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BSI Standards Publication

High-voltage switchgear and controlgear

Part 37-013: Alternating current generator circuit-breakers

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National foreword

This British Standard is the UK implementation of IEC/IEEE 62271-37-013:2021. It supersedes BS IEC/IEEE 62271-37-013:2015, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/17, High voltage switchgear, controlgear and assemblies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 37-013: Alternating current generator circuit-breakers

FOREWORD

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IEC/IEEE 62271-37-013 was prepared by subcommittee 17A: High-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear, in cooperation with the Switchgear Committee of the IEEE Power and Energy Society[1], under the IEC/IEEE Dual Logo Agreement between IEC and IEEE. It is an International Standard.

This document is published as an IEC/IEEE Dual Logo standard.

The IEEE Std C37.013™-1997 (R2008) was revised and converted into the first edition of the IEC/IEEE Dual Logo International Standard IEC/IEEE 62271-37-013 published in 2015.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

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

a) content has been added to address the requirements of the other components of the generator circuit breaker system;
b) requirements for the application of generator circuit-breakers in power plants with multiple generators connected to one step-up transformer have been added;
c) requirements for testing and application of Tee-OFF generator circuit-breakers have been added;
d) requirements for application of generator circuit-breakers in power plants with doubly-fed induction machines, pumped-storage power plants, and wind farms have been added;
e) the clause numbering has been aligned with the numbering in IEC 62271-1:2017;
f) the topic of reference mechanical characteristics has been revised to improve clarity;
g) the modifying effects of capacitors on the prospective TRVs for out-of-phase and load current switching has been addressed in Annex M and in Annex N with use of the tool named "GenCB TRV calculator". This tool provides the values of K_{E2}, $RRRV_0$, $K_{RRRV\text{-}U}$, $K_{RRRV\text{-}I}$, t_{d0}, $K_{td\text{-}U}$, $K_{td\text{-}I}$, as well as the values of the parameters of the prospective TRV modified by the capacitors of the generator circuit-breaker.

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

FDIS	Report on voting
17A/1318/FDIS	17A/1327/RVD

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

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

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

[1] A list of IEEE participants can be found at the following address: http://standards.ieee.org/downloads/62271/62271-37-013-2015/62271-37-013-2015_wg-participants.pdf.

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This document is to be read in conjunction with IEC 62271-1, to which it refers and which is applicable unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1. Amendments to these clauses and subclauses are given under the same numbering, while additional subclauses are numbered from 101.

This document contains attached files in the form of Excel spreadsheets ("GenCB TRV calculator"). These files are intended to be used as a complement and do not form an integral part of the document.

A list of all parts in the IEC 62271 series, published under the general title *High-voltage switchgear and controlgear*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 37-013: Alternating current generator circuit-breakers

1 Scope

This part of IEC 62271 is applicable to three-phase AC high-voltage generator circuit-breakers, hereafter called generator circuit-breakers, designed for indoor or outdoor installation and for operation at frequencies of 50 Hz and 60 Hz on systems having voltages above 1 kV and up to 38 kV.

It is applicable to generator circuit-breakers that are installed between the generator and the transformer terminals. Requirements relative to generator circuit-breakers intended for use with generators and transformers rated 10 MVA or more are covered specifically. Generator circuits rated less than 10 MVA and pumped-storage installations are considered special applications, and their requirements are not completely covered by this document.

This document is also applicable to the operating mechanisms of generator circuit-breakers and to their auxiliary equipment.

2 Normative references

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

If not otherwise specified throughout this document, the relevant IEC or IEEE standards for the particular components or functions of a generator circuit-breaker system apply.

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses* (available at http://www.electropedia.org)

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:2019, *Insulation co-ordination – Part 1: Definition, principles and rules*

IEC 60071-2:2018, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60296, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

IEC 60480, *Specifications for the re-use of sulphur hexafluoride (SF6) and its mixtures in electrical equipment*

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

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

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IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62271-1, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC IEEE 62271-37-082, *High-voltage switchgear and controlgear – Part 37-082: Standard practice for the measurement of sound pressure levels on alternating current circuit-breakers*

IEC 62271-100:2021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-101:2021, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*

IEC 62271-102:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC TR 62271-306, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

IEEE Std C37.011™, *IEEE Guide for the Application of Transient Recovery Voltage for AC High-Voltage Circuit Breakers with Rated Maximum Voltage above 1000 V*[2]

IEEE Std C37.59™, *IEEE Standard Requirements for Conversion of Power Switchgear Equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-441 and IEC 62271-1 and the following apply.

For definitions not specifically called out in this document, the following references could be useful:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp
- IEEE Standards Online Dictionary: available at http://dictionary.ieee.org

NOTE Additional definitions are classified to be aligned with the classification used in IEC 60050-441.

3.1 General terms and definitions

3.1.101
switchgear and controlgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:1984, 441-11-01]

[2] The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

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3.1.102
short-circuit current
over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.103
moment of inertia
sum (integral) of the products of the mass elements of a body and the squares of their distances (radii) from a given axis

3.1.104
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 generator circuit-breaker in which, at the instant of operation of the generator circuit-breaker, the phase angle between rotating vectors, representing the generated voltages on either side, exceeds the normal value

3.1.105
out-of-phase
<as prefix to a characteristic quantity> qualifying term indicating that the characteristic quantity is applicable to operation of the generator circuit-breaker in out-of-phase conditions

3.1.106
unit test
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 generator 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 generator circuit-breaker

3.1.107
loop
<of an AC current wave> part of the wave of the AC current between two successive current zero crossings

SEE: Figure 1 n and p.

Note 1 to entry: When a DC component (see Figure 1 d) is present, a distinction is made between a major loop (see Figure 1 n) and a minor loop (see Figure 1 p) depending on the time interval between two successive current zero crossings being longer or shorter, respectively, than the half-period of the alternating component of the current.

3.1.108
power factor
<of a circuit> ratio of the resistance to the impedance at power frequency of an equivalent circuit supposed to be formed by a reactance and a resistance in series

3.1.109
external insulation
distances in air and along the surfaces in contact with atmospheric air of solid insulation of the equipment, which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin, etc.

[SOURCE: IEC 60050-614:2016, 614-03-02, modified – replacement of "atmospheric air" by "air".]

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3.1.110
disruptive discharge
phenomenon associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero

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

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

Note 3 to entry: 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.

3.1.111
non-sustained disruptive discharge
NSDD
disruptive discharge associated with current interruption that does not result in the resumption of power-frequency current or, in the case of capacitive current interruption, does not result in current in the main load circuit

Note 1 to entry: Oscillations following NSDDs are associated with the parasitic capacitance and inductance local to or of the circuit-breaker itself. NSDDs may also involve the stray capacitance to earth of nearby equipment.

3.1.112
effectively earthed neutral system
system earthed through a sufficiently low impedance such that for all system conditions the ratio of the zero-sequence reactance to the positive-sequence reactance (X_0/X_1) is positive and less than 3, and the ratio of the zero-sequence resistance to the positive-sequence reactance (R_0/X_1) is positive and less than 1

Note 1 to entry: Normally such systems are solidly earthed (neutral) systems or low impedance earthed (neutral) systems.

Note 2 to entry: For the correct assessment of the earthing conditions not only the physical earthing conditions around the relevant location but the total system is to be considered.

3.1.113
non-effectively earthed neutral system
system other than effectively earthed neutral system, not meeting the conditions given in 3.1.112

Note 1 to entry: Normally such systems are isolated neutral systems, high impedance earthed (neutral) systems or resonant earthed (neutral) systems.

Note 2 to entry: For the correct assessment of the earthing conditions not only the physical earthing conditions around the relevant location but the total system is to be considered.

3.1.114
re-ignition
<of an AC mechanical switching device> resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency

[SOURCE: IEC 60050-441:1984, 441-17-45]

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3.1.115
restrike
<of an AC mechanical switching device> resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of a quarter cycle of power frequency or longer

[SOURCE: IEC 60050-441:1984, 441-17-46]

3.1.116
isolated-phase bus
IPB
bus in which each phase conductor is enclosed by an individual earthed metal housing separated from adjacent conductor housings by an air space

Note 1 to entry: The bus may be self-cooled or may be forced-cooled by means of circulating gas or liquid.

3.1.117
internal insulation
internal distances of the solid, liquid or gaseous insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.2 Assemblies of switchgear and controlgear

3.2.101
generator circuit-breaker system
assembly, utilising a generator circuit-breaker as one of the components

Note 1 to entry: Examples are assemblies which are not covered by IEC 62271-200 [17], IEEE C37.20.2 [18], or IEEE C37.20.3 [19].

Note 2 to entry: Generator circuit-breaker systems are covered in this document to ensure harmonization of requirements of the various components which form part of the system.

3.3 Parts of assemblies

3.3.101
component
<of a generator circuit-breaker system> essential part of a generator circuit-breaker system which serves one or several specific functions

Note 1 to entry: If not otherwise specified throughout this document, the relevant IEC or IEEE standards for the particular components or functions apply.

Note 2 to entry: The following are examples of components or functions of a generator circuit-breaker system:

– generator circuit-breaker;
– main-disconnector;
– phase-reversal-disconnector;
– starting switch;
– ET-switch (3.4.121);
– Tee-OFF-switch (3.4.122);
– Tee-OFF generator circuit-breaker (3.4.132);
– BTB-switch (3.4.123);
– earthing switch;
– braking switch;
– short-circuiting connection;
– capacitor;
– instrument transformer;

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– surge arrester;
– sensor/monitoring device;
– enclosure;
– cable.

3.4 Switching devices

3.4.101
switching device
device designed to make or break the current in one or more electric circuits

[SOURCE: IEC 60050-441:1984, 441-14-01]

3.4.102
mechanical switching device
switching device designed to close and open one or more electric circuits by means of separable contacts

Note 1 to entry: Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g. air, SF_6, oil.

[SOURCE: IEC 60050-441:1984, 441-14-02]

3.4.103
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit

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

3.4.104
generator circuit-breaker
circuit-breaker installed between generator and associated step-up transformer

3.4.105
oil circuit-breaker
circuit-breaker in which the contacts open and close in oil

Note 1 to entry: Typical examples of oil circuit-breakers are live tank minimum oil circuit-breakers and dead tank bulk oil circuit-breakers.

[SOURCE: IEC 60050-441:1984, 441-14-28]

3.4.106
vacuum generator circuit-breaker
generator circuit-breaker in which the contacts open and close within a highly evacuated envelope

[SOURCE: IEC 60050-441:1984, 441-14-29 modified – Addition of "generator" before circuit-breaker.]

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3.4.107
gas-blast circuit-breaker
circuit-breaker in which the arc develops in a blast of gas

Note 1 to entry: Where the gas is moved by a difference in pressure established by mechanical means during the opening operation of the circuit-breaker, it is termed a single pressure gas-blast circuit-breaker. Where the gas is moved by a difference in pressure established before the opening operation of the circuit-breaker, it is termed a double pressure gas-blast circuit-breaker.

[SOURCE: IEC 60050-441:1984, 441-14-30]

3.4.108
air-blast circuit-breaker
gas-blast circuit-breaker in which the gas used is air

[SOURCE: IEC 60050-441:1984, 441-14-32]

3.4.109
generator circuit-breaker class M1
generator circuit-breaker with normal mechanical endurance

3.4.110
generator circuit-breaker class M2 and class M3
frequently operated generator circuit-breaker for special service requirements and designed to require only limited maintenance as demonstrated by specific type tests

3.4.111
generator circuit-breaker class G1
generator circuit-breaker having a rated generator-source short-circuit breaking current characterised at contact separation by a degree of asymmetry of 110 % with the assigned AC component of the rated generator-source short-circuit breaking current and a degree of asymmetry of 130 % with a current having an AC component equal to 74 % of the assigned AC component of the rated generator-source short-circuit breaking current

3.4.112
generator circuit-breaker class G2
generator circuit-breaker having a rated generator-source short-circuit breaking current characterised at contact separation by a degree of asymmetry of 130 % with the assigned AC component of the rated generator-source short-circuit breaking current

3.4.113
disconnector
mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements.

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit.

[SOURCE: IEC 60050-441:1984, 441-14-05]

3.4.114
main-disconnector
disconnector, being a component or a function of a generator circuit-breaker system and part of the main current path

3.4.115
main-disconnector class M1
main-disconnector with normal mechanical endurance

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3.4.116
main-disconnector class M2 and class M3
frequently operated main-disconnector for special service requirements and designed so as to require only limited maintenance as demonstrated by specific type tests

3.4.117
starting switch
mechanical switching device, with or without fuse, being a component or a function of a generator circuit-breaker system, to connect the main circuit in order to start up the rotating machine

3.4.118
starting switch class M1
starting switch with normal mechanical endurance

3.4.119
starting switch class M2 and class M3
frequently operated starting switch for special service requirements and designed so as to require only limited maintenance as demonstrated by specific type tests

3.4.120
ET-switch
mechanical switching device, being a component or a function of a generator circuit-breaker system, to connect the main circuit to the excitation transformer

3.4.121
Tee-OFF-switch
mechanical switching device, being a component or a function of a generator circuit-breaker system, to connect the main circuit to the unit auxiliary transformer

3.4.122
BTB-switch
mechanical switching device, with or without fuse, being a component or a function of a generator circuit-breaker system, to connect the main circuit of a rotating machine in order to be used for starting up another rotating machine (back-to-back start-up)

3.4.123
BTB-switch class M1
BTB-switch with normal mechanical endurance

3.4.124
BTB-switch class M2 and class M3
frequently operated BTB-switch for special service requirements and designed so as to require only limited maintenance as demonstrated by specific type tests

3.4.125
earthing switch
mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short circuit, but not required to carry current under normal conditions of the circuit

3.4.126
short-circuiting connection
busbar which is connected to the three main conductors of a generator circuit-breaker system

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3.4.127
manually mounted short-circuiting connection
short-circuiting connection where the connection to the main conductors of the generator circuit-breaker system is made manually (for example by the use of bolts) and which is removed before the generator circuit-breaker system is put back in its normal operational mode

3.4.128
motor operated short-circuiting connection
short-circuiting connection that is connected to the main conductors of the generator circuit-breaker system by closing a motor operated switch

3.4.129
phase-reversal-disconnector
main-disconnector with at least two additional poles used to interchange two phases of the system in the aim of changing the direction of rotation of an electrical rotating machine

3.4.130
braking switch
mechanical switching device, used to establish a three-phase short-circuit in the aim of electrically slowing down a rotating machine already disconnected from the power grid

3.4.131
Tee-OFF generator circuit-breaker
generator circuit-breaker, being a component or a function of a generator circuit-breaker system, to connect the main circuit to the unit auxiliary transformer

3.5 Parts of switchgear and controlgear

3.5.101
pole
portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:1984, 441-15-01]

3.5.102
main circuit
all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:1984, 441-15-02]

3.5.103
control circuit
<of a switching device> all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:1984, 441-15-03]

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3.5.104
auxiliary circuit
<of a switching device> all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:1984, 441-15-04]

3.5.105
contact
<of a mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:1984, 441-15-05]

3.5.106
main contact
contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:1984, 441-15-07]

3.5.107
arcing contact
contact on which the arc is intended to be established

Note 1 to entry: An arcing contact may serve as a main contact; it may be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from injury.

[SOURCE: IEC 60050-441:1984, 441-15-08]

3.5.108
control contact
contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:1984, 441-15-09]

3.5.109
auxiliary contact
contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:1984, 441-15-10]

3.5.110
auxiliary switch
<of a mechanical switching device> switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:1984, 441-15-11]

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3.5.111
"a" contact
make contact
control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:1984, 441-15-12]

3.5.112
"b" contact
break contact
control or auxiliary contact which is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:1984, 441-15-13]

3.5.113
release
<of a mechanical switching device> device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

[SOURCE: IEC 60050-441:1984, 441-15-17]

3.5.114
connection
<bolted or equivalent> two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.5.115
terminal
component provided for the connection of a device to external conductors

3.5.116
making or breaking unit
part of a generator circuit-breaker which in itself acts as a circuit-breaker and which, operated simultaneously with one or more identical parts in series, forms the complete generator circuit-breaker

Note 1 to entry: Making units and breaking units may be separate or combined. Each unit may have several contacts.

Note 2 to entry: The means controlling the voltage distribution between units may differ from unit to unit.

3.5.117
module
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 generator circuit-breaker

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3.5.118
enclosure
component of a generator circuit-breaker system, not intended for use in equipment defined by any other standard, providing a specified degree of protection of equipment against external influences and a specified degree of protection against approach to or contact with live parts and against contact with moving parts

Note 1 to entry: For generator circuit-breakers applied in switchgear and controlgear assemblies, the enclosure requirements are defined by the applicable standard.

Note 2 to entry: A three-phase enclosed generator circuit-breaker system has all three phases in a common enclosure.

Note 3 to entry: A single-phase enclosed generator circuit-breaker system has each phase in a single independent enclosure.

Note 4 to entry: For degrees of protection specified by protection provided by enclosures (IP coding) see IEC 60529 and for degrees of protection specified by external mechanical impact (IK coding) see IEC 62262.

[SOURCE: IEC 60050-441:1984, 441-13-01, modified – "part of an assembly" has been replaced by "component of generator circuit-breaker system", "not intended...other standard" and notes to entry have been added.]

3.5.119
operating mechanism
part of the generator circuit-breaker that actuates the main contacts

3.5.120
power kinematic chain
mechanical connecting system from and including the operating mechanism up to and including the moving contacts

3.5.121
alternative operating mechanism
mechanism obtained when a change in the power kinematic chain of the original operating mechanism or the use of an entirely different operating mechanism leads to the same mechanical characteristics

Note 1 to entry: Mechanical characteristics are defined in 7.101.1.1.

Note 2 to entry: An alternative operating mechanism can utilise an operating principle different from the original one (for example the alternative mechanism can be spring-operated and the original hydraulic).

Note 3 to entry: A change in the secondary equipment does not lead to an alternative operating mechanism. However, changes in the opening time can entail differences for asymmetrical breaking conditions.

3.6 Operational characteristics of switchgear and controlgear

3.6.5 Terms and definitions relative to pressure (or density)

3.6.5.1
filling pressure p_{re} for insulation and/or making and breaking
filling density ρ_{re} for insulation and/or making and breaking
pressure (in Pa), for insulation and/or for making and breaking, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

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3.6.5.2
filling pressure p_{rm} for operation
filling density ρ_{rm} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the energy storage device is filled before being put into service or automatically replenished

3.6.5.3
alarm pressure p_{ae} for insulation and/or making and breaking
alarm density ρ_{ae} for insulation and/or making and breaking
pressure (in Pa), for insulation and/or for making and breaking, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided

3.6.5.4
alarm pressure p_{am} for operation
alarm density ρ_{am} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal from the energy storage device may be provided

3.6.5.5
minimum functional pressure p_{me} for insulation and/or making and breaking
minimum functional density ρ_{me} for insulation and/or making and breaking
pressure (in Pa), for insulation and/or for making and breaking, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained

Note 1 to entry: For generator circuit-breakers with a sealed pressure system (also termed sealed-for-life), the minimum functional pressure for insulation and/or making and breaking is the one at which the rated characteristics of the generator circuit-breaker are maintained taking into account the pressure drop at the end of the expected operating life.

3.6.5.6
minimum functional pressure p_{mm} for operation
minimum functional density ρ_{mm} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment of the energy storage device becomes necessary

Note 1 to entry: This pressure is often designated as interlocking or lockout pressure.

3.6.101
operation
<of a mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a generator circuit-breaker, this can be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:1984, 441-16-01, modified – In Note 1 to entry, addition of the word "generator" to "circuit-breaker".]

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3.6.102
operating cycle
<of a mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:1984, 441-16-02]

3.6.103
operating sequence
<of a mechanical switching device> succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:1984, 441-16-03]

3.6.104
closing operation C
<of a mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:1984, 441-16-08, modified – C has been added.]

3.6.105
opening operation O
<of a mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:1984, 441-16-09, modified – O has been added.]

3.6.106
stored energy operation
operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

Note 1 to entry: This kind of operation may be subdivided according to:

a) The manner of storing the energy (spring, weight, etc.);

b) The origin of the energy (manual, electric, etc.);

c) The manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:1984, 441-16-15]

3.6.107
closed position
<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-22]

3.6.108
open position
<of a mechanical switching device> position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-23]

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3.6.109
trip-free mechanical switching device
mechanical switching device, the moving contacts of which return to and remain in the open position when the opening operation is initiated after the initiation of the closing operation, even if the closing command is maintained

Note 1 to entry: To ensure proper breaking of the current which may have been established, it may be necessary that the contacts momentarily reach the closed position.

Note 2 to entry: If the release circuit is completed through an auxiliary switch, electrical release will not take place until such auxiliary switch is closed.

[SOURCE: IEC 60050-441:1984, 441-16-31, modified – Addition of a second note to entry.]

3.6.110
shunt release
release energized by a source of voltage

Note 1 to entry: The source of voltage can be independent of the voltage of the main circuit.

[SOURCE: IEC 60050-441:1984, 441-16-41]

3.6.111
anti-pumping device
device which prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing

[SOURCE: IEC 60050-441:1984, 441-16-48]

3.6.112
interlocking device
device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:1984, 441-16-49]

3.6.113
making operation
closing operation while power is applied to the main circuit

SEE: Figure 1.

3.6.114
breaking operation
opening operation while power is applied to the main circuit

SEE: Figure 1.

3.6.115
close-open operation
CO
closing operation followed by an opening operation

3.6.116
make-break operation
close-open operation while power is applied to the main circuit

SEE: Figure 1.

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3.7 Characteristic quantities

Figure 1 to Figure 5 illustrate some definitions of this subclause.

Time quantities, see terms and definitions 3.7.122 to 3.7.130, are expressed in milliseconds or in cycles of the rated power frequency. When expressed in cycles, the power frequency should be stated in brackets. In the case of generator circuit-breakers incorporating breaking resistors, a distinction is made, where applicable, between time quantities associated with the contacts breaking the full current and the contacts breaking the current limited by breaking resistors.

Unless otherwise stated, the time quantities referred to are associated with the contacts making and breaking the full current.

3.7.101
rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of component, device or equipment

3.7.102
prospective current
<of a circuit and with respect to a switching device or a fuse> current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is to be specified in the relevant publications.

[SOURCE: IEC 60050-441:1984, 441-17-01]

3.7.103
prospective peak current
peak value of the first major loop of the prospective current during the transient period following initiation

Note 1 to entry: The definition assumes that the current is made by an ideal generator 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.

3.7.104
peak current
peak value of the first major loop of current during the transient period following initiation

SEE: Figure 1 *a*.

3.7.105
prospective symmetrical current
<of an AC circuit> prospective current when it is initiated at such an instant that no transient phenomenon follows the initiation

Note 1 to entry: For polyphase circuits, the condition of non-transient period can only be satisfied for the current in one pole at a time.

Note 2 to entry: The prospective symmetrical current is expressed by its RMS.

[SOURCE: IEC 60050-441:1984, 441-17-03]

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3.7.106
maximum prospective peak current
<of an AC circuit> prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

Note 1 to entry: For a multiple device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[SOURCE: IEC 60050-441:1984, 441-17-04]

3.7.107
prospective making current
<for a pole of a switching device> prospective current when initiated under specified conditions

Note 1 to entry: The specified conditions may relate to the method of initiation, e.g. by an ideal switching device, or to the instant of initiation, e.g. leading to the maximum prospective peak current in an AC circuit, or to the highest rate of rise. The specification of these conditions is found in the relevant publications.

[SOURCE: IEC 60050-441:1984, 441-17-05]

3.7.108
making current
peak value of the first major loop of the current in a pole of a generator circuit-breaker during the transient period following the initiation of current during a making operation

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

Note 2 to entry: Where, for a polyphase circuit, a single value of making current is referred to, this is, unless otherwise stated, the highest value in any phase.

SEE: Figure 1 *a*.

3.7.109
prospective breaking current
<for a pole of a switching device> prospective current evaluated at the instant corresponding to the initiation of the arc during a breaking process

3.7.110
breaking current
<of a switching device or a fuse> current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[SOURCE: IEC 60050-441:1984, 441-17-07]

3.7.111
short-circuit making current
making current for which the prescribed conditions include a short circuit at the terminals of the switching device

SEE: Figure 1 *a*.

[SOURCE: IEC 60050-441:1984, 441-17-10, modified – Replacement of "capacity" by "current" and a reference to Figure 1 has been added.]

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3.7.112
short-circuit breaking current
breaking current for which the prescribed conditions include a short circuit at the terminals of the switching device

SEE: Figure 1 *b*.

[SOURCE: IEC 60050-441:1984, 441-17-11, modified – Replacement of "capacity" by "current" and a reference to Figure 1 has been added.]

3.7.113
short-time withstand current
current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

Note 1 to entry: depending on whether the source of the short-circuit current is from the generator through no transformation or from the power system through at least one transformation, it can be referred to as generator-source short-time withstand current or system-source short-time withstand current respectively

[SOURCE: IEC 60050-441:1984, 441-17-17, modified – The note has been added.]

3.7.114
peak withstand current
value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:1984, 441-17-18]

3.7.115
applied voltage
<for a switching device> voltage which exists across the terminals of a pole of a switching device just before the making of the current

[SOURCE: IEC 60050-441:1984, 441-17-24]

3.7.116
recovery voltage
voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

Note 1 to entry: This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power-frequency or the steady-state recovery voltage alone exists.

[SOURCE: IEC 60050-441:1984, 441-17-25]

3.7.117
transient recovery voltage
TRV
recovery voltage during the time in which it has a significant transient character

Note 1 to entry: The transient recovery voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and the switching device. It includes the voltage shift of the neutral of a polyphase circuit.

Note 2 to entry: The transient recovery voltage in three-phase circuits is, unless otherwise stated, that across the first-pole-to-clear, because this voltage is generally higher than that which appears across each of the other two poles.

[SOURCE: IEC 60050-441:1984, 441-17-26]

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3.7.118
prospective transient recovery voltage
<of a circuit> transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

Note 1 to entry: The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

[SOURCE: IEC 60050-441:1984, 441-17-29]

3.7.119
power-frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:1984, 441-17-27]

3.7.120
clearance
distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.7.121
clearance between open contacts
total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

[SOURCE: IEC 60050-441:1984, 441-17-34]

3.7.122
opening time
interval of time between the instant of energising the opening release, the generator circuit-breaker being in the closed position, and the instant when the arcing contacts have separated in all poles

SEE: Figure 1 *j*.

Note 1 to entry: The opening time may vary with the breaking current.

Note 2 to entry: For generator circuit-breakers with more than one interrupting unit in series per pole the following applies: for each pole the contact separation is determined by the contact separation of the first unit in that pole. The contact separation of the three-pole generator circuit-breaker is the longest of the three contact separations of the three poles.

Note 3 to entry: For generator circuit-breakers with more than one interrupting unit in parallel per pole the following applies: for each pole the contact separation is determined by the contact separation of the last unit in that pole. The contact separation of the three-pole generator circuit-breaker is the longest of the three contact separations of the three poles.

Note 4 to entry: The opening time includes the operating time of any auxiliary equipment necessary to open the generator circuit-breaker and forming an integral part of the generator circuit-breaker.

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3.7.123
arcing time
<of a pole> interval of time between the instant of the initiation of the arc in a pole and the instant of final arc extinction (of that pole)

SEE: Figure 1 k.

[SOURCE: IEC 60050-441:1984, 441-17-37, modified – "or a fuse" has been deleted, "in that pole" has been replaced by "(of that pole)" and a reference to Figure 1 has been added.]

3.7.124
break-time
<of a pole> interval of time between the beginning of the opening time of a mechanical switching device and the end of the arcing time (of that pole)

SEE: Figure 1 l.

[SOURCE: IEC 60050-441:1984, 441-17-39, modified – "(or the pre-arcing time of a fuse)" has been deleted and "(of that pole)" and a reference to Figure 1 have been added.]

3.7.125
closing time
interval of time between energising the closing circuit, the generator circuit-breaker being in the open position, and the instant when the contacts touch in all poles

Note 1 to entry: The closing time includes the operating time of any auxiliary equipment necessary to close the generator circuit-breaker and forming an integral part of the generator circuit-breaker.

3.7.126
make-time
interval of time between the beginning of the closing time and the instant when the current begins to flow in the first pole

SEE: Figure 1 m.

[SOURCE: IEC 60050-441:1984, 441-17-40, modified – The definition has been rephrased and a reference to Figure 1 has been added.]

3.7.127
pre-arcing time
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 for three-phase conditions and the instant when the contacts touch in the arcing pole for single-phase conditions

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

3.7.128
close-open time
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 1 to entry: Unless otherwise stated, it is assumed that the opening release incorporated in the generator circuit-breaker is energised at the instant when the contacts touch in the first pole during closing. This represents the minimum close-open time.

[SOURCE: IEC 60050-441:1984, 441-17-42, modified – Note 1 to entry has been added.]

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3.7.129
minimum trip signal duration
minimum time the auxiliary power is applied to the opening release to ensure complete opening of the generator circuit-breaker

3.7.130
minimum close signal duration
minimum time the auxiliary power is applied to the closing device to ensure complete closing of the generator circuit-breaker

3.7.131
first-pole-to-clear factor
<in a three-phase system> ratio of the power-frequency voltage across the first interrupting pole before current interruption in the other poles, to the power-frequency voltage occurring across the pole or the poles after interruption in all three poles (when interrupting any symmetrical three-phase current)

3.7.132
amplitude factor
ratio between the maximum excursion of the transient recovery voltage to the crest value of the power-frequency recovery voltage

3.7.133
insulation level
set of withstand voltages specified which characterise the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016, 614-03-23]

3.7.134
power-frequency withstand voltage
RMS value of sinusoidal power-frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.7.135
impulse withstand voltage
peak value of the standard impulse voltage wave which the insulation of the generator circuit-breaker withstands under specified test conditions

3.7.136
degree of asymmetry
<of a current at any time> ratio (expressed as a percentage) of the DC component to the peak value of the AC component determined from the envelope of the current wave at that time

Note 1 to entry: This value is 100 % when the DC component equals the peak value of the AC component.

3.7.137
generator-source short-circuit current
short-circuit current when the source of the short-circuit current is entirely from a generator through no transformation

3.7.138
system-source short-circuit current
short-circuit current when the source of the short-circuit current is from the power system through at least one transformation

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3.7.139
intermediate level of asymmetry
level of asymmetry in the two phases having an intermediate (reduced) level of asymmetry, when in a three-phase system the short-circuit current is initiated simultaneously in all phases and maximum asymmetry is obtained in one of the phases

SEE: Figure 6.

3.7.140
earliest possible interruption in a phase with intermediate level of asymmetry after a major loop
interruption with the shortest time (t_1) from fault current initiation to the first current zero after a major loop in the phase with intermediate level of asymmetry, taking into account:

– the minimum relay time (0,5 cycle of power frequency);
– the minimum opening time;
– the minimum arcing time;
– and that the subsequent current zero crossing of the prospective three-phase current occurs in the other phase with maximum level of asymmetry after a major loop

SEE: Figure 7

Note 1 to entry: This definition is to be used only for the determination of the test parameters during asymmetrical short-circuit breaking tests. (TD2 – System-source fault)

Note 2 to entry: Typically, the minimum opening time will occur when the opening release is energised at upper limit of the supply voltage and if applicable at maximum functional pressure for operation.

3.7.141
earliest possible interruption in a phase with intermediate level of asymmetry after a minor loop
interruption with the shortest time (t_2) from fault current initiation to the first current zero after a minor loop in the phase with intermediate level of asymmetry, taking into account:

– the minimum relay time (0,5 cycle of power frequency);
– the minimum opening time;
– the minimum arcing time;
– and that the subsequent current zero crossing of the prospective three-phase current occurs in the other phase with intermediate level of asymmetry after a major loop

SEE: Figure 8.

Note 1 to entry: This definition is to be used only for the determination of the test parameters during asymmetrical short-circuit breaking tests. (TD2 – System-source fault)

Note 2 to entry: Typically, the minimum opening time will occur when the opening release is energised at upper limit of the supply voltage and if applicable at maximum functional pressure for operation.

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3.7.142
three-phase break-time
<of a generator circuit-breaker> maximum interval between the energising of the trip circuit and the interruption of the current in all poles in the main circuit during test-duty 1 of Table 20 (see 7.103.12) under the following conditions:

– rated auxiliary supply voltage and frequency;

– filling pressures for operation, insulation and/or making and breaking;

– an ambient air temperature of (20 ± 5) °C

Note 1 to entry: According to 7.102.3.1, the breaking tests, shall be carried out at the minimum auxiliary supply voltage, at the minimum pressure for operation and at the minimum pressure for insulation and/or making and breaking. In order to verify the three-phase break-time during these test-duties, the lower auxiliary supply voltage and pressures should be taken into account as follows:

$$t_{\text{b cal}} = t_1 + t_{\text{arc sym min}} + T \cdot 132°/360°$$

where

$t_{\text{b cal}}$ is the calculated three-phase break-time;

t_1 is the opening time at rated supply voltage of the opening device, rated supply frequency of the opening device, specified pressure for operation, insulation and/or making and breaking and at ambient air temperature of 20 ± 5 °C;

$t_{\text{arc sym min}}$ is the minimum arcing time recorded during test-duty 1;

T is one period of the power frequency (20 ms for 50 Hz, 16,7 ms for 60 Hz);

Note 2 to entry: The three-phase break-time can also be referred to as rated interrupting time.

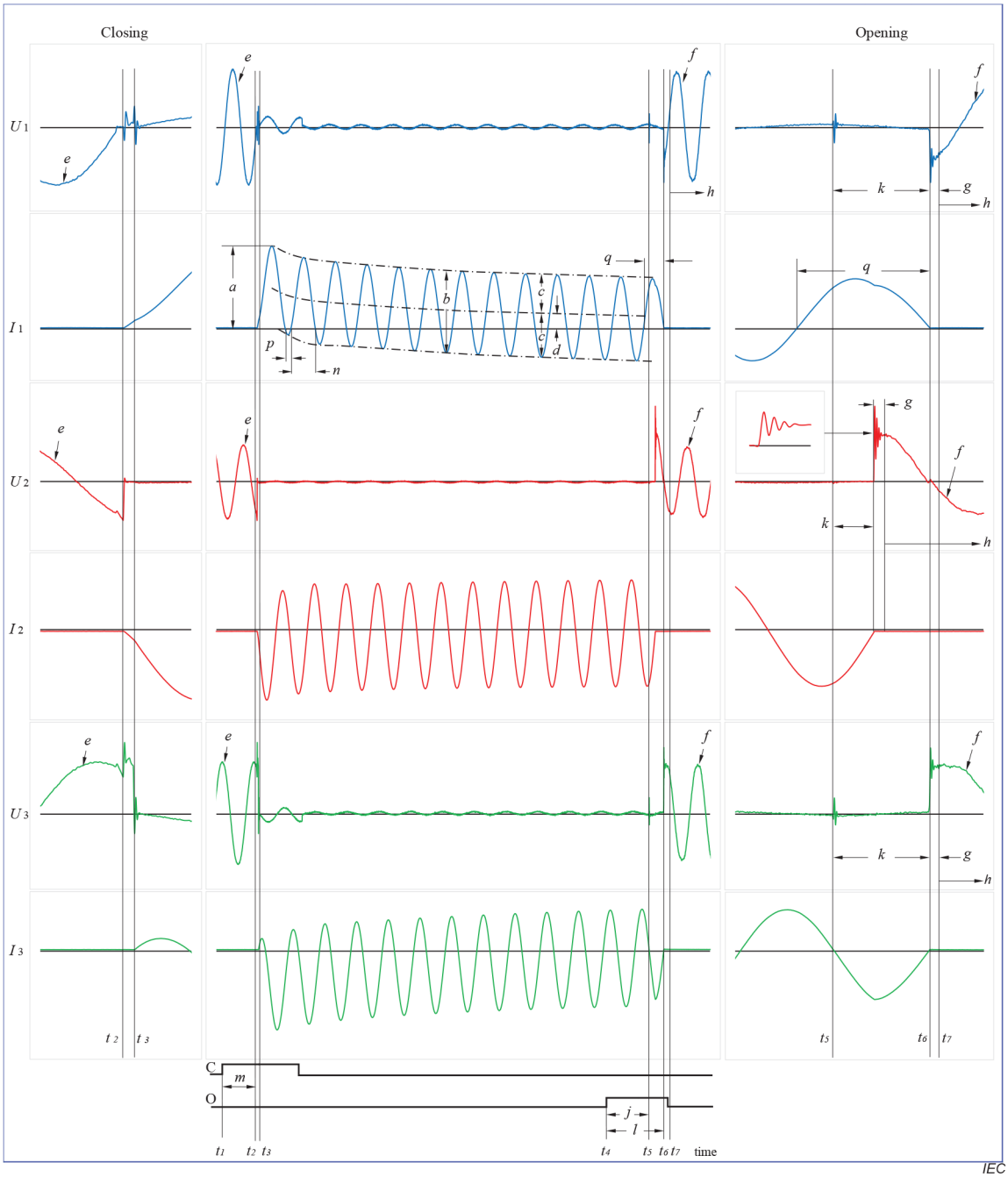
Note 3 to entry: Typical values are approximately 60 ms to 90 ms with the actual time being dependent on the rated system-source short-circuit breaking current.

Note 4 to entry: The three-phase break-time can slightly differ from the calculated three-phase break-time as the minimum arcing time can additionally be slightly influenced by the pressure for operation and the pressure for insulation and/or making and breaking. In order to show this influence, the test to show the three-phase break-time can be repeated at rated auxiliary supply voltage, specified pressure for operation and specified pressure for insulation and/or making and breaking.

Note 5 to entry: For single-phase tests simulating a three-phase operation, the recorded break-time can exceed the three-phase break-time by 30 electrical degrees because in these cases the current zeros occur less frequently than in the three-phase case.

Note 6 to entry: For generator circuit-breakers equipped with resistors, the time until final extinction of the resistor current will be longer.

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U_2	voltage across the terminals of the first-pole-to-clear	*a*	making current
I_2	current in the first-pole-to-clear	*b*	peak-to-peak value of the AC component
U_1, U_3	voltage across the terminals of the two other poles	*c*	peak value of the AC component
I_1, I_3	current in the two other poles	*d*	DC component
C	closing command, e.g. voltage across the terminals of the closing circuit	*e*	applied voltage
O	opening command, e.g. voltage across the terminals of the opening release	*f*	recovery voltage
t_1	the instant of initiation of the closing operation	*g*	transient recovery voltage
t_2	the instant when the current begins to flow in the main circuit (voltage breakdown in phases 1 and 2)	*h*	power-frequency recovery voltage
t_3	the instant when the current is established in all poles (voltage breakdown in phase 3)	*j*	opening time
t_4	the instant of energising the opening release	*k*	arcing time
t_5	the instant when the arcing contacts have separated (or instant of initiation of the arc) in all poles	*l*	three-phase break-time
t_6	the instant of final arc extinction in all poles	*m*	make time
t_7	the instant when the transient voltage phenomena have subsided in the last-pole-to-clear	*n*	major loop
		p	minor loop
		q	major extended loop

NOTE 1 Indicators *i* and *o* are not used.

NOTE 2 The RMS value of the AC component of the breaking current is $c/\sqrt{2}$.

NOTE 3 Different scale factors for voltage and current traces in each phase are used.

Figure 1 – Example of a graphical record of a three-phase short-circuit make-break test

The following notes apply to Figure 2 to Figure 5:

NOTE 1 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 is indicated with a single line for all three poles.

NOTE 2 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 is indicated with a single line for all three poles.

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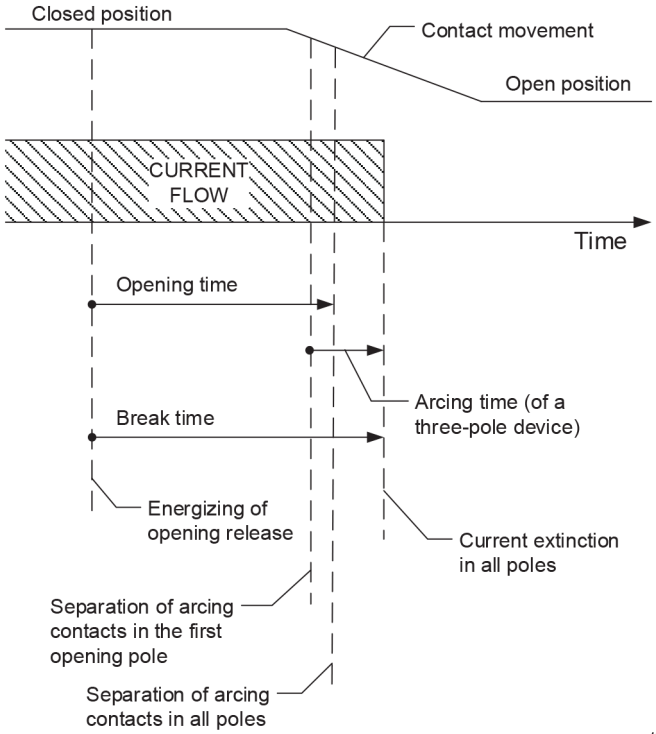


Figure 2 – Generator circuit-breaker without resistors – Opening operation

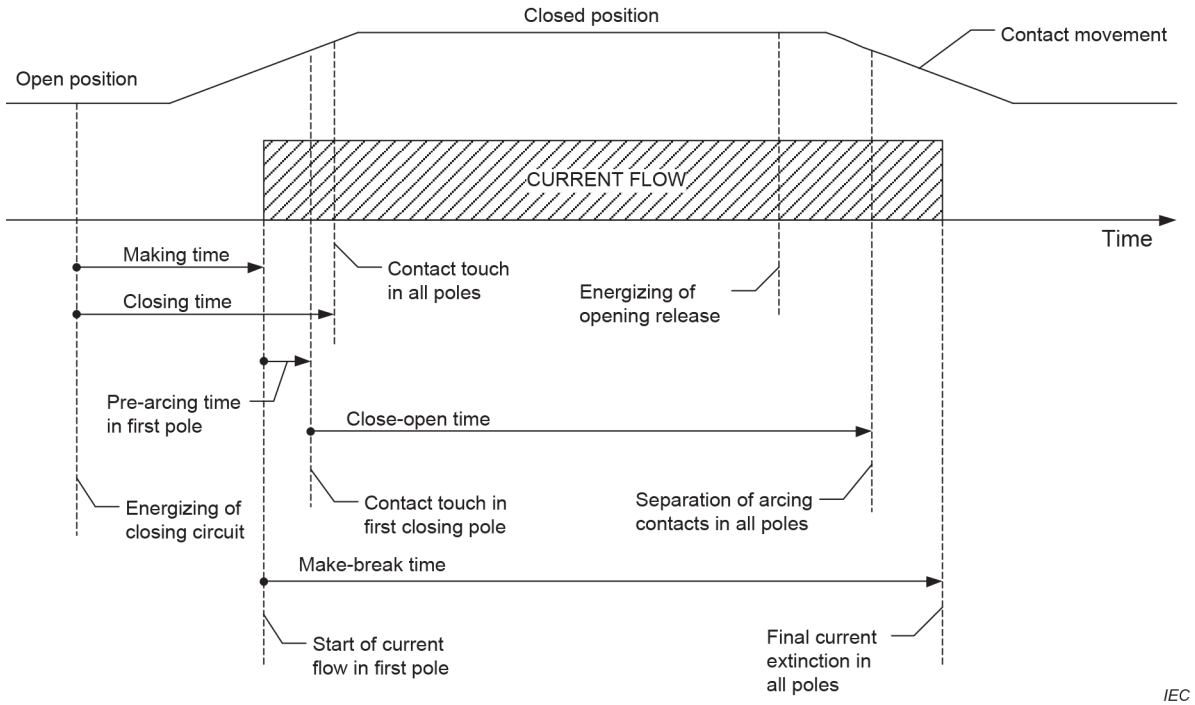


Figure 3 – Generator circuit-breaker without resistors – Close-open cycle

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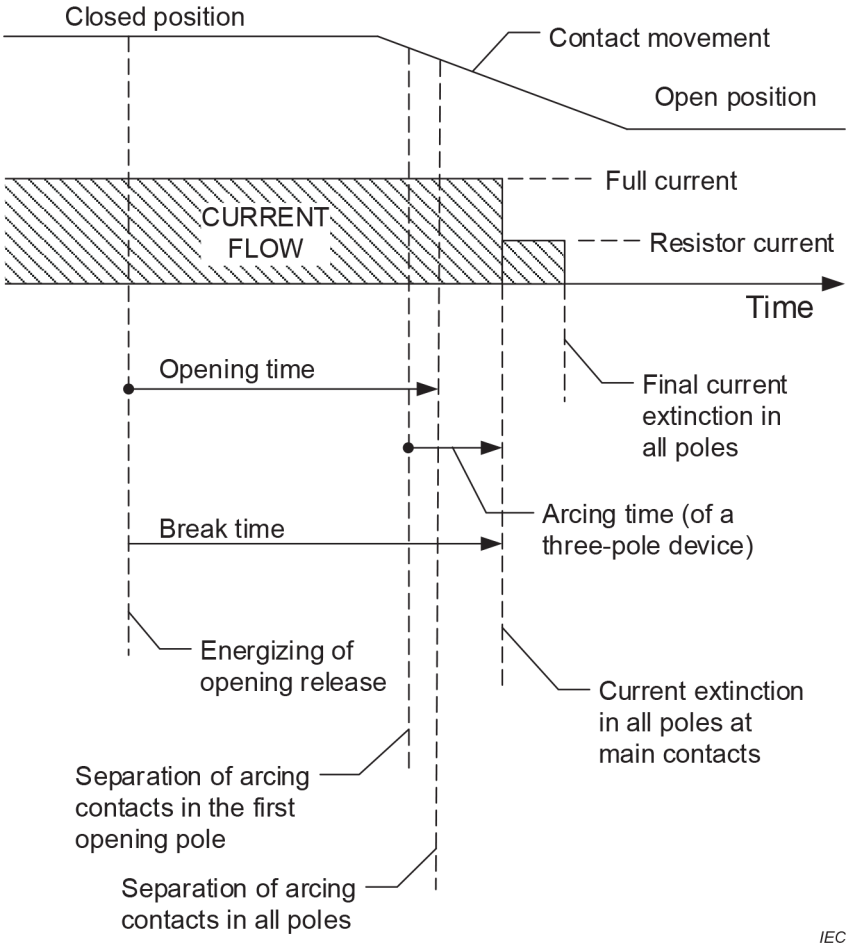


Figure 4 – Generator circuit-breaker with opening resistors – Opening operation

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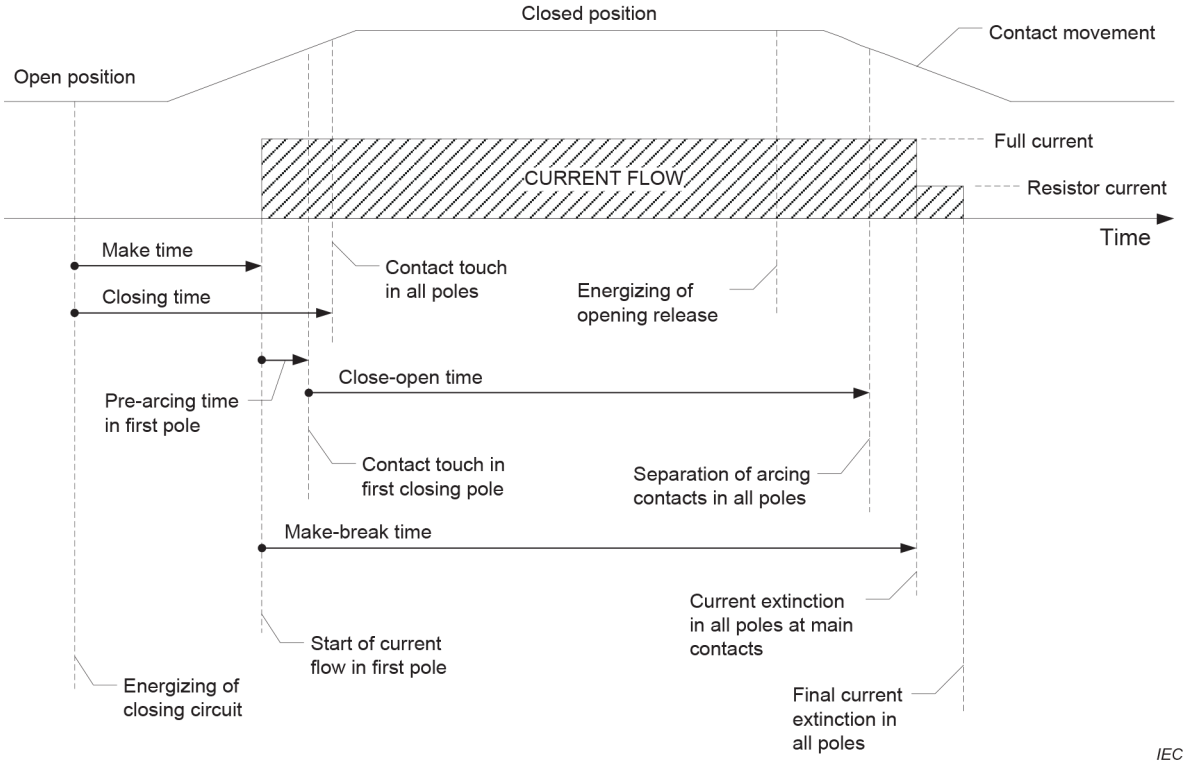


Figure 5 – Generator circuit-breaker with opening resistors – Close-open cycle

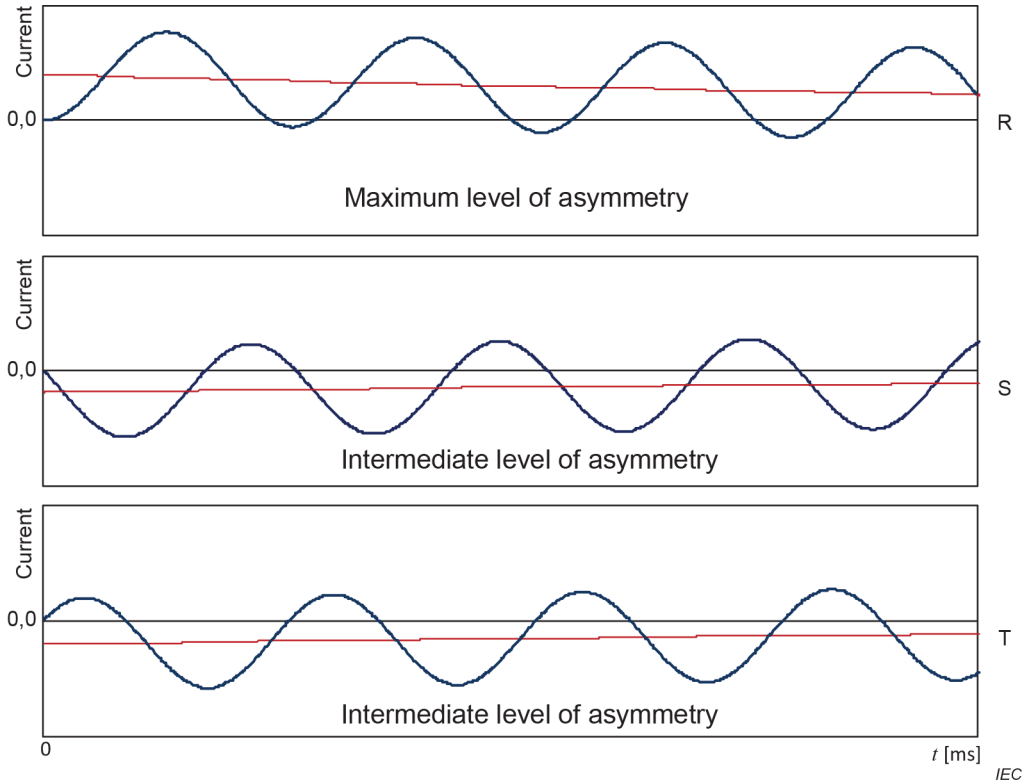


Figure 6 – Example of a three-phase asymmetrical current

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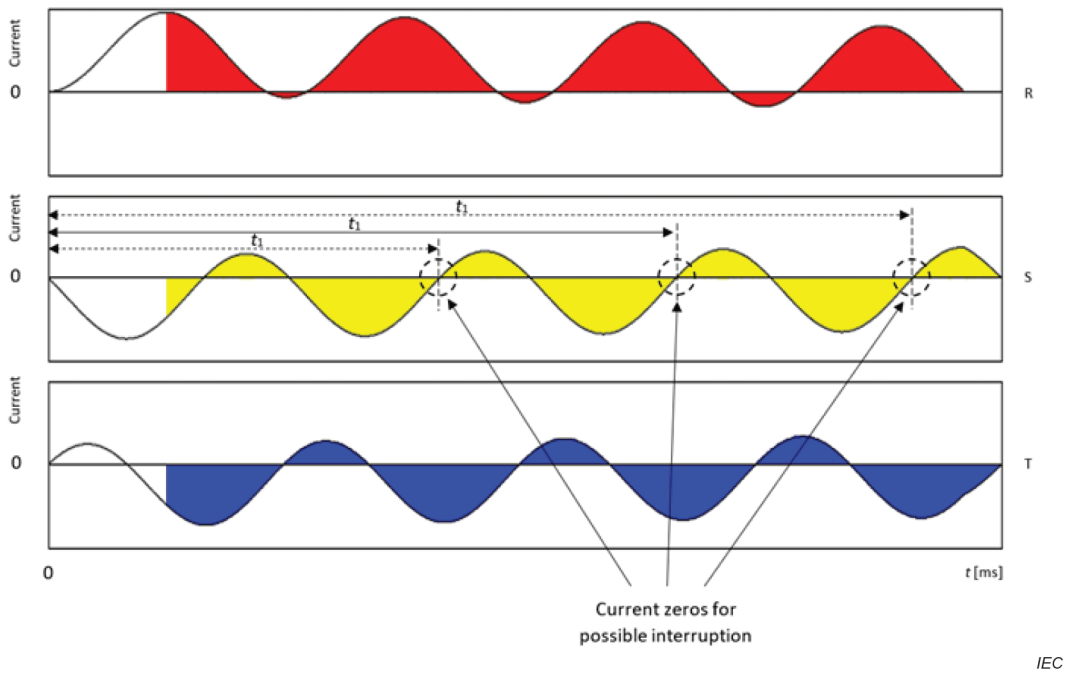


Figure 7 – Examples of possible interruptions in a phase with intermediate level of asymmetry after a major loop and a corresponding time t_1

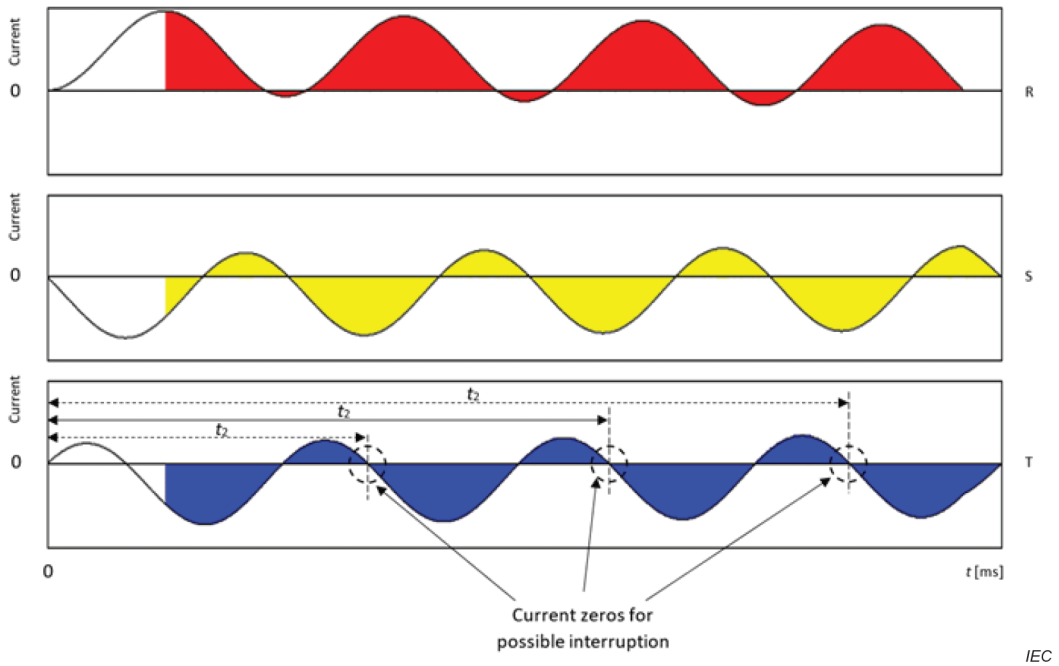


Figure 8 – Examples of possible interruptions in a phase with intermediate level of asymmetry after a minor loop and a corresponding time t_2

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