



# NORME INTERNATIONALE INTERNATIONAL STANDARD

CEI  
IEC  
56

Quatrième édition  
Fourth edition  
1987



Commission Electrotechnique Internationale  
International Electrotechnical Commission  
Международная Электротехническая Комиссия

Disjoncteurs à courant alternatif  
à haute tension

ห้องสมุด  
สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

High-voltage alternating-current  
circuit-breakers

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Bureau Central de la Commission Electrotechnique Internationale 3, rue de Varembé Genève, Suisse

000783 AC  
- 1 IEC 2534

Code prix 165  
Price code

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE ALTERNATING-CURRENT  
CIRCUIT-BREAKERS

## FOREWORD

- 1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
- 2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
- 3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

## PREFACE

This standard has been prepared by Sub-Committee 17A: High-voltage Switchgear and Controlgear, of IEC Technical Committee No. 17: Switchgear and Controlgear.

This forms the fourth edition of IEC Publication 56 and replaces IEC Publications 56-1, 56-2, 56-3, 56-4, 56-4A, 56-5 and 56-6 and their amendments.

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

| Six Months' Rule       | Reports on Voting |
|------------------------|-------------------|
| 17A(CO)145             | 17A(CO)149        |
| 17A(CO)155             | 17A(CO)169        |
| 17A(CO)156             | 17A(CO)170        |
| 17A(CO)157             | 17A(CO)171        |
| 17A(CO)159+A           | 17A(CO)172        |
| 17A(CO)160             | 17A(CO)167        |
| 17A(CO)161             | 17A(CO)165        |
| 17A(CO)173             | 17A(CO)183+A      |
| 17A(CO)174             | 17A(CO)184+A      |
| 17A(CO)175             | 17A(CO)185+A      |
| 17A(CO)176, I, II, III | 17A(CO)191        |
| 17A(CO)177             | 17A(CO)186+A      |
| 17A(CO)178             | 17A(CO)187+A      |
| 17A(CO)179             | 17A(CO)188        |
| 17A(CO)180             | 17A(CO)190        |
| 17A(CO)181             | 17A(CO)192        |
| 17A(CO)195             | 17A(CO)201        |

Further information can be found in the relevant Reports on Voting, indicated in the table above.

The supplementary sub-clauses are numbered from 101 onwards. The appendices and their figures are named, AA, BB, etc.

The following IEC publications are quoted in this standard:

Publication Nos. 50(151) (1978): International Electrotechnical Vocabulary (IEV), Chapter 151: Electrical and Magnetic Devices.

50(441) (1984): Chapter 441: Switchgear, Controlgear and Fuses.

50(604) (1986): Chapter 604: Generation, Transmission and Distribution of Electricity: Operation.

60-1 (1973): High-voltage Test Techniques, Part 1: General Definitions and Test Requirements.

68-2-5 (1975): Basic Environmental Testing Procedures, Part 2: Tests — Test Sa: Simulated Solar Radiation at Ground Level.

- 68-2-17 (1978): Test Q: Sealing.
- 71-2 (1976): Insulation Co-ordination, Part 2: Application Guide.
- 77 (1968): Rules for Electric Traction Equipment.
- 129 (1984): Alternating Current Disconnectors and Earthing Switches.
- 137 (1984): Bushings for Alternating Voltages Above 1 000 V.
- 185 (1966): Current Transformers.
- 296 (1982): Specification for Unused Mineral Insulating Oils for Transformers and Switchgear.
  
- 376 (1971): Specification and Acceptance of New Sulphur Hexafluoride.
- 427 (1973): Report on Synthetic Testing of High-voltage Alternating Current Circuit-breakers.
- 694 (1980): Common Clauses for High-voltage Switchgear and Controlgear Standards.

## HIGH-VOLTAGE ALTERNATING-CURRENT CIRCUIT-BREAKERS

### CHAPTER I: SERVICE CONDITIONS, DEFINITIONS, RATING, CONSTRUCTION AND DESIGN

#### 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.

*Notes 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.

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.

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.

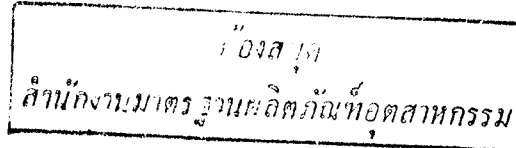
3.101.9 *Ambient air temperature* (441-11-13)

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  $180^\circ$  (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.

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

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).

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)

### 3.102.7 *Oil circuit-breaker* (441-14-28)

### 3.102.8 *Vacuum circuit-breaker* (441-14-29)

### 3.102.9 *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.

## 3.103 *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.

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

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 *Indirect over-current release* (441-16-37)

3.104.24 *Shunt release* (441-16-41)

3.104.25 *Under-voltage release* (441-16-42)

3.104.26 *Reverse current release (d.c. only)* (441-16-43)

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-breakers\**

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)

\* Figures 1 to 7 (pages 90 to 97) 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.

### 3.105.8 *(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.

*Notes 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.

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.

### 3.105.12 *Breaking capacity\* (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\* (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)*

*\* 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.

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3.105.21 *Peak withstand current* (441-17-18)

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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)

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.

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

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.

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.

- Notes* 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.  
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.

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

- Notes 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.
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<br>$U$<br>(r.m.s. value)<br><br>(kV) | Rated lightning<br>impulse withstand<br>voltage<br>(peak value)<br>To earth,<br>between poles<br>and across open<br>circuit-breaker<br><br>(kV) | Rated power frequency<br>withstand voltage<br>(r.m.s. value)<br>To earth, between<br>poles and across open<br>circuit-breaker |                              |
|----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------------|
|                                                    |                                                                                                                                                 | 1 min<br>dry<br>test<br>(kV)                                                                                                  | 10 s<br>wet<br>test*<br>(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**                                                                                                                                       | 80                                                                                                                            | 75                           |
| 48.3                                               | 250                                                                                                                                             | 105                                                                                                                           | 95                           |
| 72.5                                               | 350                                                                                                                                             | 160                                                                                                                           | 140                          |

\* 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.

\*\* 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 98.

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  $\tau$  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  $\tau$  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  $\tau$  and standard values are given in Figure 9, page 99.

*Note.* — In special applications, 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 recovery 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 parameters\*.

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 parameters\*.

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.

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.

\* Methods of drawing TRV envelopes are given in Appendix FF.

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 99):

- $u_1$  = 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 100):

- $u_c$  = reference voltage (TRV peak value), in kilovolts
- $t_3$  = time to reach  $u_c$ , in microseconds

c) Delay line of TRV (see Figures 10 and 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 101):

- $u_i$  = 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               |
|---------------|----------------|---------------------|---------------------|--------------|--------------------|----------------------------|
| $U$<br>(kV)   | $u_c$<br>(kV)  | $t_3$<br>( $\mu$ s) | $t_d$<br>( $\mu$ s) | $u'$<br>(kV) | $t'$<br>( $\mu$ s) | $u_c/t_3$<br>(kV/ $\mu$ 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                       |

$$u_c = 1.4 \cdot 1.5 \sqrt{\frac{2}{3}} U; \quad t_d = 0.15 t_3 \text{ for } U < 52 \text{ kV};$$

$$u' = \frac{1}{3} u_c; \quad t_d = 0.05 t_3 \text{ for } U \geq 52 \text{ kV}.$$

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               |
|---------------|-------------------------|---------------------|----------------|---------------------|---------------------|--------------|--------------------|----------------------------|
| $U$<br>(kV)   | $u_1$<br>(kV)           | $t_1$<br>( $\mu$ s) | $u_c$<br>(kV)  | $t_2$<br>( $\mu$ s) | $t_d$<br>( $\mu$ s) | $u'$<br>(kV) | $t'$<br>( $\mu$ s) | $u_1/t_1$<br>(kV/ $\mu$ 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                        |

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

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<br>$U$<br>(kV) | First reference voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV peak value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Time delay<br>$t_d$<br>( $\mu$ s) | Voltage<br>$u'$<br>(kV) | Time<br>$t'$<br>( $\mu$ s) | Rate of rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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<br>$U$<br>(kV) | First reference voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV peak value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Time delay<br>$t_d$<br>( $\mu$ s) | Voltage<br>$u'$<br>(kV) | Time<br>$t'$<br>( $\mu$ s) | Rate of rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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                                        |

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

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:

- a) circuit-breakers adjacent to generator circuits;

- b) 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;
- c) 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).

#### 6.102.4 Standard values of rated ITRV

TABLE III

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

| Rated voltage<br>$U$<br>(kV) | Multiplying factor to determine $u_i$ as function of the r.m.s. value of the short-circuit breaking current $I^*$<br>$f_i$<br>(kV/kA) |       | Time<br>$t_i$<br>( $\mu$ s) |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------|
|                              | 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                          | **                                                                                                                                    | **    | **                          |

\* 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.

\*\* 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  $\Omega$ . The relation between  $f_i$  and  $t_i$  is then:

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

$\omega$  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 98, 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 102), 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 Tables IVA, IVB and 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<br>$U$<br>(kV) | TRV peak value<br>$u_c$<br>(kV) | Time<br>$t_3$<br>( $\mu$ s) | Time delay<br>$t_d$<br>( $\mu$ s) | Voltage<br>$u'$<br>(kV) | Time<br>$t'$<br>( $\mu$ s) | Rate of rise<br>$u_c/t_3$<br>(kV/ $\mu$ 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<br>$U$<br>(kV) | First reference voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV peak value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Time delay<br>$t_d$<br>( $\mu$ s) | Voltage<br>$u'$<br>(kV) | Time<br>$t'$<br>( $\mu$ s) | Rate of rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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<br>voltage<br>$U$<br>(kV) | Number of<br>conductors<br>per phase | Rated<br>surge<br>impedance<br>$Z$<br>( $\Omega$ ) | Rated<br>peak<br>factor<br>$k$ | RRRV factor               |       | Time<br>delay<br>$t_{dl}^{**}$<br>( $\mu$ s) |
|---------------------------------|--------------------------------------|----------------------------------------------------|--------------------------------|---------------------------|-------|----------------------------------------------|
|                                 |                                      |                                                    |                                | 50 Hz                     | 60 Hz |                                              |
| $\leq 170$                      | 1 to 4                               | 450                                                | 1.6                            | $s^*$<br>(kV/ $\mu$ s kA) |       | 0.2                                          |
| $\geq 245$                      |                                      |                                                    |                                | 0.200                     | 0.240 | 0.5                                          |

\* For the RRRV factor  $s$ , see Appendix AA.

\*\* 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 102.

#### 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.
- 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<br>voltage<br>$U$<br>(kV) | TRV<br>peak<br>value<br>$u_c$<br>(kV) | Time<br>$t_3$<br>( $\mu$ s) | Rate of<br>rise<br>$u_c/t_3$<br>(kV/ $\mu$ 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<br>voltage<br>$U$<br>(kV) | First<br>reference<br>voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV<br>peak<br>value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Rate of<br>rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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<br>voltage<br>$U$<br>(kV) | First<br>reference<br>voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV<br>peak<br>value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Rate of<br>rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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<br>voltage<br>$U$<br>(kV) | First<br>reference<br>voltage<br>$u_1$<br>(kV) | Time<br>$t_1$<br>( $\mu$ s) | TRV<br>peak<br>value<br>$u_c$<br>(kV) | Time<br>$t_2$<br>( $\mu$ s) | Rate of<br>rise<br>$u_1/t_1$<br>(kV/ $\mu$ 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<br>$U$<br>(kV) | Rated line-charging<br>breaking current<br>$I_1$<br>(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<br>$U$<br>(kV) | Rated cable-charging<br>breaking current<br>$I_c$<br>(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.

*Notes 1.* — In service, the frequency of the inrush current is normally in the range 2-5 kHz.

*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<br>(r.m.s. value)<br><br>(kV) | Rated lightning impulse withstand voltage*<br>(peak value)<br><br>(kV) | Maximum permissible switching overvoltage to earth |                                                     |                      |                                                     |
|---------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------|----------------------|-----------------------------------------------------|
|                                             |                                                                        | A                                                  |                                                     | B                    |                                                     |
|                                             |                                                                        | (Peak value)<br>(kV)                               | Col. (3)<br>Col. (1) $\sqrt{\frac{2}{3}}$<br>(p.u.) | (Peak value)<br>(kV) | Col. (5)<br>Col. (1) $\sqrt{\frac{2}{3}}$<br>(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                                                 |

TABLE IX (continued)

| Rated voltage<br>(r.m.s. value)<br><br>(kV) | Rated lightning impulse withstand voltage*<br>(peak value)<br><br>(kV) | Maximum permissible switching overvoltage to earth |                                                     |                      |                                                     |
|---------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------|----------------------|-----------------------------------------------------|
|                                             |                                                                        | A                                                  |                                                     | B                    |                                                     |
|                                             |                                                                        | (Peak value)<br>(kV)                               | Col. (3)<br>Col. (1) $\sqrt{\frac{2}{3}}$<br>(p.u.) | (Peak value)<br>(kV) | Col. (5)<br>Col. (1) $\sqrt{\frac{2}{3}}$<br>(p.u.) |
| (1)                                         | (2)                                                                    | (3)                                                | (4)                                                 | (5)                  | (6)                                                 |
| 12                                          | 60<br>75                                                               | 29.5<br>39.2                                       | 3<br>4                                              | 24.5<br>24.5         | 2.5<br>2.5                                          |
| 17.5                                        | 75<br>95                                                               | 43<br>57                                           | 3<br>4                                              | 35.7<br>35.7         | 2.5<br>2.5                                          |
| 24                                          | 95<br>125                                                              | 59<br>74                                           | 3<br>3.8                                            | 49<br>49             | 2.5<br>2.5                                          |
| 36                                          | 145<br>170                                                             | 88<br>112                                          | 3<br>3.8                                            | 73<br>73             | 2.5<br>2.5                                          |
| 52                                          | 250                                                                    | 149                                                | 3.5                                                 | 106                  | 2.5                                                 |
| 72.5                                        | 325                                                                    | 207                                                | 3.5                                                 | 148                  | 2.5                                                 |
| 100                                         | 380<br>450                                                             | 246<br>286                                         | 3<br>3.5                                            | 204<br>204           | 2.5<br>2.5                                          |
| 123                                         | 450<br>550                                                             | 302<br>352                                         | 3<br>3.5                                            | 251<br>251           | 2.5<br>2.5                                          |
| 145                                         | 550<br>650                                                             | 356<br>415                                         | 3<br>3.5                                            | 297<br>297           | 2.5<br>2.5                                          |
| 170                                         | 650<br>750                                                             | 417<br>487                                         | 3<br>3.5                                            | 348<br>348           | 2.5<br>2.5                                          |
| 245                                         | 850<br>950<br>1 050                                                    | 540<br>600<br>600                                  | 2.7<br>3<br>3                                       | 400<br>400<br>400    | 2<br>2<br>2                                         |
| 300                                         | 950<br>1 050                                                           | 637<br>735                                         | 2.6<br>3                                            | 490<br>490           | 2<br>2                                              |
| 362                                         | 1 050<br>1 175                                                         | 710<br>800                                         | 2.4<br>2.7                                          | 592<br>592           | 2<br>2                                              |
| 420                                         | 1 300<br>1 425                                                         | 790<br>895                                         | 2.3<br>2.6                                          | 688<br>688           | 2<br>2                                              |
| 525                                         | 1 425<br>1 550                                                         | 900<br>985                                         | 2.1<br>2.3                                          | 858<br>858           | 2<br>2                                              |
| 765                                         | 1 800<br>2 100                                                         | 1 125<br>1 250                                     | 1.8<br>2                                            | 1 125<br>1 250       | 1.8<br>2                                            |

\* 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.

*Notes 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.

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

#### 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  $20 \pm 5^\circ\text{C}$ . 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.

*Notes 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.

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.
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 Tables XA to 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.

TABLE XA

Co-ordination table of rated values for circuit-breakers

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

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*

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

\* Values more in line with IEC standard values are under consideration.

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.

TABLE XC

Co-ordination table of rated values for circuit-breakers

| Rated voltage<br>$U$<br>(kV) | Rated short-circuit<br>breaking current<br>$I_{sc}$<br>(kV) | Rated normal current<br>$I_n$<br>(A) |       |       |       |       |       |
|------------------------------|-------------------------------------------------------------|--------------------------------------|-------|-------|-------|-------|-------|
|                              |                                                             |                                      |       |       |       |       |       |
| 123                          | 12.5                                                        | 800                                  | 1 250 |       |       |       |       |
|                              | 20                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 25                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 |       |       |
| 145                          | 12.5                                                        | 800                                  | 1 250 |       |       |       |       |
|                              | 20                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 25                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 31.5                                                        |                                      | 1 250 | 1 600 | 2 000 | 3 150 |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
|                              | 50                                                          |                                      |       |       | 2 000 | 3 150 |       |
| 170                          | 12.5                                                        | 800                                  | 1 250 |       |       |       |       |
|                              | 20                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 31.5                                                        |                                      | 1 250 | 1 600 | 2 000 | 3 150 |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
| 245                          | 20                                                          |                                      |       |       |       |       |       |
|                              | 31.5                                                        |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
|                              | 50                                                          |                                      |       |       | 2 000 | 3 150 |       |
| 300                          | 16                                                          |                                      | 1 250 | 1 600 |       |       |       |
|                              | 20                                                          |                                      | 1 250 | 1 600 | 2 000 |       |       |
|                              | 31.5                                                        |                                      | 1 250 | 1 600 | 2 000 | 3 150 |       |
|                              | 50                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
| 362                          | 20                                                          |                                      |       |       | 2 000 |       |       |
|                              | 31.5                                                        |                                      |       |       | 2 000 |       |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
| 420                          | 20                                                          |                                      |       | 1 600 | 2 000 |       |       |
|                              | 31.5                                                        |                                      |       | 1 600 | 2 000 |       |       |
|                              | 40                                                          |                                      |       | 1 600 | 2 000 | 3 150 |       |
|                              | 50                                                          |                                      |       |       | 2 000 | 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, omitting 100 kV. 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 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.

### 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.

Notes 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.

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)             |                  |                                                        |

TABLE XI (continued)

|                                                       | Abbreviation | Unit       | Circuit-breaker    | Operating device | Condition: Marking required only if                |
|-------------------------------------------------------|--------------|------------|--------------------|------------------|----------------------------------------------------|
| (1)                                                   | (2)          | (3)        | (4)                | (5)              | (6)                                                |
| 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<br>X<br>(X)<br>y | y                | More than 300 kg                                   |
| Rated operating sequence                              |              |            |                    |                  |                                                    |
| Year of manufacture                                   |              |            |                    |                  |                                                    |
| Temperature class                                     |              |            |                    |                  | Different from<br>– 5 °C indoor<br>– 25 °C outdoor |

X = the marking of these values is mandatory; blanks indicate the value zero.

(X) = the marking of these values is optional.

y = the marking of these values to the conditions in column (6).

Note. — The abbreviations in column (2) may be used instead of the terms in column (1). When terms of column (1) are used the word "rated" need not appear.

### 5.103 Pressure limits of compressed gas for interruption in gas blast circuit-breakers

The manufacturer shall state the maximum and minimum pressures of the compressed gas for interruption at which the circuit-breaker is capable of performing according to its ratings and at which the appropriate low and high-pressure interlocking devices shall be set (see Sub-clause 5.8).

For double-pressure gas-blast circuit-breakers, the manufacturer may specify pressure limits at which the circuit-breaker is capable of each of the following performances:

- breaking its rated short-circuit breaking current i.e. an "O" operation;
- making its rated short-circuit making current immediately followed by breaking its rated short-circuit breaking current i.e. a "CO" operating cycle;
- for circuit-breakers intended for rapid auto-reclosing; breaking its rated short-circuit breaking current followed after a time interval  $t$  of the rated operating sequence (Sub-clause 4.104) by making its rated short-circuit making current immediately followed by again breaking its rated short-circuit breaking current i.e. an "O- $t$ -CO" operating sequence.

The circuit-breakers shall be provided with energy storage of sufficient capacity for satisfactory performance of the appropriate operations at the corresponding minimum pressures stated.

Furthermore, for circuit-breakers having individual pumps or compressors the output of the pump or compressor and the capacity of the receivers shall be sufficient to provide for the performance of the rated operating sequence (Sub-clause 4.104) at all currents up to the rated short-circuit making and breaking currents of the circuit-breaker. The pressure at the commencement of the operating sequence shall be equal to the appropriate minimum pressure stated by the manufacturer in accordance with the above requirements, and with the pump or compressor operating normally. When appropriate the manufacturer may specify pressure limits for the operation of the pump or compressor.

#### 4.104 *Vent outlets*

Vent outlets of circuit-breakers shall be so situated that a discharge of oil or gas or both will not cause electrical breakdown and is directed away from any location where persons may be present.

The construction shall be such that gas cannot collect at any point where ignition can be caused, during or after operation, by sparks arising from normal operation of the circuit-breaker or its auxiliary equipment.

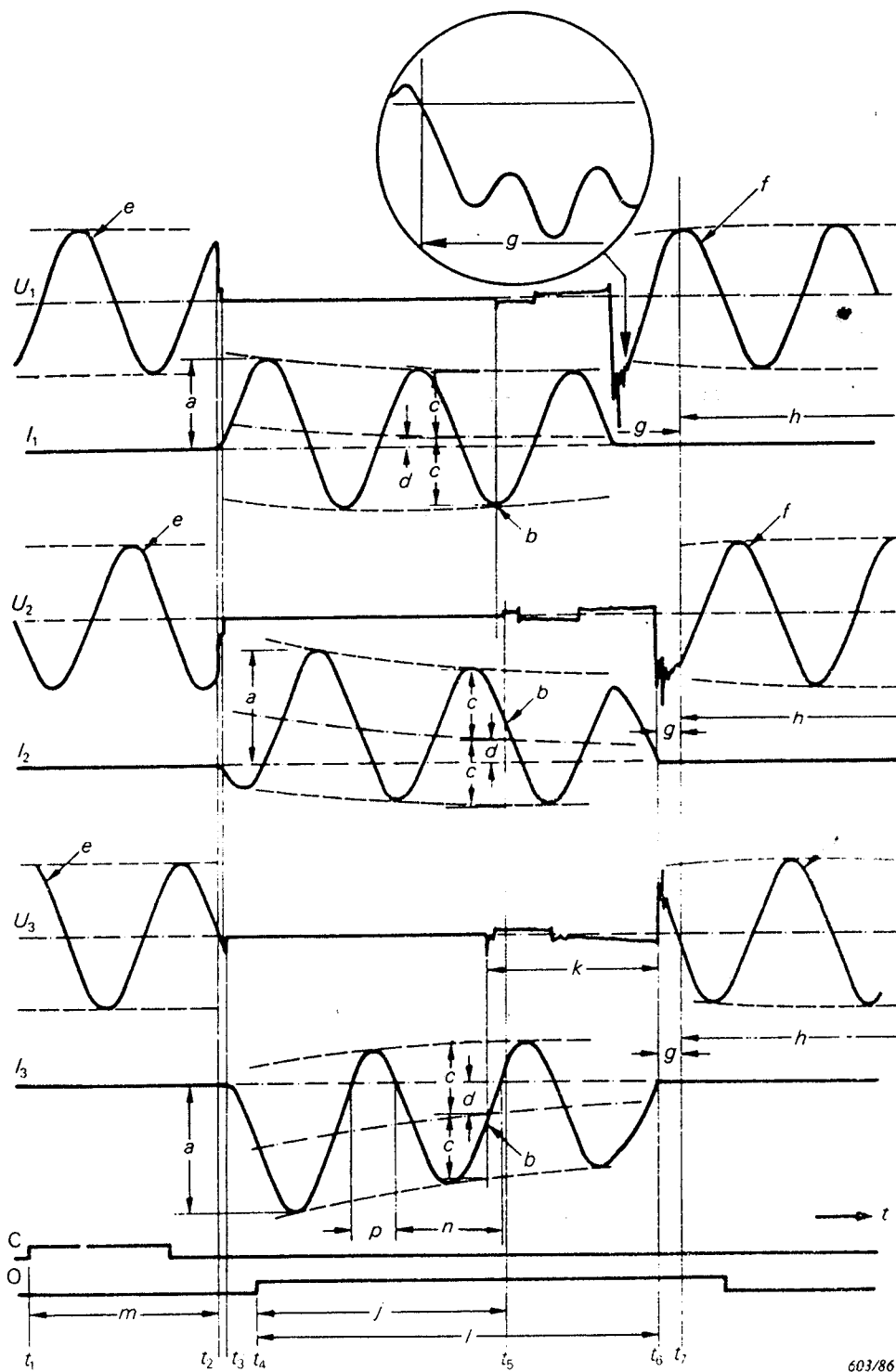


FIG. 1. — Oscillogramme type d'un cycle d'établissement-coupure en court-circuit triphasé.  
Typical oscillogram of a three-phase short-circuit make-break cycle.

Legende de la figure 1 ci-contre:  
Legend to Figure 1, opposite:

|            |                                                                                                                                                                                                        |     |                                                                                            |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------------------------------------------------------------------|
| $t_1$      | = tension entre les bornes du premier pôle qui coupe<br>voltage across the terminals of the first pole to clear                                                                                        | $a$ | = (valeur de crête du) courant établi<br>(peak) making current                             |
| $i_1$      | = courant dans le premier pôle qui coupe<br>current in the first pole to clear                                                                                                                         | $b$ | = courant coupé<br>breaking current                                                        |
| $t_2, t_3$ | = tension entre les bornes des deux autres pôles<br>voltage across the terminals of the two other poles                                                                                                | $c$ | = valeur de crête de la composante périodique<br>peak value of the alternating component   |
| $i_2, i_3$ | = courant dans les deux autres pôles<br>current in the two other poles                                                                                                                                 | $d$ | = composante apériodique<br>direct current component                                       |
| $c$        | = commande de fermeture, par exemple tension aux bornes du circuit de fermeture<br>closing command, e.g. voltage across the terminals of the closing circuit                                           | $e$ | = tension appliquée<br>applied voltage                                                     |
| $o$        | = commande d'ouverture, par exemple tension aux bornes du déclencheur d'ouverture<br>opening command, e.g. voltage across the terminals of the opening release                                         | $f$ | = tension de rétablissement<br>recovery voltage                                            |
| $t_4$      | = instant du début de la manœuvre de fermeture<br>the instant of initiation of the closing operation                                                                                                   | $g$ | = tension transitoire de rétablissement<br>transient recovery voltage (restriking voltage) |
| $t_5$      | = instant où le courant commence à circuler dans le circuit principal<br>the instant when the current begins to flow in the main circuit                                                               | $h$ | = tension de rétablissement à fréquence industrielle<br>power frequency recovery voltage   |
| $t_6$      | = instant où le courant est établi sur tous les pôles<br>the instant when the current is established in all poles                                                                                      | $j$ | = durée d'ouverture<br>opening time                                                        |
| $t_7$      | = instant de mise sous tension du déclencheur d'ouverture<br>the instant of energizing the opening release                                                                                             | $k$ | = durée d'arc<br>arcing time                                                               |
| $t_8$      | = instant de la séparation des contacts d'arc (ou de l'amorçage de l'arc) sur tous les pôles<br>the instant when the arcing contacts have separated (or instant of initiation of the arc) in all poles | $l$ | = durée de coupure<br>break time                                                           |
| $t_9$      | = instant de l'extinction finale de l'arc sur tous les pôles<br>the instant of final arc extinction in all poles                                                                                       | $m$ | = durée d'établissement<br>make time                                                       |
| $t_{10}$   | = instant de la disparition des phénomènes transitoires de tension dans le dernier pôle qui coupe<br>the instant when the transient voltage phenomena have subsided in the last pole to clear          | $n$ | = grande alternance<br>major loop                                                          |
|            |                                                                                                                                                                                                        | $p$ | = petite alternance<br>minor loop                                                          |

Notes concernant les figures 2 à 7 suivantes:

Notes to the following Figures 2 to 7:

Notes 1. — En pratique, il se produira une dispersion des durées entre les courses des contacts des trois pôles. Pour plus de clarté sur les figures, la course des contacts est indiquée avec une seule ligne pour les trois pôles.

In practice, there will be a time spread between the travel of the contacts of the three poles. For clarity the travel of the contacts in the figures is indicated with a single line for all three poles.

2. — En pratique, il se produira une dispersion entre le début ainsi qu'entre la fin de la circulation du courant dans les trois pôles. Pour plus de clarté sur les figures, le début ainsi que la fin de la circulation du courant sont indiqués avec une seule ligne pour les trois pôles.

In practice, there will be a time spread between both the start and end of current flow in the three poles. For clarity, both the start and end of current flow in the figures is indicated with a single line for all three poles.

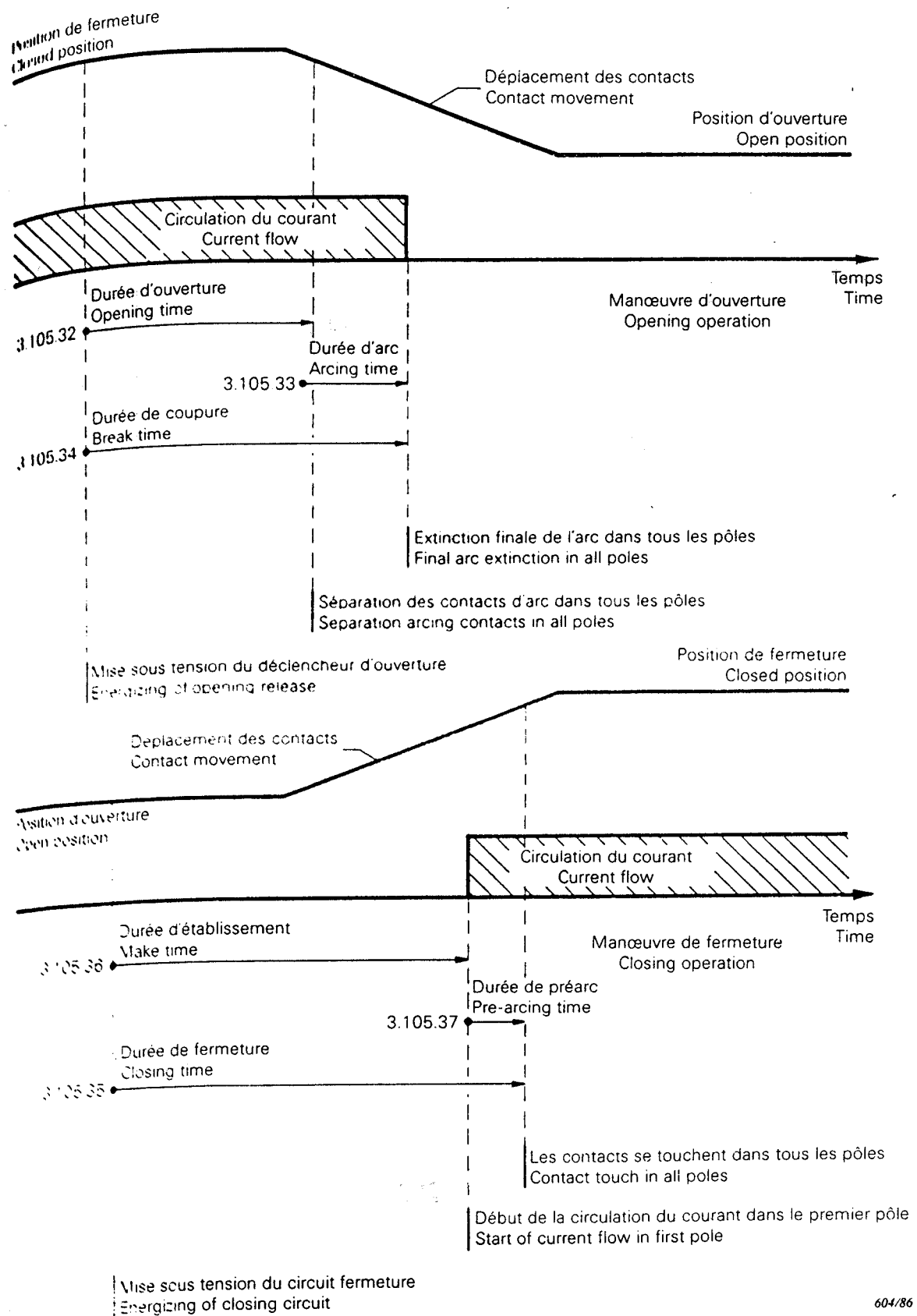
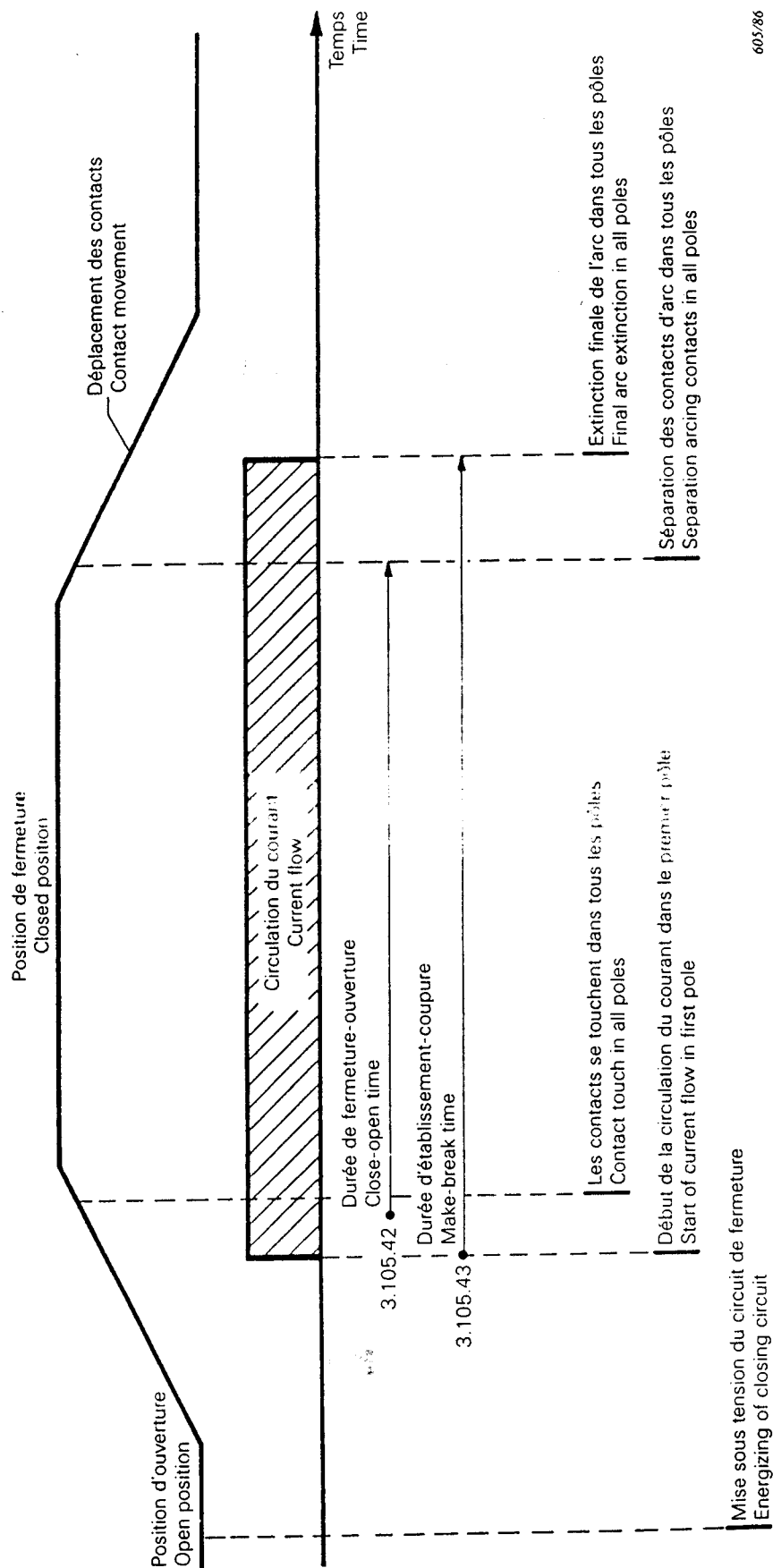


FIG. 2 — Disjoncteur sans résistance intercalaire. Manœuvres d'ouverture et de fermeture.  
Circuit-breaker without switching resistors. Opening and closing operations.



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FIG. 3. — Disjoncteur sans résistance intercalaire. Cycle de fermeture-ouverture.  
Circuit-breaker without switching resistors. Close-open cycle.