BS EN 60427:1992.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, the HD title page, pages 2 to 166, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Descriptors: Switchgear and controlgear, high voltage, circuit-breaker, characteristic, design, test

English version

High-voltage alternating-current circuit-breakers

(IEC 56:1987 + A1:1992 + A2:1995 + A3:1996, modified)

Disjoncteurs à courant alternatif à haute
tension
(CEI 56:1987 + A1:1992 + A2:1995 + A3:1996,
modifiée)

Hochspannungs-Wechselstrom-
Leistungsschalter
(IEC 56:1987 + A1:1992 + A2:1995 + A3:1996,
modifiziert)

This Harmonization Document was approved by CENELEC on 1998-04-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for implementation of this Harmonization Document on a national level.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This Harmonization Document exists in three official versions (English, French, German).

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword to HD 384 S6

The text of the International Standard IEC 56:1987 and its amendment 1:1992, prepared by SC 17A, High-voltage switchgear and controlgear, of IEC TC 17. Switchgear and controlgear, together with common modifications prepared by Technical Committee CENELEC TC 17A, was submitted to the formal vote and was approved by CENELEC as HD 348 S5.

The text of document 17A(CO)249, future amendment 2 to IEC 56:1987, was submitted to the IEC-CENELEC parallel vote.

As CENELEC TC 17A had decided to postpone the conversion of the HD into an EN to the next edition of IEC 56, the combined text of HD 348 S5 and amendment 2:1995 to IEC 56:1987 was approved by CENELEC as HD 348 S6 on 1995-07-04.

The following dates were fixed:

- latest date by which the existence of the HD has to be announced at national level (doa) 1995-08-15
- latest date by which the HD has to be implemented at national level by publication of a harmonized national standard or by endorsement (dop) 1996-02-15
- latest date by which the national standards conflicting with the HD have to be withdrawn (dow) 1996-02-15

Annexes designated “normative” are part of the body of the standard. In this standard, Appendix AA, Appendix BB, Appendix CC, Appendix DD, Appendix EE, Appendix FF, Appendix GG, Appendix HH, Appendix JJ, Annex ZA and Annex ZB are normative.

Annex ZA and Annex ZB have been added by CENELEC.

Foreword to HD 384 S7

The text of the International Standard IEC 60056:1987 and its amendment 3:1996, prepared by SC 17A, High-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, together with common modifications prepared by the Technical Committee CENELEC TC 17A, High-voltage switchgear controlgear, was submitted to the Unique Acceptance Procedure and was approved by CENELEC as HD 348 S7 on 1998-04-01.

This European Standard supersedes HD 348 S6:1995.

The following dates were fixed:

- latest date by which the existence of the HD has to be announced at national level (doa) 1998-07-01
- latest date by which the HD has to be implemented at national level by publication of a harmonized national standard or by endorsement (dop) 1999-01-01
- latest date by which the national standards conflicting with the HD have to be withdrawn (dow) 1999-01-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, Appendix AA, Appendix BB, Appendix CC, Appendix DD, Appendix EE, Appendix FF, Appendix GG, Appendix HH, Annex ZA and Annex ZB are normative and Appendix JJ and Annex KK are informative. Annex ZA and Annex ZB have been added by CENELEC.

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1 Scope

This standard is applicable to a.c. circuit-breakers designed for indoor or outdoor installation and for operation at frequencies up to and including 60 Hz on systems having voltages above 1 000 V.

It is only applicable to three-pole circuit-breakers for use in three-phase systems and single-pole circuit-breakers for use in single-phase systems. Two-pole circuit-breakers for use in single-phase systems are subject to agreement between manufacturer and user.

This standard is also applicable to the operating devices of circuit-breakers and to their auxiliary equipment. However, a circuit-breaker with a closing mechanism for dependent manual operation is not covered by this standard, as a rated short-circuit making-current cannot be specified, and such dependent manual operation may be objectionable because of safety considerations.

This standard does not cover circuit-breakers intended for use on motive power units of electrical traction equipment; these are covered by IEC Publication 77: Rules for Electric Traction Equipment.

Circuit-breakers for use with overhead lines which include series capacitors are not within the scope of this standard.

NOTE Tests to prove the performance under abnormal conditions should be subject to agreement between manufacturer and user. Such abnormal conditions are, for instance, cases where the voltage is higher than the rated voltage of the circuit-breaker, conditions which may occur due to sudden loss of load on long lines or cables.

This standard is not necessarily applicable to circuit-breakers for special conditions, for example, those produced by two earth faults on two different phases one of which occurs on one side of the circuit-breaker and the other on the other side.

2 Normal and special service conditions

Clause 2 of IEC Publication 694: Common Clauses for High-voltage Switchgear and Controlgear Standards, is applicable.

3 Definitions

In this clause reference is made to definitions in the following publications of the International Electrotechnical Vocabulary (IEV):

- 50(151) (1978): Chapter 151: Electrical and Magnetic Devices,
- 50(441) (1984): Chapter 441: Switchgear; Controlgear and Fuses,
- 50(604) (—): Chapter 604: Generation, Transmission and Distribution of Electricity: Operation (being printed).

For the purpose of this standard, the following definitions are applicable.

3.101 General terms

3.101.1

switchgear and controlgear (441-11-01)

3.101.2

indoor switchgear and controlgear (441-11-04)

3.101.3

outdoor switchgear and controlgear (441-11-05)

3.101.4

short-circuit current (441-11-07)

3.101.5

isolated neutral system

a system which has no intentional connection to earth except through indicating, measuring or protective devices of very high impedance

3.101.6**resonant earthed system; system earthed through an arc-suppression coil**

a system in which the neutral is earthed through a reactor, the reactance having a value such that during a single phase-to-earth fault, the power frequency inductive current passed by this reactor substantially neutralizes the power frequency capacitive component of the earth-fault current

NOTE With resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in air is usually self-extinguishing.

3.101.7**earthed neutral system**

a system in which the neutral is connected to earth, either solidly, or through a resistance or reactance of a value low enough to reduce materially any transient oscillations and to improve the conditions for selective earth-fault protection

3.101.8**earth fault factor**

at a selected location of a three-phase system (generally the point of installation of an equipment) and for a given system configuration, the ratio of the highest r.m.s. phase-to-earth power-frequency voltage on a sound phase during a fault to earth (affecting one or more phases at any point) to the r.m.s. phase-to-earth power-frequency voltage which would be obtained at the selected location without the fault

NOTE 1 This factor is a pure numerical ratio (higher than 1) and characterizes in general terms the earthing conditions of a system as viewed from the stated location, independently of the actual operating values of the voltage at that location.

The “earth fault factor” is the product of $\sqrt{3}$ and the “factor of earthing” which has been used in the past.

NOTE 2 The earth fault factors are calculated from the phase-sequence impedance components of the system, as viewed from the selected location, using for any rotating machines the subtransient reactances.

NOTE 3 If, for all credible system configurations, the zero-sequence reactance is less than three times the positive-sequence reactance and if the zero-sequence resistance does not exceed the positive-sequence reactance, the earth fault factor will not exceed 1.4.

3.101.9**ambient air temperature (441-11-13)****3.101.10****temperature rise (of a part of a circuit-breaker)**

the difference between the temperature of the part and the ambient air temperature

3.101.11**single capacitor bank**

a bank of shunt capacitors in which the inrush current is limited by the inductance of the supply system and the capacitance of the bank of capacitors being energized, there being no other capacitors connected in parallel to the system sufficiently close to increase the inrush current appreciably

3.101.12**multiple (parallel) capacitor bank (back-to-back capacitor bank)**

a bank of shunt capacitors or capacitor assemblies each of them switched independently to the supply system, the inrush current of one unit being appreciably increased by the capacitors already connected to the supply

3.101.13**overvoltage (in a system) (604-03-09)**

any voltage between one phase and earth or between phases having a peak value or values exceeding the corresponding peak of the highest voltage for equipment

3.101.14**out-of-phase conditions**

abnormal circuit conditions of loss or lack of synchronism between the parts of an electrical system on either side of a circuit-breaker in which, at the instant of operation of the circuit-breaker, the phase angle between rotating vectors, representing the generated voltages on either side, exceeds the normal value and may be as much as 180° (phase opposition)

3.101.15**out-of-phase (as prefix to a characteristic quantity)**

a qualifying term indicating that the characteristic quantity is applicable to operation of the circuit-breaker in out-of-phase conditions

3.101.16**unit test**

a test made on a making or breaking unit or group of units at the making current or the breaking current, specified for the test on the complete pole of a circuit-breaker and at the appropriate fraction of the applied voltage, or the recovery voltage, specified for the test on the complete pole of the circuit-breaker

3.101.17**loop**

the part of the wave of the current embraced by two successive current zero crossings

NOTE A distinction is made between a major loop and a minor loop depending on the time interval between two successive current zero crossings being longer or shorter than the half-period of the alternating component of the current.

3.101.18**short-line fault**

a short-circuit on an overhead line at a short, but significant, distance from the terminals of the circuit-breaker

NOTE As a rule this distance is not more than a few kilometres.

3.101.19**power factor (of a circuit)**

the ratio of the resistance to the impedance at power frequency of an equivalent circuit supposed to be formed by an inductance and a resistance in series

3.101.20**external insulation (604-03-02)**

the distances in air and the surfaces in contact with open air of solid insulation of the equipment, which are subject to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity, vermin, etc.

3.101.21**internal insulation (604-03-03)**

the internal solid, liquid or gaseous parts of the insulation of equipment, which are protected from the effects of atmospheric and other external conditions

3.101.22**self-restoring insulation (604-03-04)**

insulation which completely recovers its insulating properties after a disruptive discharge

3.101.23**non-self-restoring insulation (604-03-05)**

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

3.101.24**disruptive discharge**

phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero

NOTE 1 This term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

NOTE 2 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss may be only temporary (self-restoring insulation).

NOTE 3 The term “sparkover” is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term “flashover” is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term “puncture” is used when a disruptive discharge occurs through a solid dielectric.

3.102 Switching devices

3.102.1

switching device (441-14-01)

3.102.2

mechanical switching device (441-14-02)

3.102.3

circuit-breaker (441-14-20)

3.102.4

dead tank circuit-breaker (441-14-25)

3.102.5

live tank circuit-breaker (441-14-26)

3.102.6

air circuit-breaker (441-14-27)

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oil circuit-breaker (441-14-28)

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vacuum circuit-breaker (441-14-29)

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gas-blast circuit-breaker (441-14-30)

3.102.10

sulphur hexafluoride circuit-breaker (441-14-31)

3.102.11

air-blast circuit-breaker (441-14-32)

3.102.12

restrike-free circuit-breaker

a circuit-breaker that interrupts without restrike during the capacitive current-breaking test duties specified in this standard

3.102.13

circuit-breaker class A

a circuit-breaker not falling into the category of class B as defined in **3.102.14**

3.102.14

circuit-breaker class B

a circuit-breaker designed so as not to require maintenance of the interrupting parts of the main circuit during the expected operating life of the circuit-breaker, and only minimal maintenance of its other parts

NOTE 1 Minimal maintenance may include lubrication, replenishment of gas and cleaning of external surfaces, where applicable.

NOTE 2 This definition is restricted to circuit-breakers having a rated voltage up to and including 52 kV. See Annex KK for rationale behind introduction of class B.

3.103 Parts of circuit-breakers

3.103.1

pole (441-15-01)

3.103.2

main circuit (441-15-02)

3.103.3

control circuit (441-15-03)

3.103.4

auxiliary circuit (441-15-04)

3.103.5

contact (441-15-05)

3.103.6

contact piece (441-15-06)

3.103.7

main contact (441-15-07)

3.103.8

arcing contact (441-15-08)

3.103.9

control contact (441-15-09)

3.103.10

auxiliary contact (441-15-10)

3.103.11

auxiliary switch (441-15-11)

3.103.12

“a” contact, make contact (441-15-12)

3.103.13

“b” contact, break contact (441-15-13)

3.103.14

sliding contact (441-15-15)

3.103.15

rolling contact (441-15-16)

3.103.16

release (441-15-17)

3.103.17

arc control device (441-15-18)

3.103.18

position indicating device (indicator) (441-15-25)

3.103.19

connection (bolted or the equivalent)

two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.103.20

terminal (151-01-03)

a component provided for the connection of a circuit-breaker to external conductors

3.103.21

(making or breaking) unit

a part of a circuit-breaker which in itself acts as a circuit-breaker and which in series with one or more identical and simultaneously operated making or breaking units forms the complete circuit-breaker

NOTE 1 Making units and breaking units may be separate or combined. Each unit may have several contacts.

NOTE 2 The means controlling the voltage distribution between units may differ from unit to unit.

3.103.22

module (of a pole of a circuit-breaker)

an assembly which generally comprises making or breaking units, post-insulators and mechanical parts and which is mechanically and electrically connected to other identical assemblies to form a pole of a circuit-breaker

3.104 Operation

3.104.1

operation (441-16-01)

3.104.2

operating cycle (441-16-02)

3.104.3

operating sequence (441-16-03)

3.104.4

closing operation (441-16-08)

3.104.5

opening operation (441-16-09)

3.104.6

auto-reclosing (441-16-10)

3.104.7

positive opening operation (441-16-11)

3.104.8

positively driven operation (441-16-12)

3.104.9

dependent manual operation (441-16-13)

3.104.10

dependent power operation (441-16-14)

3.104.11

stored energy operation

an operation by means of energy stored in the mechanism itself prior to the switching operation and sufficient to complete the specified operating cycle under predetermined conditions

3.104.12

independent manual operation (441-16-16)

3.104.13

closed position (441-16-22)

3.104.14

open position (441-16-23)

3.104.15

fixed trip circuit-breaker (441-16-30)

3.104.16

trip-free circuit-breaker (441-16-31)

3.104.17

instantaneous release (441-16-32)

3.104.18

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

3.104.19

over-current release (441-16-33)

3.104.20

definite time-delay over-current release (441-16-34)

3.104.21

inverse time-delay over-current release (441-16-35)

3.104.22

direct over-current release (441-16-36)

3.104.23

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3.104.24

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3.104.25

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3.104.26

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3.104.27

operating current (of an over-current release) (441-16-45)

3.104.28

current setting (of an over-current release) (441-16-46)

3.104.29

current setting range (of an over-current release) (441-16-47)

3.104.30

anti-pumping device (441-16-48)

3.104.31

interlocking device (441-16-49)

3.104.32

circuit-breaker with lock-out preventing closing (441-14-23)

3.105 Characteristic quantities of circuit-breakers¹⁾**3.105.1****rated value (151-04-03)**

a quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

3.105.2**prospective current (of a circuit and with respect to a circuit-breaker) (441-17-01)****3.105.3****prospective peak current**

the peak value of the first major loop of the prospective current during the transient period following initiation

NOTE The definition assumes that the current is made by an ideal circuit-breaker, i.e. with instantaneous and simultaneous transition of its impedance across the terminals of each pole from infinity to zero. The peak value may differ from one pole to another; it depends on the instant of current initiation relative to the voltage wave across the terminals of each pole.

3.105.4**peak current**

the peak value of the first major loop of current during the transient period following initiation

3.105.5**prospective symmetrical current (of an a.c. circuit) (441-17-03)****3.105.6****maximum prospective peak current (of an a.c. circuit) (441-17-04)****3.105.7****prospective making current (for a pole of a circuit-breaker) (441-17-05)****3.105.8****(peak) making current**

the peak value of the first major loop of the current in a pole of a circuit-breaker during the transient period following the initiation of current during a making operation

NOTE 1 The peak value may differ from one pole to another and from one operation to another as it depends on the instant of current initiation relative to the wave of the applied voltage.

NOTE 2 Where, for a polyphase circuit, a single value of (peak) making current is referred to, this is, unless otherwise stated, the highest value in any phase.

3.105.9**prospective breaking current (for a pole of a circuit-breaker)**

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

3.105.10**breaking current (441-17-07)****3.105.11****critical (breaking) current**

a value of breaking current, less than rated short-circuit breaking current, at which the arcing time is a maximum and is significantly longer than at the rated short-circuit breaking current

¹⁾ Figure 1 to Figure 7 (pages 46 to 53) illustrate some definitions of this sub-clause.

Time quantities, see definitions **3.105.32** to **3.105.45**, are expressed in milliseconds or in cycles. When expressed in cycles, the power frequency should be stated in brackets.

In the case of circuit-breakers incorporating switching resistors, a distinction is made, where applicable, between time quantities associated with the contacts switching the full current and the contacts switching the current limited by switching resistors.

Unless otherwise stated the time quantities referred to are associated with the contacts switching the full current.

3.105.12**breaking capacity**²⁾ (441-17-08)**3.105.13****line-charging (line off-load) breaking capacity**

a breaking capacity for which the specified conditions of use and behaviour include the opening of an overhead line operating at no load

3.105.14**cable-charging (cable off-load) breaking capacity**

a breaking capacity for which the specified conditions of use and behaviour include the opening of an insulated cable operating at no load

3.105.15**capacitor bank breaking capacity**

a breaking capacity for which the specified conditions of use and behaviour include the opening of a capacitor bank

3.105.16**making capacity**²⁾ (441-17-09)**3.105.17****out-of-phase (making or breaking) capacity**

a making or breaking capacity for which the specified conditions of use and behaviour include the loss or the lack of synchronism between the parts of an electrical system on either side of the circuit-breaker

3.105.18**short-circuit making capacity** (441-17-10)**3.105.19****short-circuit breaking capacity** (441-17-11)**3.105.20****short-time withstand current** (441-17-17)**3.105.21****peak withstand current** (441-17-18)**3.105.22****applied voltage** (441-17-24)**3.105.23****recovery voltage** (441-17-25)**3.105.24****transient recovery voltage (TRV)** (441-17-26)**3.105.25****prospective transient recovery voltage (of a circuit)** (441-17-29)**3.105.26****power frequency recovery voltage** (441-17-27)

²⁾ *Note concerning the rated values:*

In English, the terms “rated making current” and “rated breaking current” are being used where formerly “rated making capacity” and “rated breaking capacity” were used, the intended meaning being adequately conveyed by the use of “rated”. In French, the terms “pouvoir de fermeture assigné” and “pouvoir de coupure assigné” continue to be used.

3.105.27

peak arc voltage (441-17-30)

3.105.28

clearance (441-17-31)

3.105.29

clearance between poles (441-17-32)

3.105.30

clearance to earth (441-17-33)

3.105.31

clearance between open contacts (441-17-34)

3.105.32

opening time

the opening time of a circuit-breaker is defined according to the tripping method as stated below and with any time delay device forming an integral part of the circuit-breaker adjusted to its minimum setting:

- a) For a circuit-breaker tripped by any form of auxiliary power, the opening time is the interval of time between the instant of energizing the opening release, the circuit-breaker being in the closed position, and the instant when the arcing contacts have separated in all poles.
- b) For a circuit-breaker tripped by a current in the main circuit without the aid of any form of auxiliary power, the opening time is the interval of time between the instant at which, the circuit-breaker being in the closed position, the current in the main circuit reaches the operating value of the overcurrent release and the instant when the arcing contacts have separated in all poles.

NOTE 1 The opening time may vary significantly with the breaking current.

NOTE 2 For circuit-breakers with more than one interrupting unit per pole the instant when the arcing contacts have separated in all poles is determined as the instant of contact separation in the first unit of the last pole.

NOTE 3 The opening time includes the operating time of any auxiliary equipment necessary to open the circuit-breaker and forming an integral part of the circuit-breaker.

3.105.33

arcing time (441-17-38)

3.105.34

break time (441-17-39)

3.105.35

closing time

the interval of time between energizing the closing circuit, the circuit-breaker being in the open position, and the instant when the contacts touch in all poles

NOTE The closing time includes the operating time of any auxiliary equipment necessary to close the circuit-breaker and forming an integral part of the circuit-breaker.

3.105.36

make time

the interval of time between energizing the closing circuit, the circuit-breaker being in the open position, and the instant when the current begins to flow in the first pole

NOTE 1 The make time includes the operating time of any auxiliary equipment necessary to close the circuit-breaker and forming an integral part of the circuit-breaker.

NOTE 2 The make time may vary due to the variation of the pre-arcing time.

3.105.37

pre-arcing time

the interval of time between the initiation of current flow in the first pole during a closing operation and the instant when the contacts touch in all poles

NOTE 1 The pre-arcing time depends on the instantaneous value of the applied voltage during a specific closing operation and therefore may vary considerably.

NOTE 2 This definition for pre-arcing time for a circuit-breaker should not be confused with the definition for pre-arcing time for a fuse.

3.105.38**open-close time (during auto-reclosing)**

the interval of time between the instant when the arcing contacts have separated in all poles and the instant when the contacts touch in the first pole during a reclosing operation

3.105.39**dead time (during auto-reclosing)**

the interval of time between final arc extinction in all poles in the opening operation and the first re-establishment of current in any pole in the subsequent closing operation

NOTE The dead time may vary due to the variation of the pre-arcing time.

3.105.40**reclosing time**

the interval of time between the beginning of the opening time and the instant when the contacts touch in all poles during a reclosing operation

3.105.41**re-make time (during reclosing)**

the interval of time between the beginning of the opening time and the first re-establishment of current in any pole in the subsequent closing operation

NOTE The re-make time may vary due to the variation of the pre-arcing time.

3.105.42**close-open time**

the interval of time between the instant when the contacts touch in the first pole during a closing operation and the instant when the arcing contacts have separated in all poles during the subsequent opening operation

NOTE Unless otherwise stated, it is assumed that the opening release incorporated in the circuit-breaker is energized at the instant when the contacts touch in the first pole during closing. This represents the minimum close-open time.

3.105.43**make-break time**

the interval of time between the initiation of current flow in the first pole during a closing operation and the end of the arcing time during the subsequent opening operation

NOTE 1 Unless otherwise stated, it is assumed that the opening release of the circuit-breaker is energized one half-cycle after current begins to flow in the main circuit during making. It should be noted that the use of relays with shorter operating times may subject the circuit-breaker to asymmetrical currents that are in excess of those provided for in Sub-clause 6.106.5.

NOTE 2 The make-break time may vary due to the variation of the pre-arcing time.

3.105.44**minimum trip duration**

the minimum time the auxiliary power has to be applied to the opening release to ensure complete opening of the circuit-breaker

3.105.45**minimum close duration**

the minimum time the auxiliary power has to be applied to the closing device to ensure complete closing of the circuit-breaker

3.105.46**re-ignition (441-17-45)**

3.105.47**restrike** (441-17-46)**3.105.48****normal current**

the current which the main circuit of a circuit-breaker is capable of carrying continuously under specified conditions of use and behaviour

3.105.49**peak factor (of the line transient voltage)**

the ratio between the maximum excursion and the initial value of the line transient voltage to earth of a phase of an overhead line after the breaking of a short-line fault current

NOTE The initial value of the transient voltage corresponds to the instant of arc extinction in the pole considered.

3.105.50**first-pole-to-clear factor (of a three-phase system, at the location of a circuit-breaker)**

the ratio of the power frequency voltage between the sound phase and the other two phases during a two-phase short-circuit, which may or may not involve earth, at the location of the circuit breaker, to the phase-to-neutral voltage which would be obtained at the same location with the short-circuit removed

3.105.51**insulation level** (604-03-46)

for a circuit-breaker a characteristic defined by one or two values indicating the insulation withstand voltages

3.105.52**power frequency withstand voltage** (604-03-39)

the r.m.s. value of sinusoidal power frequency voltage that the circuit-breaker can withstand during tests made under specified conditions and for a specified time

3.105.53**impulse withstand voltage**

the peak value of the standard impulse voltage wave which the insulation of the circuit-breaker withstands under specified test conditions

NOTE Depending on the shape of wave, the term may be qualified as “switching impulse withstand voltage” or “lightning impulse withstand voltage”.

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4 Rating

A circuit-breaker in correct condition of maintenance and adjustment shall be able to withstand all stresses that occur in service provided that these do not exceed its rated characteristics.

The characteristics of a circuit-breaker, including its operating devices and auxiliary equipment, that shall be used to determine the rating are the following:

A) Rated characteristics to be given for all circuit-breakers

- a) Rated voltage.
- b) Rated insulation level.
- c) Rated frequency.
- d) Rated normal current.
- e) Rated short-time withstand current.
- f) Rated peak withstand current.
- g) Rated duration of short circuit, for circuit-breakers not fitted with direct over-current release.
- h) Rated supply voltage of closing and opening devices and of auxiliary circuits.
- i) Rated supply frequency of closing and opening devices and of auxiliary circuits.
- j) Rated pressures of compressed gas supply for operation and for interruption, if applicable.
- k) Rated short-circuit breaking current.
- l) Rated transient recovery voltage for terminal faults.
- m) Rated short-circuit making current.
- n) Rated operating sequence.

B) Rated characteristics to be given in the specific cases indicated below

- o) Rated characteristics for short-line faults, for three-pole circuit-breakers designed for direct connection to overhead transmission lines and rated at 52 kV and above and at more than 12.5 kA rated short-circuit breaking current.
- p) Rated line-charging breaking current, for three-pole circuit-breakers intended for switching overhead transmission lines and rated at 72.5 kV and above.

C) Rated characteristics to be given on request

- q) Rated out-of-phase breaking current.
- r) Rated cable-charging breaking current.
- s) Rated single capacitor bank breaking current.
- t) Rated back-to-back capacitor bank breaking current.
- u) Rated capacitor bank inrush making current.
- v) Rated small inductive breaking current.
- w) Rated time quantities.

4.1 Rated voltage

Sub-clause 4.1 of IEC Publication 694 is applicable.

NOTE The rated voltage 27 kV is also used in the United States of America and Canada.

4.2 Rated insulation level

Sub-clause 4.2 of IEC Publication 694 is applicable.

4.2.1 For rated voltages up to and including 72.5 kV

Sub-clause 4.2.1 including Table I of IEC Publication 694 is applicable with the exception of columns (3), (5), (7) and the note and with the following addition:

For series II (based on current practice in the United States of America and Canada, for 60 Hz only), Table I is applicable:

Table I — Series II (based on current practice in the United States of America and Canada, for 60 Hz only)

Rated voltage U (r.m.s. value) (kV)	Rated lightning impulse withstand voltage (peak value) To earth, between poles and across open circuit-breaker (kV)	Rated power frequency withstand voltage (r.m.s. value) To earth, between poles and across open circuit-breaker	
		1 min dry test (kV)	10 s wet test ^a (kV)
(1)	(2)	(3)	(4)
4.76	60	19	—
8.25	95	36	—
15.0	95	36	—
15.5	110	50	45
25.8 and 27.0	150	60	50
38.0	200/150 ^b	80	75
48.3	250	105	95
72.5	350	160	140

^a Applicable only to outdoor circuit-breakers. Test requirements are given in IEC Publication 60-1: High-voltage Test Techniques, Part 1: General Definitions and Test Requirements.
^b Applicable only to indoor circuit-breakers.

4.2.2 For rated voltages from 100 kV to 245 kV

Sub-clause 4.2.2 including Table III of IEC Publication 694 is applicable with the exception of columns (3), (5) and the note.

4.2.3 Rated voltages 300 kV and above

Sub-clause 4.2.3 of IEC Publication 694 is applicable with the following addition:

The standard value of rated switching impulse withstand voltage across the open circuit-breaker is given in column (5) of Table IV of IEC Publication 694. However, for special circuit-breakers intended for use in synchronizing operation simultaneously with a substantial switching surge, such as from the line energization, the insulation of a standard circuit-breaker may be insufficient. In such cases which are subject to agreement between manufacturer and user, it is suggested either to use a standard circuit-breaker having a higher rated voltage or to use a special circuit-breaker, increasing the severity of the test with the circuit-breaker open. In this last case, the rated switching impulse withstand voltage across the open circuit-breaker is given in column (6) of Table IV of IEC Publication 694.

4.3 Rated frequency

Sub-clause 4.3 of IEC Publication 694 is applicable.

4.4 Rated normal current and temperature rise

Sub-clauses 4.4.1 and 4.4.2 of IEC Publication 694 are applicable with the following additions:

The values of rated normal currents shall be selected from the following standard values:

400 A; 630 A; 800 A; 1 250 A; 1 600 A; 2 000 A; 2 500 A; 3 150 A; 4 000 A; 5 000 A; 6 300 A.

NOTE The above values are selected from the R 10 series, and, if required, higher values than those shown should also be selected from this series.

If the circuit-breaker is fitted with a series connected accessory, such as a direct over-current release, the rated normal current of the accessory is the r.m.s. value of the current which the accessory shall be able to carry continuously without deterioration at its rated frequency, with a temperature rise not exceeding the values specified in Table V of IEC Publication 694.

Current transformers shall comply with IEC Publication 185: Current Transformers.

4.5 Rated short-time withstand current

Sub-clause 4.5 of IEC Publication 694 is applicable with the following addition:

The rated short-time withstand current is equal to the rated short-circuit breaking current (see Sub-clause 4.101).

4.6 Rated peak withstand current

Sub-clause 4.6 of IEC Publication 694 is applicable with the following addition:

The rated peak withstand current is equal to the rated short-circuit making current (see Sub-clause 4.103).

4.7 Rated duration of short-circuit

Sub-clause 4.7 of IEC Publication 694 is applicable with the following addition:

A rated duration of a short-circuit need not be assigned to a circuit-breaker fitted with a direct over-current release provided that, when connected in a circuit the prospective breaking current of which is equal to its rated short-circuit breaking current, the circuit-breaker shall be capable of carrying the resulting current for the break-time required by the circuit-breaker with the over-current release set for the maximum time lag, when operating in accordance with its rated operating sequence.

4.8 Rated supply voltage of closing and opening devices and auxiliary circuits

Sub-clause 4.8 of IEC Publication 694 is applicable with the following addition:

The specified upper limit of the supply voltage for a closing solenoid shall be 105 % of the rated supply voltage.

4.9 Rated supply frequency of closing and opening devices and auxiliary circuits

Sub-clause 4.9 of IEC Publication 694 is applicable

4.10 Rated pressures of compressed gas supply for operation and for interruption

The values of the pressures to which the circuit-breaker is filled.

Sub-clause 4.10 of IEC Publication 694 is applicable to the pressure of the compressed gas supply for operation.

No standard values are given for rated pressure of compressed gas supply for interruption.

4.101 Rated short-circuit breaking current

The rated short-circuit breaking current is the highest short-circuit current which the circuit-breaker shall be capable of breaking under the conditions of use and behaviour prescribed in this standard in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the circuit-breaker and having a transient recovery voltage equal to the rated value specified in Sub-clause 4.102. For three-pole circuit-breakers the a.c. component relates to a three-phase short-circuit. Where applicable the provisions of Sub-clause 4.105 concerning short-line faults shall be taken into account.

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

- the r.m.s. value of its a.c. component, termed “rated short-circuit current” for shortness, and
- the percentage d.c. component.

NOTE If the d.c. component does not exceed 20 %, the rated short-circuit breaking current is characterized only by the r.m.s. value of its a.c. component.

For determination of the a.c. and d.c. components, see Figure 8, page 54.

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

The following applies to a standard circuit-breaker:

- a) At voltages below the rated voltage, it will be capable of breaking its rated short-circuit breaking current.

NOTE For circuit-breakers with rated voltages not exceeding 72.5 kV having proved rated short-circuit breaking currents I at two different rated voltages U , intermediate characteristics may be assigned from the straight line drawn between the two proved rating points on a plot of $\log U$ versus $\log I$. In case of doubt, tests should be carried out to check the validity of the interpolation.

b) At voltages above the rated voltage, no short-circuit breaking current is guaranteed except to the extent provided for in Sub-clause 4.106.

4.101.1 A.C. component of the rated short-circuit breaking current

The r.m.s. value of the a.c. component of the rated short-circuit breaking current shall be selected from the following values:

6.3 kA; 8 kA; 10 kA; 12.5 kA; 16 kA; 20 kA; 25 kA; 31.5 kA; 40 kA; 50 kA; 63 kA; 80 kA; 100 kA

NOTE The above values are selected from the R 10 series, and, if required, higher values than those shown should also be selected from this series.

4.101.2 D.C. component of the rated short-circuit breaking current

The value of the percentage d.c. component shall be determined as follows:

- a) For a circuit-breaker which can be tripped by the short-circuit current without the aid of any form of auxiliary power, the percentage d.c. component shall correspond to a time interval τ equal to the minimum opening time of the circuit-breaker.
- b) For a circuit-breaker which is intended to be tripped solely by a form of auxiliary power, the percentage d.c. component shall correspond to a time interval τ equal to the minimum opening time of the circuit-breaker plus one-half cycle of rated frequency.

The minimum opening time mentioned above is the shortest opening time of the circuit-breaker obtainable under any service conditions whether in a breaking operation or a make-break operating cycle.

The percentage value of the d.c. component is dependent on the time interval τ and standard values are given in Figure 9, page 55.

NOTE Depending on the characteristics of the system, for example if a circuit-breaker is close to a generator, the percentage d.c. component corresponding to the circuit-breaker opening time may be higher than the value given in Figure 9, which is based on negligible decrement of the a.c. component of the short-circuit current and on an exponential decay of the d.c. component to an 80 % value in 10 ms, i.e. a time constant of approximately 45 ms. In this case, the required percentage d.c. component should be specified in the enquiry and testing should be subject to agreement between manufacturer and user.

4.102 Rated transient recovery voltage for terminal faults

The rated transient recover voltage (TRV) for terminal faults, relating to the rated short-circuit breaking current in accordance with Sub-clause 4.101, is the reference voltage which constitutes the limit of the prospective transient recovery voltage of circuits which the circuit-breaker shall be capable of breaking in the event of a short-circuit at its terminals.

4.102.1 Representation of transient recovery voltage waves

The waveform of transient recovery voltages varies according to the arrangement of actual circuits.

In some cases, particularly in systems with a voltage greater than 100 kV, and where the short-circuit currents are relatively large in relation to the maximum short-circuit current at the point under consideration, the transient recovery voltage contains first a period of high rate of rise, followed by a later period of lower rate of rise. This waveform is generally adequately represented by an envelope consisting of three line segments defined by means of four parameters³⁾.

In other cases, particularly in systems with a voltage less than 100 kV, or in systems with a voltage greater than 100 kV in conditions where the short-circuit currents are relatively small in relation to the maximum short-circuit currents and fed through transformers, the transient recovery voltage approximates to a damped single frequency oscillation. This waveform is adequately represented by an envelope consisting of two line segments defined by means of two parameters³⁾.

Such a representation in terms of two parameters is a special case of representation in terms of four parameters.

The influence of local capacitance on the source side of the circuit-breaker produces a slower rate of rise of the voltage during the first few microseconds of the TRV. This is taken into account by introducing a time delay.

³⁾ Methods of drawing TRV envelopes are given in Appendix FF.

It appears that every part of the TRV wave may influence the interrupting capability of a circuit-breaker. The very beginning of the TRV may be of importance for some types of circuit-breakers.

This part of the TRV, called initial TRV (ITRV), is caused by the initial oscillation of small amplitude due to reflections from the first major discontinuity along the busbar. The ITRV is mainly determined by the busbar and line bay configuration of the substation. The ITRV is a physical phenomenon which is very similar to the short-line fault. Compared with the short-line fault, the first voltage peak is rather low, but the time to the first peak is extremely short, that is within the first microseconds after current zero. Therefore the thermal mode of interruption may be influenced.

If the circuit-breaker has a short-line fault rating the ITRV requirements are considered to be covered if the short-line fault tests are carried out using a line without time delay (see Sub-clause 6.104.5.2).

Since the ITRV is proportional to the busbar surge impedance and to the current, the ITRV requirements can be neglected for metal-enclosed switchgear because of the low surge impedance and for all switchgear with a rated short-circuit breaking current of less than 25 kA.

4.102.2 Representation of rated TRV

The following parameters are used for the representation of rated TRV:

- a) Four-parameter reference line (see Figure 10, page 55):

u_1 = first reference voltage, in kilovolts

t_1 = time to each u_1 , in microseconds

u_c = second reference voltage (TRV peak value), in kilovolts

t_2 = time to reach u_c , in microseconds

- b) Two-parameter reference line (see Figure 11, page 56):

u_c = reference voltage (TRV peak value), in kilovolts

t_3 = time to reach u_c , in microseconds

- c) Delay line of TRV (see Figure 10 and Figure 11):

t_d = time delay, in microseconds

u' = reference voltage, in kilovolts

t' = time to reach u' , in microseconds

the delay line starts on the time axis at the rated time delay and runs parallel to the first section of the reference line of rated TRV and terminates at the voltage u' (time-coordinate t').

- d) ITRV (see Figure 12, page 57):

u_i = reference voltage (ITRV peak), in kilovolts

t_i = time to reach u_i , in microseconds

the rate of rise of the ITRV is dependent on the short-circuit current interrupted and its amplitude depends upon the distance to the first discontinuity along the busbar. The rated ITRV is expressed firstly as a straight line drawn between the origin and the point (u_i, t_i) and secondly as a horizontal straight line drawn from the point (u_i, t_i) to intersect the delay line of the specified TRV at point A.

4.102.3 Standard values of rated TRV

Standard values of rated TRV for three-pole circuit-breakers of rated voltages below 100 kV, make use of two parameters. Values are given in Table IIA for rated voltages Series I. Table IIB for rated voltages Series II is under consideration.

For rated voltages of 100 kV and above, four parameters are used. Values are given in Table IIC for a first-pole-to-clear factor of 1.3 for rated voltages from 100 kV to 170 kV. Table IID gives values appropriate to a first-pole-to-clear factor of 1.5 for this range of rated voltages. Table IIE gives values for rated voltages of 245 kV and above.

For rated breaking currents greater than 50 kA and voltages 100 kV and above, it may be justified and more economical to use circuit-breakers having lower capabilities in terms of rate of rise of the TRV. Such cases shall be subject to agreement between manufacturer and user.

Table IIA — Standard values of rated transient recovery voltage
Rated voltages Series I
Representation by two parameters — First-pole-to-clear factor 1.5

Rated voltage	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U (kV)	u_c (kV)	t_3 (μ s)	t_d (μ s)	u' (kV)	t' (μ s)	u_c/t_3 (kV/ μ s)
3.6	6.2	40	6	2.1	19	0.15
7.2	12.3	52	8	4.1	25	0.24
12	20.6	60	9	6.9	29	0.34
17.5	30	72	11	10	35	0.42
24	41	88	13	14	42	0.47
36	62	108	16	21	52	0.57
52	89	132	7	30	51	0.68
72.5	124	166	8	41	64	0.75

$u_c = 1.4 \cdot 1.5 \sqrt{\frac{2}{3}} U$; $t_d = 0.15 t_3$ for $U < 52$ kV;
 $u' = \frac{1}{3} u_c$; $t_d = 0.05 t_3$ for $U \geq 52$ kV.

Table IIB — Standard values of rated transient recovery voltage
Rated voltages Series II
Representation by two parameters — First-pole-to-clear factor 1.5

Under consideration.

Table IIC — Standard values of rated transient recovery voltage
Rated voltages 100 kV to 170 kV
Representation by four parameters — First-pole-to-clear factor 1.3

Rated voltage	First reference voltage	Time	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U (kV)	u_1 (kV)	t_1 (μ s)	u_c (kV)	t_2 (μ s)	t_d (μ s)	u' (kV)	t' (μ s)	u_1/t_1 (kV/ μ s)
100	106	53	149	159	2	53	29	2.0
123	131	65	183	195	2	65	35	2.0
145	154	77	215	231	2	77	40	2.0
170	180	90	253	270	2	90	47	2.0

$u_1 = 1.3 \sqrt{\frac{2}{3}} U$; $t_2 = 3 t_1$; $u_c = 1.4 u_1$; $u' = \frac{1}{2} u_1$.

Table IID — Standard values of rated transient recovery voltage
Rated voltages 100 kV to 170 kV
Representation by four parameters — First-pole-to-clear factor 1.5

Rated voltage	First reference voltage	Time	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U (kV)	u_1 (kV)	t_1 (μ s)	u_c (kV)	t_2 (μ s)	t_d (μ s)	u' (kV)	t' (μ s)	u_1/t_1 (kV/ μ s)
100	122	61	171	183	2	61	33	2.0
123	151	75	211	225	2	75	40	2.0
145	178	89	249	267	2	89	46	2.0
170	208	104	291	312	2	104	54	2.0

$u_1 = 1.5 \sqrt{\frac{2}{3}} U$; $t_2 = 3 t_1$; $u_c = 1.4 u_1$; $u' = \frac{1}{2} u_1$.

Table IIE — Standard values of rated transient recovery voltage
Rated voltages from 245 kV and above
Representation by four parameters — First-pole-to-clear factor 1.3

Rated voltage U (kV)	First reference voltage u_1 (kV)	Time t_1 (μ s)	TRV peak value u_c (kV)	Time t_3 (μ s)	Time delay t_d (μ s)	Voltage u' (kV)	Time t' (μ s)	Rate of rise u_1/t_1 (kV/ μ s)
245	260	130	364	390	2	130	67	2.0
300	318	159	446	477	2	159	82	2.0
362	384	192	538	576	2	192	98	2.0
420	446	223	624	669	2	223	113	2.0
525	557	279	780	837	2	279	141	2.0
765	812	406	1 137	1 218	2	406	205	2.0

$$u_1 = 1.3 \sqrt{\frac{2}{3}} U; t_2 = 3 t_1; u_c = 1.4 u_1; u' = \frac{1}{2} u_1.$$

Table IIF — Multipliers for transient recovery voltage values for second and third clearing poles for rated voltages above 72,5 kV, to be applied at three-phase testing

First-pole-to-clear factor	Multipliers			
	2nd clearing pole		3rd clearing pole	
	RRRV	u_c	RRRV	u_c
1,5	0,70	0,58	0,70	0,58
1,3	0,95	0,98	0,70	0,77

RRRV: Rate-of-rise of recovery voltage.

In order to obtain the values of RRRV and u_c for the second and third clearing poles, the multiplier shall be applied to the values of RRRV and u_c of the first clearing pole at the relevant first-pole-to-clear factor. The RRRV-multipliers are related to u_1/t_1 ; the times t_1 and t_2 are the same for the first, second and last clearing poles.

NOTE 1 For rated voltage for 72,5 kV and below, the values are under consideration.

NOTE 2 See also Appendix JJ.

NOTE 3 This table is valid for test duty 1, 2, 3, 4 and 5. For test duty 5 the same reduction method shall be applied as indicated in IEC 427 for the first clearing pole. The figures are an approximation for test duties 1, 2 and 3 and are subject to further consideration.

NOTE 4 The values are rounded values, depending on Z_0/Z_1 of the TRV-circuits, the time constant of the system and the rated voltages.

NOTE 5 Values of Table IIF for 1,5 first-pole-to-clear factor are only valid to breakers having less than one-quarter of a cycle difference in pole simultaneity.

The tables also indicate values of rate of rise, taken as u_c/t_3 and u_1/t_1 , in the two-parameter and four-parameter cases respectively, which together with TRV peak values u_c may be used for purposes of specification of TRV.

The values given in the tables are prospective values. They apply to circuit-breakers for general transmission and distribution in three-phase systems having service frequencies of 50 Hz or 60 Hz and consisting of transformers, overhead lines and short lengths of cable.

In the case of single-phase systems or where circuit-breakers are for use in an installation having more severe conditions, the values shall be subject to agreement between manufacturer and user, particularly for the following cases:

- circuit-breakers adjacent to generator circuits;
- circuit-breakers directly connected to transformers without appreciable additional capacitance between the circuit-breaker and the transformer which provides more than 50 % of the rated short-circuit breaking-current of the circuit-breaker;
- circuit-breakers adjacent to series reactors.

In circuits having large cable networks directly on the source side, it may be more economical to use circuit-breakers having a lower rate of rise of rated transient recovery voltage, but in this case the values shall be subject to agreement between manufacturer and user.

The rated transient recovery voltage corresponding to the rated short-circuit breaking current on the occurrence of a terminal fault is used for testing at short-circuit breaking currents equal to the rated value. However, for testing at short-circuit breaking currents less than 100 % of the rated value, other values of transient recovery voltage are specified (see Sub-clause 6.104.5), further additional requirements apply to circuit-breakers rated at 52 kV and above and having rated short-circuit breaking currents exceeding 12.5 kA, which may be called upon to operate in short-line fault conditions (see Sub-clause 4.105).

4.102.4 Standard values of rated ITRV

Table III — Standard values of rated initial transient recovery voltage
Rated voltages 100 kV and above

Rated voltage U (kV)	Multiplying factor to determine u_i as function of the r.m.s. value of the short-circuit breaking current I^a		Time t_i (μ s)
	f_i (kV/kA)	f_i (kV/kA)	
	50 Hz	60 Hz	
100	0.046	0.056	0.4
123	0.046	0.056	0.4
145	0.046	0.056	0.4
170	0.058	0.07	0.5
245	0.069	0.084	0.6
300	0.081	0.098	0.7
362	0.092	0.112	0.8
420	0.092	0.112	0.8
525	0.116	0.139	1.0
765	^b	^b	^b

^a The actual initial peaks are obtained by multiplying the figures of this column with the r.m.s. value of the short-circuit breaking current.
^b Under consideration.

NOTE The values of Table III are deemed to cover both three-phase and single-phase faults and are based on the assumption that the busbar, including the elements connected to it (supports, current and voltage transformers, disconnectors, etc.), can be roughly represented by a resulting surge impedance Z_i of about 260 Ω . The relation between f_i and t_i is then:

$$f_i = t_i \cdot Z_i \cdot \omega \sqrt{2}$$

ω corresponding to the rated frequency of the circuit-breaker.

4.103 Rated short-circuit making current

The rated short-circuit making current, see Figure 8, page 54, of a circuit-breaker is that which corresponds to the rated voltage, and shall be 2.5 times the r.m.s. value of the a.c. component of its rated short-circuit breaking current (see Sub-clause 4.101).

4.104 Rated operating sequence

There are two alternative rated operating sequences as follows:

- a) O – t – CO – t' – CO

Unless otherwise specified:

$t = 3$ min for circuit-breakers not intended for rapid auto-reclosing

$t = 0.3$ s for circuit-breakers intended for rapid auto-reclosing (dead time)

$t' = 3$ min

NOTE Instead of $t' = 3$ min, other values: $t' = 15$ s (for rated voltages less than or equal to 52 kV) and $t' = 1$ min are also used for circuit-breakers intended for rapid auto-reclosing.

b) CO – t'' – CO

with:

$t'' = 15$ s, for circuit-breakers not intended for rapid auto-reclosing

where:

O represents an opening operation

CO represents a closing operation followed immediately (that is, without any intentional time-delay) by an opening operation

t , t' and t'' = time-intervals between successive operations

t and t' = should always be expressed in minutes or in seconds

t'' = should always be expressed in seconds

If the dead time is adjustable, the limits of adjustment shall be specified.

4.105 Rated characteristics for short-line faults

Rated characteristics for short-line faults are required for three-pole circuit-breakers designed for direct connection to overhead transmission lines and having a rated voltage of 52 kV and above and a rated short-circuit breaking current exceeding 12.5 kA. These characteristics relate to the breaking of a single-phase earth fault in a system with earthed neutral.

NOTE For the purpose of this standard, a single-phase test at the voltage to earth is deemed to cover all types of short-line fault. In this context it is considered immaterial that in isolated neutral systems, single-phase earth faults do not subject a circuit-breaker to short-line fault conditions.

The short-line fault circuit is taken as composed of a supply circuit on the source side of the circuit-breaker and a short-line on its load side (see Figure 13, page 58), with the following rated characteristics:

a) Rated supply circuit characteristics:

Voltage equal to the phase-to-earth voltage $U/\sqrt{3}$ corresponding to the rated voltage U of the circuit-breaker.

Short-circuit current, in case of terminal fault, equal to the rated short-circuit breaking current of the circuit-breaker.

Prospective transient recovery voltage, in case of terminal fault, given by the standard values in Table IVA, Table IVB and Table IVC.

ITRV characteristics derived from Table III.

b) Rated line characteristics:

Standard values of rated surge impedance Z , rated peak factor k and time delay t_{dL} are given in Table V.

The method for calculation of transient recovery voltages from rated characteristics is given in Appendix AA.

Table IVA — Standard values of rated transient recovery voltage of the supply circuit for short-line faults
Rated voltages Series I — Representation by two parameters

Rated voltage U (kV)	TRV peak value u_c (kV)	Time t_3 (μ s)	Time delay t_d (μ s)	Voltage u' (kV)	Time t' (μ s)	Rate of rise u_c/t_3 (kV/ μ s)
52	59	132	7	20	51	0.45
72.5	83	166	8	28	64	0.50
$u_c = 1.4 \sqrt{\frac{2}{3}} U$; $t_d = 0.05 t_3$; $u' = \frac{1}{3} u_c$						

Table IVB — Standard values of rated transient recovery voltage of the supply circuit for short-line faults
Rated voltages Series II — Representation by two parameters

Under consideration.

Table IVC — Standard values of rated transient recovery voltage of the supply circuit for short-line faults

Rated voltages 100 kV and above — Representation by four parameters

Rated voltage U (kV)	First reference voltage u_1 (kV)	Time t_1 (μ s)	TRV peak value u_c (kV)	Time t_2 (μ s)	Time delay t_d (μ s)	Voltage u' (kV)	Time t' (μ s)	Rate of rise u_1/t_1 (kV/ μ s)
100	82	41	114	123	2	41	22	2.0
123	100	50	141	150	2	50	27	2.0
145	118	59	166	177	2	59	32	2.0
170	139	69	194	207	2	69	37	2.0
245	200	100	280	300	2	100	52	2.0
300	245	122	343	366	2	122	63	2.0
362	296	148	414	444	2	148	76	2.0
420	343	171	480	513	2	171	88	2.0
525	429	214	600	642	2	214	109	2.0
765	625	312	874	936	2	312	158	2.0

$$u_1 = \sqrt{\frac{2}{3}} U; t_2 = 3 t_1; u_c = 1.4 u_1; u' = \frac{1}{2} u_1.$$

Table V — Standard values of rated line characteristics for short-line faults

Rated voltage U (kV)	Number of conductors per phase	Rated surge impedance Z (Ω)	Rated peak factor k	RRRV factor		Time delay t_{dl}^b (μ s)
				50 Hz	60 Hz	
≤ 170	1 to 4	450	1.6	s^a		0.2
≥ 245				0.200	0.240	0.5

^a For the RRRV factor s , see Appendix AA.

^b A local capacitance on the line side of the circuit-breaker (e.g. disconnector, current and voltage transformer) produces a slower rate-of-rise of the line side voltage in its very initial stage. This is taken into account by introducing a line side time delay t_{dl} . This capacitance does not have any influence upon the surge impedance of the actual line.

For determination of the line side time delay and the rate-of-rise of the line side voltage, see Figure 14, page 58.

4.106 Rated out-of-phase breaking current

The rated out-of-phase breaking current is the maximum out-of-phase current that the circuit-breaker shall be capable of breaking under the conditions of use and behaviour prescribed in this standard in a circuit having a recovery voltage as specified below.

The specification of a rated out-of-phase breaking current is not mandatory. If a rated out-of-phase breaking current is assigned, the following applies:

- The power frequency recovery voltage shall be $2.0/\sqrt{3}$ times the rated voltage for earthed neutral systems and $2.5/\sqrt{3}$ times the rated voltage for other systems.
- The transient recovery voltage shall be in accordance with table:
 - VIA, for circuit-breakers with rated voltages below 100 kV intended to be used in systems other than earthed neutral systems.
 - VIB, for circuit-breakers with rated voltages from 100 kV up to and including 170 kV intended to be used in earthed neutral systems.
 - VIC, for circuit-breakers with rated voltages from 100 kV up to and including 170 kV intended to be used in systems other than earthed neutral systems.
 - VID, for circuit-breakers with rated voltages 245 kV and above intended to be used in earthed neutral systems.

c) The rated out-of-phase breaking current shall be 25 % of the rated short-circuit breaking current, unless otherwise specified.

The standard conditions of use with respect to the rated out-of-phase breaking current are as follows:

- Opening and closing operations carried out in conformity with the instructions given by the manufacturer for the operation and proper use of the circuit-breaker and its auxiliary equipment.
- Earthing condition of the neutral for the power system corresponding to that for which the circuit-breaker has been tested.
- Absence of a fault on either side of the circuit-breaker.

Table VIA — Standard values of rated transient recovery voltage for out-of-phase breaking
Rated voltages Series I — Representation by two parameters Systems other than earthed neutral systems

Rated voltage U (kV)	TRV peak value u_c (kV)	Time t_3 (μ s)	Rate of rise u_c/t_3 (kV/ μ s)
3.6	9.2	80	0.12
7.2	18.4	104	0.18
12	30.6	120	0.26
17.5	45	144	0.31
24	61	176	0.35
36	92	216	0.43
52	133	264	0.50
72.5	185	336	0.55
$u_c = 1.25 \cdot 2.5 \sqrt{\frac{2}{3}} U$			

Table VIB — Standard values of rated transient recovery voltages for out-of-phase breaking
Rated voltages 100 kV to 170 kV — Representation by four parameters Earthed neutral systems

Rated voltage U (kV)	First reference voltage u_1 (kV)	Time t_1 (μ s)	TRV peak value u_c (kV)	Time t_2 (μ s)	Rate of rise u_1/t_1 (kV/ μ s)
100	163	106	204	318	1.54
123	201	130	251	390	1.54
145	237	154	296	462	1.54
170	278	180	347	540	1.54
$u_1 = 2 \sqrt{\frac{2}{3}} U$; $u_c = 1.25 u_1$; $t_2 = 3 t_1$					

Table VIC — Standard values of rated transient recovery voltages for out-of-phase breaking
Rated voltages 100 kV to 170 kV — Representation by four parameters Systems other than earthed neutral systems

Rated voltage U (kV)	First reference voltage u_1 (kV)	Time t_1 (μ s)	TRV peak value u_c (kV)	Time t_2 (μ s)	Rate of rise u_1/t_1 (kV/ μ s)
100	204	122	255	366	1.67
123	251	150	314	450	1.67
145	296	178	370	534	1.67
170	347	208	434	624	1.67
$u_1 = 2.5 \sqrt{\frac{2}{3}} U$; $t_2 = 3 t_1$; $u_c = 1.25 u_1$					

**Table VID — Standard values of rated transient recovery voltage
for out-of-phase breaking
Rated voltages 245 kV and above — Representation by four parameters
Earthed neutral systems**

Rated voltage U (kV)	First reference voltage u_1 (kV)	Time t_1 (μ s)	TRV peak value u_c (kV)	Time t_2 (μ s)	Rate of rise u_1/t_1 (kV/ μ s)
245	400	260	500	780	1.54
300	490	318	612	954	1.54
362	591	384	739	1 152	1.54
420	686	446	857	1 338	1.54
525	857	558	1 071	1 674	1.54
765	1 249	812	1 562	2 436	1.54
$u_1 = 2 \sqrt{\frac{2}{3}} U$; $t_2 = 3 t_1$; $u_c = 1.25 u_1$.					

4.107 Rated line-charging breaking current

The rated line-charging breaking current is the maximum line-charging current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the maximum permissible switching over-voltages specified by the manufacturer. Suggested values are given in Table IX.

The specification of a rated line-charging breaking current is confined to circuit-breakers intended to be used for switching three-phase overhead lines and having a rated voltage equal to or greater than 72.5 kV. Standard values are given in Table VII.

Table VII — Standard values of rated line-charging breaking current

Rated voltage U (kV)	Rated line-charging breaking current I_1 (A)
72.5	10
100	20
123	31.5
145	50
170	63
245	125
300	200
362	315
420	400
525	500
NOTE For single conductor overhead lines operating at 50 Hz, the rated line-charging breaking currents indicated in Table VII imply a length in kilometres approximately equal to 1.2 times the rated voltage of the circuit-breaker in kilovolts.	

4.108 Rated cable-charging breaking current

The rated cable-charging breaking current is the maximum cable-charging current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the appropriate maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table IX.

The specification of a rated cable-charging breaking current to a circuit-breaker is not mandatory but is made on request, and is considered unnecessary for circuit-breakers of rated voltages equal to or less than 24 kV. If assigned, it is recommended that the rated cable-charging breaking current be in accordance with Table VIII.

Table VIII — Standard values of rated cable-charging breaking current

Rated voltage U (kV)	Rated cable-charging breaking current I_c (A)
3.6	10
7.2	10
12	25
17.5	31.5
24	31.5
36	50
52	80
72.5	125
100	125
123	140
145	160
170	160
245	250
300	315
362	355
420	400
525	500
NOTE The values of Table VIII correspond to the normal maximum requirements of the majority of power systems. Cable-charging currents in excess of these values should be the subject of special agreement between manufacturer and user.	

4.109 Rated single capacitor bank breaking current

The rated single capacitor bank breaking current is the maximum capacitor current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table IX, columns B.

This breaking current refers to the switching of a shunt capacitor bank where no shunt capacitors are connected to the source side of the circuit-breaker.

The specification of a rated single capacitor bank breaking current is not mandatory.

Values of rated single capacitor bank breaking currents should be selected from the R 10 series.

4.110 Rated back-to-back capacitor bank breaking current

The rated back-to-back capacitor bank breaking current is the maximum capacitor current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table IX, columns B.

This breaking current refers to the switching of a shunt capacitor bank where one or several shunt capacitor banks are connected to the source side of the circuit-breaker giving an inrush making current equal to the rated capacitor bank inrush making current.

The specification of a rated back-to-back capacitor bank breaking current is not mandatory.

Values of rated back-to-back capacitor bank breaking currents should be selected from the R 10 series.

NOTE Similar conditions could apply for switching of cables.

4.111 Rated capacitor bank inrush making current

The rated capacitor bank inrush making current is the peak value of the current that the circuit-breaker shall be capable of making at its rated voltage and with a frequency of the inrush current appropriate to the service conditions (see Appendix BB).

The specification of a rated capacitor bank inrush making current is mandatory for circuit-breakers that have a rated back-to-back capacitor bank breaking current.

Values of rated capacitor bank inrush making currents should be selected from the R 10 series.

NOTE 1 In service, the frequency of the inrush current is normally in the range 2–5 kHz.

NOTE 2 The circuit-breaker is considered to be suitable for any frequency of the inrush current lower than that for which it has been tested.

Table IX — Suggested values of maximum permissible switching overvoltages when interrupting line-charging, cable-charging and single capacitor bank breaking current

Rated voltage (r.m.s. value) (kV)	Rated lightning impulse withstand voltage ^a (peak value) (kV)	Maximum permissible switching overvoltage to earth			
		A		B	
		(Peak value) (kV)	$\frac{\text{Col. (3)}}{\text{Col. (1)} \sqrt{\frac{2}{3}}}$ (p.u.)	(Peak value) (kV)	$\frac{\text{Col. (5)}}{\text{Col. (1)} \sqrt{\frac{2}{3}}}$ (p.u.)
(1)	(2)	(3)	(4)	(5)	(6)
3.6	20	8.8	3	7.3	2.5
	40	13.2	4.5	7.3	2.5
7.2	40	17.6	3	14.7	2.5
	60	26.4	4.5	14.7	2.5
12	60	29.5	3	24.5	2.5
	75	39.2	4	24.5	2.5
17.5	75	43	3	35.7	2.5
	95	57	4	35.7	2.5
24	95	59	3	49	2.5
	125	74	3.8	49	2.5
36	145	88	3	73	2.5
	170	112	3.8	73	2.5
52	250	149	3.5	106	2.5
72.5	325	207	3.5	148	2.5
100	380	246	3	204	2.5
	450	286	3.5	204	2.5
123	450	302	3	251	2.5
	550	352	3.5	251	2.5
145	550	356	3	297	2.5
	650	415	3.5	297	2.5
170	650	417	3	348	2.5
	750	487	3.5	348	2.5
245	850	540	2.7	400	2
	950	600	3	400	2
	1 050	600	3	400	2
300	950	637	2.6	490	2
	1 050	735	3	490	2
362	1 050	710	2.4	592	2
	1 175	800	2.7	592	2
420	1 300	790	2.3	688	2
	1 425	895	2.6	688	2
525	1 425	900	2.1	858	2
	1 550	985	2.3	858	2

Table IX — Suggested values of maximum permissible switching overvoltages when interrupting line-charging, cable-charging and single capacitor bank breaking current

Rated voltage (r.m.s. value)	Rated lightning impulse withstand voltage ^a (peak value)	Maximum permissible switching overvoltage to earth			
		A		B	
		(Peak value)	$\frac{\text{Col. (3)}}{\text{Col. (1)} \sqrt{\frac{2}{3}}}$	(Peak value)	$\frac{\text{Col. (5)}}{\text{Col. (1)} \sqrt{\frac{2}{3}}}$
(kV)	(kV)	(kV)	(p.u.)	(kV)	(p.u.)
(1)	(2)	(3)	(4)	(5)	(6)
765	1 800 2 100	1 125 1 250	1.8 2	1 125 1 250	1.8 2

NOTE 1 These values apply only to the test conditions of Sub-clause 6.111. Other overvoltages such as, for instance, those appearing when reclosing a line with trapped charges and when breaking a small inductive current, as well as phase-to-phase overvoltages, are not covered by this table.

NOTE 2 These values cannot always guarantee that phase-to-phase flashovers will not occur.

NOTE 3 Maximum permissible switching overvoltages for rated voltages of Series II, which are based on current practice in the United States of America and Canada, are under consideration.

NOTE 4 The values of columns A apply to circuit-breakers for general use intended for switching unloaded lines and cables of the types most generally used in power systems.

The values of columns B apply to circuit-breakers for special use intended for switching capacitor banks or no-load lines and cables in power systems where there are special insulation co-ordination problems such as, for instance, limitation of energy absorption by surge diverters, spark-over of spark-gaps, etc.

NOTE 5 At 245 kV and above, only earthed neutral systems and capacitor banks, if any, with earthed neutral, are considered for the application of the values of columns B.

^a The insulation level is indicated in this table by the rated lightning impulse withstand voltage; the corresponding rated power-frequency or switching impulse withstand voltage can be ascertained from Tables I to IV of IEC Publication 694.

4.112 Rated small inductive breaking current

Under consideration.

4.113 Rated time quantities

Rated values may be assigned to the following time quantities:

- opening time;
- break time;
- closing time;
- open-close time;
- reclosing time;
- close-open time.

Rated time quantities are based on:

- rated values for supply voltages of closing and opening devices and auxiliary circuits (see Sub-clause 4.8);
- rated value for supply frequency of closing and opening devices and auxiliary circuits (see Sub-clause 4.9);
- rated values for pressures of compressed gas supply for operation and for interruption (see Sub-clause 4.10);
- rated value for pressure of hydraulic supply for operation;
- an ambient air temperature of 20 ± 5 °C. If tests are carried out at other ambient temperatures, agreement between manufacturer and user may be necessary for interpretation of the results.

NOTE Usually it is not practical to assign a rated value of make time or of make-break time due to the variation of the pre-arcing time.

4.113.1 Rated break time

The maximum break time determined during Test-duties 2, 3 and 4 of Sub-clauses **6.106.2**, **6.106.3** and **6.106.4** with the circuit-breaker operated at auxiliary supply voltage and frequency and pressures of pneumatic or hydraulic supply at their rated values and at an ambient air temperature of $20 \pm 5^\circ\text{C}$ (see Sub-clause **4.113**) shall not exceed the rated break time.

NOTE 1 According to Sub-clause **6.102.2** the basic short-circuit test-duties should be carried out at minimum voltage or pressure of the operating devices. In order to verify the rated break time during these test-duties the recorded maximum break time should be amended to take account of the lower auxiliary supply voltage and pressure as follows:

$$t_b \geq t_1 - (t_2 - t_3)$$

where:

t_b = rated break time

t_1 = maximum recorded break time during Test-duties 2, 3 and 4.

t_2 = opening time recorded on no-load with auxiliary supply voltage and pressures of compressed gas supply as used during Test-duties 2, 3 and 4

t_3 = rated opening time

If the break time determined according to this procedure exceeds the rated break time the test-duty which has given the longest break time may be repeated with auxiliary supply voltage and frequency and pressure of pneumatic or hydraulic supply at their rated values and if applicable, at rated pressure of the interrupting medium.

NOTE 2 For single-phase tests simulating a three-phase operation, the recorded break time, amended according to Note 1, may exceed the rated break time by 0.1 cycle because in these cases the current zeros occur less frequently than in the three-phase case.

NOTE 3 The break time during a make-break operation of Test-duty 4 should not exceed the rated break time by more than 0.5 cycle.

4.114 Co-ordination of rated values

Co-ordinated values of rated voltages (Sub-clause **4.1**), short-circuit breaking-currents (Sub-clause **4.101**) and rated normal currents (Sub-clause **4.4**) are given in Table XA to Table XC.

The co-ordination tables are not mandatory and are intended to be used as a guide for preferred values. Therefore a circuit-breaker with another combination of the rated values is not outside the IEC Standard for circuit-breakers.

5 Design and construction

5.1 Requirements for liquids in circuit-breakers

Sub-clause **5.1** of IEC Publication 694 is applicable.

5.2 Requirements for gases in circuit-breakers

Sub-clause **5.2** of IEC Publication 694 is applicable.

5.3 Earthing of circuit-breakers

Sub-clause **5.3** of IEC Publication 694 is applicable.

5.4 Auxiliary equipment

Auxiliary equipment is used in the control and auxiliary circuits of circuit-breakers.

Sub-clause **5.4** of IEC Publication 694 is applicable with the following additions:

- Connections shall withstand the stresses imposed by the circuit-breaker, especially those due to mechanical forces during operations.
- In the case of outdoor circuit-breakers all auxiliary equipment including the wiring shall be adequately protected against rain and humidity.
- Where auxiliary switches are used as position indicators, they shall indicate the end position of the circuit-breaker at rest, open or closed.
- Where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, quenching and operating media, and be able to switch the loads which are stated by the circuit-breaker manufacturer.
- Special items of auxiliary equipment such as liquid-indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of quenching and operating media.

— The power consumption of heaters at rated voltage shall be within the tolerance of $\pm 10\%$ of the values stated by the manufacturer.

Table XA — Co-ordination table of rated values for circuit-breakers

Rated voltage U (kV)	Rated short-circuit breaking current I_{sc} (kA)	Rated normal current I_n (A)							
3.6	10	400	630		1 250	1 600		2 500	4 000
	16				1 250				
	25				1 250				
	40				1 250				
7.2	8	400	630		1 250	1 600		2 500	4 000
	12.5	400			1 250				
	16				1 250				
	25				1 250				
	40				1 250				
12	8	400	630		1 250	1 600		2 500	4 000
	12.5	400			1 250				
	16				1 250				
	25				1 250				
	40				1 250				
	50				1 250				
17.5	8	400	630		1 250	1 600		2 500	
	12.5				1 250				
	16				1 250				
	25				1 250				
	40				1 250				
24	8	400	630		1 250	1 600		2 500	4 000
	12.5				1 250				
	16				1 250				
	25				1 250				
36	8		630		1 250	1 600		2 500	4 000
	12.5				1 250				
	16				1 250				
	25				1 250				
52	8			800	1 250	1 600	2 000		
	12.5				1 250				
	20				1 250				
72.5	12.5			800	1 250	1 600	2 000		
	16				1 250				
	20				1 250				
	31.5				1 250				

NOTE The values of the rated voltage are those given Sub-clause 4.1.1 of IEC Publication 694 for Series I. The values of the rated short-circuit breaking current and rated normal current are selected from those given in Sub-clauses 4.101.1 and 4.4.

Table XB — The values given in this table show for information the present practice in the United States of America and Canada

Minimum rated voltage (kV)	Rated short-circuit breaking current at maximum rated voltage (kA) ^a	Minimum rated voltage (kV) ^a	Rated short-circuit breaking current at maximum rated voltage (kA) ^a	Rated normal current (A)					
4.76	6.1 8.8 18.0 29.0 41.0	2.3 3.5 3.5 3.85 4.0	13 12 24 36 49		1 250 1 250 1 250 1 250 1 250	2 000	3 150		
8.25	3.5 7.0 17.0 33.0	2.3 2.3 4.6 6.6	13 25 30 41	630 630	1 250 1 250 1 250	2 000 2 000			
15.0	5.8 9.3 9.8 18.0 19.0 28.0 37.0	4.0 6.6 4.0 11.5 6.6 11.5 11.5	22 21 37 23 43 36 48	630	1 250 1 250 1 250 1 250 1 250 1 250 1 250	2 000 2 000 2 000	3 150		
15.5	8.9 18.0 35.0 56.0 93.0	5.8 12.0 12.0 12.0 12.0	24 23 45 73 120	630	1 250 1 250	2 000	3 150	4 000	5 000
25.8	5.4 11.0	12.0 12.0	12 24	630	1 250				
38.0	22.0 36.0	23.0 24.0	36 57		1 250	2 000	3 150		
48.3	17.0	40.0	21		1 250				
72.5	19.0 37.0	60.0 66.0	23 41		1 250	2 000			

NOTE The values of the maximum rated voltage are those given in Sub-clause 4.1.1 of IEC Publication 694 for Series II. The values of rated normal current are selected from those given in Sub-clause 4.4. See note in Sub-clause 4.101 regarding interpolation of short-circuit breaking currents for intermediate voltages.

^a Values more in line with IEC standard values are under consideration.

Table XC — Co-ordination table of rated values for circuit-breakers

Rated voltage U (kV)	Rated short-circuit breaking current I_{sc} (kA)	Rated normal current I_n (A)					
100	16 20 31,5		1 250		2 000	3 150	
123	12,5 20 25 40	800	1 250 1 250 1 250	1 600 1 600 1 600	2 000 2 000 2 000		
145	12,5 20 25 31,5 40 50	800	1 250 1 250 1 250 1 250	1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000	3 150 3 150 3 150	
170	12,5 20 31,5 40 50	800	1 250 1 250 1 250	1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000	3 150 3 150 3 150	
245	20 31,5 40 50		1 250 1 250	1 600 1 600 1 600	2 000 2 000 2 000 2 000	3 150 3 150	
300	16 20 31,5 50		1 250 1 250 1 250	1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000	3 150 3 150	
362	20 31,5 40			1 600	2 000 2 000 2 000	3 150	
420	20 31,5 40 50			1 600 1 600 1 600	2 000 2 000 2 000 2 000	3 150 3 150	4 000
525	40				2 000	3 150	
765	40				2 000	3 150	
NOTE The values of rated voltage are those given in Sub-clauses 4.1.2 of IEC Publication 694. The values of rated short-circuit breaking current and rated normal current are selected from those given in Sub-clauses 4.101.1 and 4.4.							

5.5 Dependent power closing

Sub-clause 5.5 of IEC Publication 694 is applicable with the following addition:

A circuit-breaker arranged for dependent power closing with external energy supply shall also be capable of opening immediately following the closing operation with the rated short-circuit making current.

5.6 Stored energy closing

Sub-clause 5.6 of IEC Publication 694 is applicable with the following addition to the first paragraph:

A circuit-breaker arranged for stored energy closing shall also be capable of opening immediately following the closing operation with the rated short-circuit making current.

5.7 Operation of releases

Sub-clause 5.7 of IEC Publication 694 is applicable with the following additions:

5.7.101 *Over-current release*

5.7.101.1 *Operating current*

An over-current release shall be marked with its rated normal current and its current setting range.

Within the current setting range, the over-current release shall always operate at currents of 110 % and above of the current setting, and shall never operate at currents of 90 % and below of this current setting.

5.7.101.2 *Operating time*

For an inverse time delay over-current release, the operating time shall be measured from the instant at which the over-current is established until the instant at which the release actuates the tripping mechanism of the circuit-breaker.

The manufacturer shall provide tables or curves, each with the applicable tolerances, showing the operating time as a function of current, between twice and six times the operating current. These tables or curves shall be provided for the extreme current settings together with the extreme settings of time delay.

5.7.101.3 *Resetting current*

If the current in the main circuit falls below a certain value, before the time delay of the over-current release has expired, the release shall not complete its operation and shall reset to its initial position.

The relevant information shall be given by the manufacturer.

5.7.102 *Multiple releases*

If a circuit-breaker is fitted with multiple releases for the same function, a defect in one release shall not disturb the function in the others.

5.8 Low and high pressure interlocking devices

Sub-clause 5.8 of IEC Publication 694 is replaced by the following:

All circuit-breakers having an energy storage in gas receivers or hydraulic accumulators (see Sub-clause 5.6.1 of IEC Publication 694) and all circuit-breakers except sealed pressure devices, using compressed gas for interruption (see Sub-clause 5.103) shall be fitted with low pressure interlocking device, and can also be fitted with high pressure interlocking device, set to operate at, or within, the appropriate limits of pressure stated by the manufacturer.

5.9 Nameplates

Sub-clause 5.9 of IEC Publication 694 is applicable with the following additions:

The nameplates of a circuit-breaker and its operating devices shall be marked in accordance with Table XI.

Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer.

Releases shall bear the appropriate data.

In addition, it is desirable that the year of manufacture of the circuit-breaker is recognizable.

The nameplate shall be visible in the position of normal service and installation.

5.101 *Requirements for simultaneity of poles*

When no special requirement with respect to simultaneous operation of poles is stated, the maximum difference between the instants of contacts touching during closing and the maximum difference between the instants of contacts separating during opening shall not exceed one half cycle of rated frequency.

NOTE 1 In some circumstances, the permissible deviation differs considerably from one half cycle (see e.g. Sub-clause 6.111.7) and in others (e.g. single-pole operation), this requirement is not applicable.

NOTE 2 For a circuit-breaker having separate poles the requirement is applicable when these operate in the same conditions; after a single-pole reclosing operation, the conditions of operation for the three mechanisms may not be the same.

5.102 *General requirement for operation*

A circuit-breaker including its operating devices shall be capable of completing its rated operating sequence (Sub-clause 4.104) in accordance with the relevant provisions of Sub-clauses 5.5 to 5.8 and Sub-clause 5.103.

This requirement is not applicable to auxiliary manual operating devices; where provided, these shall be used only for maintenance and for emergency operation on a dead circuit.

Table XI — Nameplate information

	Abbreviation	Unit	Circuit-breaker	Operating device	Condition: Marking required only if
(1)	(2)	(3)	(4)	(5)	(6)
Manufacturer			X	X	
Type designation and serial number			X	X	
Rated voltage	U	kV	X		
Rated lightning impulse withstand voltage	U_w	kV	X		
Rated switching impulse withstand voltage	U_s	kV	y		Rated voltage 300 kV and above
Rated frequency	f	Hz	y		Rating is not applicable at both 50 Hz and 60 Hz
Rated normal current	I_n	A	X		
Rated duration of short-circuit	t_{th}	s	y		Different from 1 s
Rated short-circuit breaking current	I_{sc}	kA	X		
First-pole-to-clear factor			y		Different from 1.3 for rated voltages 100 kV to 170 kV
Rated out-of-phase breaking current	I_d	kA	(X)		
Rated line-charging breaking current	I_l	A	y		Rated voltage 72.5 kV and above
Rated cable-charging breaking current	I_c	A	(X)		
Rated single capacitor bank breaking current	I_{sb}	A	(X)		
Rated back-to-back capacitor bank breaking current	I_{bb}	A	(X)		
Rated capacitor bank inrush making current	I_{bi}	kA	(X)		
Rated gas pressure for operation	P_{op}	MPa or bar		(X)	
Rated gas pressure for interruption	P_{cb}	MPa or bar	(X)		
Rated supply voltage of closing and opening devices		V		(X)	
Rated supply frequency of closing and opening devices		Hz		(X)	
Rated supply voltage of auxiliary circuits	U_a	V		(X)	
Rated supply frequency of auxiliary circuits		Hz		(X)	
Mass (including oil for oil circuit-breakers)	m	kg	y	y	More than 300 kg