

INTERNATIONAL STANDARD



**High-voltage switchgear and controlgear –
Part 105: Alternating current switch-fuse combinations for rated voltages above
1 kV up to and including 52 kV**



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**High-voltage switchgear and controlgear –
Part 105: Alternating current switch-fuse combinations for rated voltages above
1 kV up to and including 52 kV**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 105: Alternating current switch-fuse combinations
for rated voltages above 1 kV up to and including 52 kV**

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62271-105:2012. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62271-105 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

This third edition cancels and replaces the second edition published in 2012. This edition constitutes a technical revision.

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

- a) the document has been updated to be in alignment with the second edition of IEC 62271-1:2017;
- b) rated TRV has been removed (TRV is only a test parameter), as in the latest revision of IEC 62271-100;
- c) differentiation has been introduced between requirements expressed for fulfilling the function expected from a switch-fuse combination, from requirements only relevant when the function is performed by a stand-alone device. The goal is to avoid duplication or conflicts of requirements with a standard dealing with assemblies, when the function is implemented within such an assembly.

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

FDIS	Report on voting
17A/1300/FDIS	17A/1306/RVD

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

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

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

This document is to be read in conjunction with IEC 62271-1:2017, 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 62271-1:2017. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

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

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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV

~~1~~ **General**

1 Scope

~~Subclause 1.1 of IEC 62271-1:2007 is not applicable, and is replaced as follows:~~

This part of IEC 62271 applies to three-pole units for public and industrial distribution systems which are functional assemblies of switches ~~including~~ composed of switches or switch-disconnectors and current-limiting fuses designed so as to be capable of

- breaking, at the rated ~~recovery~~ voltage, any current up to and including the rated short-circuit breaking current;
- making, at the rated voltage, circuits to which the rated short-circuit breaking current applies.

~~It does not apply to fuse circuit-breakers, fuse contactors, combinations for motor-circuits or to combinations incorporating single capacitor bank switches.~~

It does not apply to combinations of fuses with circuit-breakers, contactors or circuit switchers, nor for combinations for motor-circuits nor to combinations incorporating single capacitor bank switches.

This document applies to combinations designed with rated voltages above 1 kV up to and including 52 kV for use on three-phase alternating current systems of either 50 Hz or 60 Hz.

In this document, the word "combination" is used for a combination in which the components constitute a functional assembly. Each association of a given type of switch and a given type of fuse defines one type of switch-fuse combination. ~~In practice,~~ Different types of fuses ~~may~~ can be combined with one type of switch, which give several combinations with different characteristics, in particular concerning the rated continuous currents. ~~Moreover, for maintenance purposes, the user should know the types of fuses that can be combined to a given switch, without impairing compliance to the standard, and the corresponding characteristics of the so-made combination.~~

A switch-fuse combination is ~~then~~ therefore defined by its type designation and a list of selected fuses defined by the manufacturer, the so-called "reference list of fuses". Compliance with this document of a given combination means that every combination using one of the selected fuses is proven to be in compliance with this document.

The fuses are incorporated in order to extend the short-circuit breaking rating of the combination beyond that of the switch alone. They are fitted with strikers in order both to open automatically all three poles of the switch on the operation of a fuse and to achieve a correct operation at values of fault current above the minimum melting current but below the minimum breaking current of the fuses. In addition to the fuse strikers, the combination ~~may~~ can be fitted with either an over-current release or a shunt release.

NOTE In this document the term "fuse" is used to designate either the fuse or the fuse-link where the general meaning of the text does not result in ambiguity.

~~This standard applies to combinations designed with rated voltages above 1 kV up to and including 52 kV for use on three-phase alternating current systems of either 50 Hz or 60 Hz.~~

Fuses are ~~covered by~~ in accordance with IEC 60282-1:2020.

Devices that require dependent manual operation are not covered by this document.

Switches, including their specific mechanism, ~~shall be~~ are in accordance with IEC 62271-103 except for the short-time current and short-circuit making requirements where the current-limiting effects of the fuses are taken into account.

Earthing switches forming an integral part of a combination are covered by IEC 62271-102.

In addition, switches which include other functions (not covered by IEC 62271-103) are covered by their relevant standards (e.g. IEC 62271-102 for disconnectors and earthing switches).

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.

~~Subclause 1.2 of IEC 62271-1:2007 is applicable with the following additions:~~

Clause 2 of IEC 62271-1:2017 applies with the following additions:

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

IEC 60282-1:2009/2020, *High-voltage fuses – Part 1: Current-limiting fuses*

~~IEC/TR 60787:2007, Application guide for the selection of high-voltage current-limiting fuse-links for transformer circuits~~

IEC 62271-1:2007/2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:2008/2021, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

IEC 62271-102:2001/2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-103:2011/2021, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

3 Terms and definitions

~~Clause 3 of IEC 62271-1:2007 is applicable with the the following additions.~~

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

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

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

NOTE Some of the terms given in IEC 60050-441 are listed hereunder.

3.1 General terms and definitions

~~Subclause 3.1 of IEC 62271-1:2007 is applicable.~~

Subclause 3.1 of IEC 62271-1:2017 applies.

3.2 Assemblies of switchgear and controlgear

~~Subclause 3.2 of IEC 62271-1:2007 is applicable.~~

Subclause 3.2 of IEC 62271-1:2017 applies.

3.3 Parts of assemblies

~~Subclause 3.3 of IEC 62271-1:2007 is applicable.~~

Subclause 3.3 of IEC 62271-1:2017 applies.

3.4 Switching devices

~~Subclause 3.4 of IEC 62271-1:2007 is applicable, with the following additions~~

Subclause 3.4 of IEC 62271-1:2017 applies, with the following additions:

3.4.101

switch-fuse combination

combination of a three-pole switch with three fuses provided with strikers, the operation of any striker causing all three poles of the switch to open automatically

Note 1 to entry: The switch-fuse combination includes the fuse-switch combination.

3.4.102

switch-fuse combination base

combination base

switch-fuse combination without fuse-links mounted

3.4.103

switch-fuse

switch in which one or more poles have a fuse in series in a composite unit

[SOURCE: IEC 60050-441:20072000, 441-14-14]

3.4.104

fuse-switch

switch in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:20072000, 441-14-17]

3.4.105 switch-disconnector

switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[SOURCE: IEC 60050-441:2007, 441-14-12]

3.4.106 release-operated combination

combination in which automatic opening of the switch can also be initiated by either an over-current release or a shunt release

3.5 Parts of switchgear and controlgear

~~Subclause 3.5 of IEC 62271-1:2007 is applicable, with the following additions.~~

Subclause 3.5 of IEC 62271-1:2017 applies, with the following additions:

3.5.101 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 60050-441:2007, 441-15-17]

3.5.102 over-current release

release which permits a mechanical switching device to open with or without time-delay when the current in the release exceeds a predetermined value

Note 1 to entry: This value can in some cases depend upon the rate-of-rise of current.

[SOURCE: IEC 60050-441:2007, 441-16-33]

3.5.103 shunt release

release energized by a source of voltage

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

[SOURCE: IEC 60050-441:2007, 441-16-41]

3.6 Operational characteristics of switchgear and controlgear

~~Subclause 3.6 of IEC 62271-1:2007 is applicable, with the following additions.~~

3.6.101

~~independent manual operation (of a mechanical switching device)
stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator~~

~~[SOURCE: IEC 60050-441:2007, 441-16-16]~~

3.6.102

~~stored energy operation (of a mechanical switching device)
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 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 60050-441:2007, 441-16-15]~~

Subclause 3.6 of IEC 62271-1:2017 applies.

3.7 Characteristic quantities

~~Subclause 3.7 of IEC 62271-1:2007 is applicable, with the following additions.~~

Subclause 3.7 of IEC 62271-1:2017 applies, with the following additions:

3.7.101

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 60050-441:20072000, 441-17-01]

3.7.102

prospective peak current

peak value of a prospective current during the transient period following initiation

Note 1 to entry: The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[SOURCE: IEC 60050-441:20072000, 441-17-02]

3.7.103

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 60050-441:20072000, 441-17-04]

~~3.7.104~~

~~**prospective breaking current (for a pole of a switching device or a fuse)**~~

~~prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process~~

~~Note 1 to entry: Specifications concerning the instant of the initiation of the breaking process are to be found in the relevant publications. For mechanical switching devices or fuses, it is usually defined as the moment of initiation of the arc during the breaking process.~~

~~[SOURCE: IEC 60050-441:2007, 441-17-06]~~

3.7.105

~~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 60050-441:2007, 441-17-07]~~

3.7.104

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 60050-441:2000, 441-17-07]

3.7.105

minimum breaking current

minimum value of prospective current that a fuse-link is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:20072000, 441-18-29]

3.7.106

short-circuit making capacity

making capacity for which the prescribed conditions include a short circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:20072000, 441-17-10]

3.7.107

cut-off current

let-through current ~~(of a fuse)~~

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:20072000, 441-17-12]

3.7.108

transfer current

I_{transfer}

<striker operation> value of the three-phase symmetrical current at which the fuses and the switch exchange breaking duties

Note 1 to entry: Above this value the three-phase current is interrupted by the fuses only. Immediately below this value, the current in the first-pole-to-clear is interrupted by the fuse and the current in the other two poles by the switch, or by the fuses, depending on the tolerances of the fuse time current characteristic and the fuse-initiated opening time of the switch.

3.7.109

take-over current

current co-ordinate of the intersection between the time-current characteristics of two over-current protective devices

[SOURCE: IEC 60050-441:20072000, 441-17-16]

3.7.110

minimum take-over current

<of a release-operated combination> current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to

- a) the maximum break-time plus, where applicable, the maximum operating time of an external over-current or earth-fault relay,
- b) the minimum pre-arcing time of the fuse

3.7.111

maximum take-over current

<of a release-operated combination> current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to:

- a) the minimum ~~break~~ opening time plus, where applicable, the minimum operating time of an external over-current or earth-fault relay,
- b) the maximum ~~pre-arcing~~ operating time of the fuse

3.7.112

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 60050-441:2007/2000, 441-17-24]

3.7.113

fused short-circuit current

~~conditional short-circuit current when the current limiting device is a fuse~~

~~[SOURCE: IEC 60050-441:2007, 441-17-21]~~

3.7.113

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 60050-441:2007/2000, 441-17-25]

3.7.114

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 voltages 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 60050-441:2007/2000, 441-17-26]

3.7.115

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:20072000, 441-17-27]

3.7.116

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 60050-441:20072000, 441-17-29]

3.7.117

fuse-initiated opening time

<of the switch-fuse combination> time taken from the instant at which arcing in the fuse commences to the instant when the arcing contacts of the switch of the combination have separated in all poles (including all elements influencing this time)

3.7.118

release-initiated opening time

<of the switch-fuse combination> release-initiated opening time is defined according to the tripping method as stated below with any time-delay device forming an integral part of the switch adjusted to a specified setting:

- a) for a switch tripped by any form of auxiliary power, interval of time between the instant of energizing the opening release, the switch being in the closed position, and the instant when the arcing contacts have separated in all poles;
- b) for a switch tripped (other than by the striker) by a current in the main circuit without the aid of any form of auxiliary power, interval of time between the instant at which, the switch being in the closed position, the current in the main circuit reaches the operating value of the over-current release and the instant when the arcing contacts have separated in all poles

3.7.119

minimum release-initiated opening time

<of the switch-fuse combination> release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its minimum setting

3.7.120

maximum release-initiated opening time

<of the switch-fuse combination> release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its maximum setting

3.7.121

break-time

interval of time between the beginning of the opening time of a mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[SOURCE: IEC 60050-441:20072000, 441-17-39]

3.7.122

arcing time

<of a pole or a fuse> interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[SOURCE: IEC 60050-441:20072000, 441-17-37]

3.101 Fuses

3.101.1

reference list of fuses

list of fuses defined by the manufacturer for a given type of switch-fuse combination base, for which compliance to the present document of all corresponding switch-fuse combinations is assessed

Note 1 to entry: ~~This list can be updated.~~ Conditions for extending the validity of the type tests are given in 7.105 and 9.102.

3.101.2

fuse-base

fuse mount

fixed part of a fuse provided with contacts and terminals

[SOURCE: IEC 60050-441:20072000, 441-18-02]

3.101.3

striker

mechanical device forming part of a fuse-link which, when the fuse operates, releases the energy required to cause operation of other apparatus or indicators or to provide interlocking

[SOURCE: IEC 60050-441:20072000, 441-18-18]

3.101.4

pre-arcing time

melting time

interval of time between the beginning of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated

[SOURCE: IEC 60050-441:20072000, 441-18-21]

3.101.5

operating time

total clearing time

sum of the pre-arcing time and the arcing time

[SOURCE: IEC 60050-441:20072000, 441-18-22]

~~3.101.6~~

~~arcing time (of a pole or a fuse)~~

~~interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse~~

~~[SOURCE: IEC 60050-441:2007, 441-17-37]~~

3.101.6

I^2t

Joule integral

integral of the square of the current over a given time interval:

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

Note 1 to entry: The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

Note 2 to entry: The operating I^2t is the I^2t integral extended over the operating time of the fuse.

Note 3 to entry: The energy in joules liberated in one ohm of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in A²s.

[SOURCE: IEC 60050-441:2007, 441-18-23]

4 Normal and special service conditions

~~Clause 2 of IEC 62271-1:2007 is applicable.~~

Clause 4 of IEC 62271-1:2017 applies.

5 Ratings

~~Clause 4 of IEC 62271-1:2007 is applicable with the following additions and exceptions.~~

~~In addition to the ratings listed in IEC 62271-1 the following ratings apply:~~

- ~~a) rated short-circuit breaking current,~~
- ~~b) rated transient recovery voltage,~~
- ~~c) rated short-circuit making current,~~
- ~~d) rated transfer current for striker operation,~~
- ~~e) rated take-over current for a release-operated combination.~~

5.1 General

Subclause 5.1 of IEC 62271-1:2017 applies with the following additions:

- k) rated short-circuit breaking current;
- l) rated short-circuit making current;
- m) rated transfer current for striker operation;
- n) rated take-over current for a release-operated combination.

If the switch-fuse combination is not used as a stand-alone device, the influences to the different ratings are covered by the relevant standards (e.g. if it is used as a part of switchgear and controlgear assembly).

5.2 Rated voltage (U_r)

~~Subclause 4.1 of IEC 62271-1:2007 is applicable.~~

Subclause 5.2 of IEC 62271-1:2017 applies.

5.3 Rated insulation level (U_d , U_p , U_s)

~~Subclause 4.2 of IEC 62271-1:2007 is applicable.~~

Subclause 5.3 of IEC 62271-1:2017 applies.

5.4 Rated frequency (f_r)

~~Subclause 4.3 of IEC 62271-1:2007 is applicable.~~

Subclause 5.4 of IEC 62271-1:2017 applies.

5.5 ~~Rated normal current and temperature rise~~ Rated continuous current (I_r)

4.4.1 ~~Rated normal current (I_r)~~

~~Subclause 4.4.1 of IEC 62271-1:2007 is applicable with the following addition:~~

~~The rated normal current applies to the complete combination, made of the combination base and the selected fuses.~~

~~It is not required that the rated normal current is selected from the R10 series.~~

4.4.2 ~~Temperature rise~~

~~Subclause 4.4.2 of IEC 62271-1:2007 is applicable and, as far as fuses are concerned, IEC 60282-1.~~

Subclause 5.5 of IEC 62271-1:2017 applies with the following additions:

The rated continuous current applies to the complete switch-fuse combination.

Each combination of a given type of switch and a given type of fuse defines one type of switch-fuse combination. Different types of fuses may be combined with one type of switch, which give several switch-fuse combinations with different rated continuous currents.

It is not required that the rated continuous current is selected from the R10 series.

5.6 Rated short-time withstand current (I_k)

~~Subclause 4.5 of IEC 62271-1:2007 is not applicable.~~

Subclause 5.6 of IEC 62271-1:2017 does not apply.

5.7 Rated peak withstand current (I_p)

~~Subclause 4.6 of IEC 62271-1:2007 is not applicable.~~

Subclause 5.7 of IEC 62271-1:2017 does not apply.

5.8 Rated duration of short-circuit (t_k)

~~Subclause 4.7 of IEC 62271-1:2007 is not applicable.~~

Subclause 5.8 of IEC 62271-1:2017 does not apply.

5.9 Rated supply voltage ~~of closing and opening devices and~~ of auxiliary and control circuits (U_a)

~~Subclause 4.8 of IEC 62271-1:2007 is applicable.~~

Subclause 5.9 of IEC 62271-1:2017 applies.

5.10 Rated supply frequency ~~of closing and opening devices and~~ of auxiliary and control circuits

~~Subclause 4.9 of IEC 62271-1:2007 is applicable.~~

Subclause 5.10 of IEC 62271-1:2017 applies.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

~~Subclause 4.10 of IEC 62271-1:2007 is applicable.~~

Subclause 5.11 of IEC 62271-1:2017 applies.

~~4.11 Rated filling levels for insulation and/or operation~~

~~Subclause 4.11 of IEC 62271-1:2007 is applicable.~~

5.101 Rated short-circuit breaking current

The rated short-circuit breaking current is the highest prospective short-circuit current which the combination shall be capable of breaking under the conditions of use and behaviour ~~prescribed~~ defined in this document in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the combination and having a prospective ~~transient recovery voltage equal to the rated value specified in 4.102~~ TRV as specified in 7.101.2.8 and the values specified in test-duty 1 of IEC 60282-1:2020.

The rated short-circuit breaking current is expressed by the RMS value of its AC component.

The rated short-circuit breaking currents shall be selected from the R10 series.

NOTE 1 The R10 series comprises the numbers: 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n .

NOTE 2 It is recognized that the series impedance of the combination or rapid operation of the fuses or switch ~~may~~ can cause one or both of the following effects:

- a) a reduction of short-circuit current to a value appreciably below that which would otherwise be reached;
- b) such rapid operation that the short-circuit current wave is distorted from its normal form.

This is why the term "prospective current" is used when assessing breaking and making performances.

~~4.102 Rated transient recovery voltage~~

~~The rated transient recovery voltage related to the rated short-circuit breaking current (in accordance with 4.101) is the reference voltage which constitutes the upper limit of the prospective transient recovery voltage of circuits which the combination shall be capable of breaking in the event of a short circuit.~~

~~For the parameters of the prospective transient recovery voltage, IEC 60282-1 applies.~~

5.102 Rated short-circuit making current

The rated short-circuit making current is the highest prospective peak current which the ~~switch-fuse~~ combination shall be capable of making under the conditions of use and behaviour defined in this document in a circuit having a power-frequency voltage corresponding to the rated voltage of the ~~switch-fuse~~ combination. It shall be at least 2,5 times (50 Hz) or 2,6 times (60 Hz) the value of the rated short-circuit breaking current.

NOTE 1 See also Note 2 in 5.101.

NOTE 2 A higher peak factor, linked with possible long time constant of the network, does not influence the performance of the switch-fuse combination under short-circuit conditions, thanks to the current-limiting behaviour of the fuses. That is stated in IEC 60282-1:2020, 6.1.2.

5.103 Rated transfer current (striker operation) (I_{transfer})

The rated transfer current is the maximum RMS value of the transfer current which the switch in the combination is able to interrupt.

5.104 Rated take-over current for release-operated combinations (I_{to} I_{rto})

The rated take-over current is the maximum RMS value of the take-over current which the switch in the combination is able to interrupt.

6 Design and construction

6.1 Requirements for liquids in switch-fuse combinations

~~Subclause 5.1 of IEC 62271-1:2007 is applicable.~~

Subclause 6.1 of IEC 62271-1:2017 applies.

6.2 Requirements for gases in switch-fuse combinations

~~Subclause 5.2 of IEC 62271-1:2007 is applicable.~~

Subclause 6.2 of IEC 62271-1:2017 applies.

6.3 Earthing of switch-fuse combinations

Subclause 6.3 of IEC 62271-1:2017 applies.

~~Subclause 5.3 of IEC 62271-1:2007 is applicable.~~

6.4 Auxiliary and control equipment and circuits

~~Subclause 5.4 of IEC 62271-1:2007 is applicable.~~

Subclause 6.4 of IEC 62271-1:2017 applies.

6.5 Dependent power operation

~~Subclause 5.5 of IEC 62271-1:2007 is applicable with the following addition:~~

Subclause 6.5 of IEC 62271-1:2017 applies with the following addition:

Dependent manual operation is not allowed.

6.6 Stored energy operation

~~Subclause 5.6 of IEC 62271-1:2007 is applicable.~~

Subclause 6.6 of IEC 62271-1:2017 applies.

6.7 ~~Independent manual or power operation (independent unlatched operation)~~ Independent unlatched operation (independent manual or power operation)

~~Subclause 5.7 of IEC 62271-1:2007 is applicable with the following addition:~~

Subclause 6.7 of IEC 62271-1:2017 applies with the following addition:

NOTE The switch-fuse combination is able to break the fault current, without need of a time delay.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 applies.

6.9 Operation of releases

~~Subclause 5.8 of IEC 62271-1:2007 is applicable.~~

Subclause 6.9 of IEC 62271-1:2017 applies.

~~5.9 Low and high pressure interlocking and monitoring devices~~

~~Subclause 5.9 of IEC 62271-1:2007 is applicable.~~

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 applies.

6.11 Nameplates

~~Subclause 5.10 of IEC 62271-1:2007 is applicable with the following addition:~~

~~The nameplate of a switch-fuse combination shall contain information according to Table 1.~~

Subclause 6.11 of IEC 62271-1:2017 applies with the following modifications:

The nameplate of a switch-fuse combination shall contain information in accordance with Table 1.

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Table 1 – Nameplate ~~markings~~ information

(1)	Abbreviation (2) ^a	Unit (3)	Switch-fuse combination (4)	Operating device (5)	Condition for marking required (6)
Manufacturer			X	Y	Only if not integral with the combination and/or if manufacturers are different.
Type designation			X	Y	Only if not integral with the combination and/or if manufacturers are different.
Serial number			X	(Y)	Only if not integral with the combination and/or if manufacturers are different.
Number of this document			X		
Instruction book reference			X		
Rated voltage	U_r	kV	X		
Rated lightning impulse withstand voltage	U_p	kV	X		
Rated frequency	f_r	Hz	X		
Rated ~~normal~~ continuous current with fuses	See reference list		X		
~~Rated~~ Filling pressure for operation(*)	P_{rm}	~~MPa~~ kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for operation(*)	p_{mm}	kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Alarm pressure for operation(*)	P_{am}	kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Filling pressure for insulation(*)	P_{re}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for insulation(*)	p_{me}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for switching(*)	p_{sw}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Rated supply voltage of ~~closing and opening devices and~~ of auxiliary and control circuits	U_a	V		Y	If applicable.
Year of manufacture			X		
~~Temperature class~~			~~Y~~		~~Different from~~ ~~–5 °C indoors~~ ~~–25 °C outdoors~~
Minimum and maximum ambient air temperature		°C	Y		If different from –5 °C and/or 40 °C.
Insulating fluid and mass	M_f	kg	Y		If applicable.
Key (*) Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate or in the instruction book. X The marking of these values is mandatory; blank spaces indicate zero values. Y The marking of these values is mandatory, subject to the conditions in column (6). (Y) The marking of these values is optional and subject to the conditions in column (6). NOTE ^a Abbreviations in column (2) may be used instead of terms in column (1). When terms of column (1) are used, the word "rated" need not appear.					

6.12 ~~Interlocking~~ Locking devices

~~Subclause 5.11 of IEC 62271-1:2007 is applicable.~~

Subclause 6.12 of IEC 62271-1:2017 applies.

6.13 Position indication

~~Subclause 5.12 of IEC 62271-1:2007 is applicable.~~

Subclause 6.13 of IEC 62271-1:2017 applies.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 applies.

~~Subclause 5.13 of IEC 62271-1:2007 is applicable.~~

6.15 Creepage distances for outdoor insulators

~~Subclause 5.14 of IEC 62271-1:2007 is applicable.~~

Subclause 6.15 of IEC 62271-1:2017 applies.

6.16 Gas and vacuum tightness

~~Subclause 5.15 of IEC 62271-1:2007 is applicable.~~

Subclause 6.16 of IEC 62271-1:2017 applies.

6.17 ~~Liquid tightness~~ Tightness for liquid systems

~~Subclause 5.16 of IEC 62271-1:2007 is applicable.~~

Subclause 6.17 of IEC 62271-1:2017 applies.

6.18 Fire hazard (flammability)

~~Subclause 5.17 of IEC 62271-1:2007 is applicable.~~

Subclause 6.18 of IEC 62271-1:2017 applies.

6.19 Electromagnetic compatibility (EMC)

~~Subclause 5.18 of IEC 62271-1:2007 is applicable.~~

Subclause 6.19 of IEC 62271-1:2017 applies.

6.20 X-ray emission

~~Subclause 5.19 of IEC 62271-1:2007 is applicable.~~

Subclause 6.20 of IEC 62271-1:2017 applies.

6.21 Corrosion

~~Subclause 5.20 of IEC 62271-1:2007 is applicable.~~

Subclause 6.21 of IEC 62271-1:2017 applies.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 applies.

6.101 Linkages between the fuse striker(s) and the switch release

The linkages between the fuse striker(s) and the switch release shall be such that the switch operates satisfactorily under both three-phase and single-phase conditions at the minimum and maximum requirements of a given type of striker (medium or heavy) irrespective of the method of striker operation (spring or explosive). The requirements for strikers are given in IEC 60282-1:2020. This requirement is considered to be demonstrated by the tests specified for test duties $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$ and mechanical operation tests.

6.102 Low over-current conditions (long fuse-pre-arcing time conditions)

The switch-fuse combination shall be designed so that the combination will perform satisfactorily at all values of breaking current from the rated maximum breaking current of the fuse down to the minimum melting current under low over-current conditions. This is achieved by compliance with the following:

- a) time coordination between switch and fuse is provided by either 1), 2) or 3) below:
 - 1) the fuse-initiated opening time of the switch-fuse combination shall be shorter than the maximum arcing time the fuse can withstand as specified in IEC 60282-1:2020;

NOTE Tests have been introduced in IEC 60282-1 in order to assess that the maximum arcing withstand time of the fuse under long pre-arcing conditions is at least 100 ms.
 - 2) where the fuse manufacturer can show that the fuse has been satisfactorily proven at all values of breaking current from the rated maximum breaking current of the fuse down to the rated minimum melting current of the fuse in the combination (i.e. full range fuses) then the fuse-initiated opening time of the switch-fuse combination is deemed not relevant;
 - 3) where it can be shown that the thermal release of the fuse striker makes the switch clear the current before arcing in the fuse can occur, for all currents below I_3 (minimum breaking current of the fuse in accordance with IEC 60282-1:2020);
- b) temperature rise under these conditions does not impair the performances of the combination as proven by the test described in 7.104.

7 Type tests

~~Clause 6 of IEC 62271-1:2007 is applicable, with the additions and exceptions indicated below.~~

~~NOTE All tolerances are defined in Annex C.~~

7.1 General

7.1.1 Basics

~~Subclause 6.1 of IEC 62271-1:2007 is replaced as follows:~~

Subclause 7.1.1 of IEC 62271-1:2017 applies with the following additions:

The purpose of type tests is to prove the characteristics of switch-fuse combinations, their operating devices and their operating equipment.

It is required that the switch of the combination has been tested as an individual component for compliance with IEC 62271-103:2021, except for the short-time withstand current and short-circuit making current requirements, because these parameters will be influenced by the fuses.

Furthermore, it is ~~understood~~ required that the fuses have been tested to the applicable requirements of IEC 60282-1:2020.

Type tests include:

- ~~dielectric tests;~~
- ~~temperature-rise tests;~~
- ~~measurement of the resistance of the main circuit;~~
- ~~tests to prove the ability of the combination to make and break the specified currents;~~
- ~~tests to prove the satisfactory mechanical operation and endurance;~~
- ~~verification of the degree of protection provided by enclosures;~~
- ~~tightness tests;~~
- ~~electromagnetic compatibility tests.~~

For combinations, three groups of tests are involved:

- a) tests on the switch in accordance with IEC 62271-103:2021; these tests may be carried out on a combination other than that used for tests c);
- b) tests on the fuse in accordance with IEC 60282-1:2020;
- c) tests on the combination in accordance with this document.

In the case of a fuse-switch, the tests of IEC 62271-103:2021 and the tests of 7.102 of this document shall be carried out after replacing, as specified, the fuses with solid links of the same shape, dimension and mass as that of the fuses.

The combination submitted for test shall be in new condition with clean contact parts and fitted with the appropriate fuses.

6.1.1 Grouping of tests

~~Subclause 6.1.1 of IEC 62271-1:2007 is applicable with the following additions:~~

- ~~Short circuit making and breaking tests may be performed on an additional specimen;~~
- ~~Additional test samples may be used for additional type tests.~~

7.1.2 Information for identification of ~~specimens~~ test objects

~~Subclause 6.1.2 of IEC 62271-1:2007 is applicable.~~

Subclause 7.1.2 of IEC 62271-1:2017 applies.

7.1.3 Information to be included in type-test reports

~~Subclause 6.1.3 of IEC 62271-1:2007 is applicable.~~

Subclause 7.1.3 of IEC 62271-1:2017 applies.

7.2 Dielectric tests

~~Subclause 6.2 of IEC 62271-1:2007 is applicable with the following additions:~~

~~6.2.9 Partial discharge tests~~

~~Subclause 6.2.9 of IEC 62271-1:2007 is replaced by the following:~~

~~No partial discharge tests are required on the complete combination. However, components shall comply in this respect with their relevant IEC standards.~~

Subclause 7.2 of IEC 62271-1:2017 and 7.4 of IEC 60282-1:2020 apply.

7.3 Radio interference voltage (RIV) test

~~Subclause 6.3 of IEC 62271-1:2007 is applicable.~~

RIV tests are not required.

7.4 ~~Measurement of the resistance of circuits~~ Resistance measurement

~~Subclause 6.4 of IEC 62271-1:2007 is applicable with the following addition:~~

~~Solid links of negligible resistance shall be used instead of fuses and the resistance of the links shall be recorded.~~

Subclause 7.4 of IEC 62271-1:2017 applies with the following addition:

Solid links of negligible resistance shall be used instead of fuses and the resistance of the links shall be recorded.

7.5 ~~Temperature-rise~~ Continuous current tests

~~Subclause 6.5 of IEC 62271-1:2007 is applicable with the following additions:~~

~~The temperature-rise tests of the combination shall be carried out at the rated normal currents of the combination with all fuses of the reference list. However, the number of tests may be reduced by applying the criteria of 6.105.2.~~

Subclause 7.5 of IEC 62271-1:2017 applies with the following additions:

The continuous current tests of the combination shall be carried out at the rated continuous currents of the combination with all fuses of the reference list. However, the number of tests may be reduced by applying the criteria of 7.105.2.

The power (in W) dissipated by each individual (1-phase) fuse-link just before the end of the test period shall be recorded in the type test report.

NOTE 1 The power dissipated by the fuse is defined by the product of the applied AC continuous test current (RMS value) and the measured steady voltage drop across the fuse-link.

NOTE 2 The voltage drop is measured on the fuse-link contacts as close as possible to the point of contact with the immediate mating contact piece.

Reference of fuse-links used for the test, or tests, shall be recorded in the test report.

As long as IEC 60282-1:2020 provide different temperature rise limits compared to IEC 62271-1:2017, the lower values are applicable.

7.6 Short-time withstand current and peak withstand current tests

~~Subclause 6.6 of IEC 62271-1:2007 is not applicable.~~

Subclause 7.6 of IEC 62271-1:2017 does not apply.

7.7 Verification of the protection

~~Subclause 6.7 of IEC 62271-1:2007 is applicable.~~

Subclause 7.7 of IEC 62271-1:2017 applies.

7.8 Tightness tests

~~Subclause 6.8 of IEC 62271-1:2007 is applicable.~~

Subclause 7.8 of IEC 62271-1:2017 applies.

7.9 Electromagnetic compatibility tests (EMC)

~~Subclause 6.9 of IEC 62271-1:2007 is applicable.~~

Subclause 7.9 of IEC 62271-1:2017 applies.

7.10 Additional tests on auxiliary and control circuits

~~Subclause 6.10 of IEC 62271-103:2011 is applicable.~~

Subclause 7.10 of IEC 62271-103:2021 applies.

7.11 X-radiation test ~~procedure~~ for vacuum interrupters

~~Subclause 6.11 of IEC 62271-1:2007 is applicable with the following addition.~~

~~As this test is independent of the switching device, but only applied to the interrupters (vacuum bottles) alone as a component, the test results can be valid for several types of switching devices provided the type of interrupter is properly identified and the tested open gap spacing is lower than used in the switch fuse combination.~~

Subclause 7.11 of IEC 62271-1:2017 applies.

7.101 Making and breaking tests

7.101.1 General

~~This clause contains four test duties:~~

Subclause 7.101.1 describes four independent test duties:

- $TD_{I_{sc}}$: making and breaking tests at the rated short-circuit current;
- $TD_{I_{Wmax}}$: making and breaking tests at the maximum breaking I^2t ;
- $TD_{I_{transfer}}$: breaking tests at the rated transfer current;
- $TD_{I_{to}}$: breaking tests at the rated take-over current.

7.101.2 Conditions for performing the tests

7.101.2.1 Condition of the combination before testing

~~The combination under test shall be mounted complete on its own support or on an equivalent support. Its operating device shall be operated in the manner specified and, in particular, if it is electrically or pneumatically operated, it shall be operated at the minimum voltage or gas pressure respectively as specified in 4.8 and 4.10 of IEC 62271-1:2007, unless current chopping influences the test results. In the latter case, the combination shall be operated at a voltage or gas pressure within the tolerances specified for 4.8 and 4.10 of IEC 62271-1:2007, chosen so as to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.~~

The combination under test shall be mounted in accordance with the manufacturer's instructions, on a specified or equivalent support. Its operating device shall be operated in the manner specified and in particular, if it is electrically or pneumatically operated, it shall be operated at the minimum voltage or gas pressure respectively as specified in 5.9 and 5.11 of IEC 62271-1:2017, unless current chopping influences the test results. In the latter case, the combination shall be operated at a voltage or gas pressure within the tolerances specified in 5.9 and 5.11 of IEC 62271-1:2017, chosen so as to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

It shall be shown that the combination will operate satisfactorily under the above conditions on no-load.

Combinations with independent ~~manual~~ unlatched operation may be operated by an arrangement provided for the purpose of making remote control possible.

Due consideration shall be given to the choice of the ~~live~~ supply side connections. When the combination is intended for power supply from either side, and the physical arrangement of one side of the break, or breaks, of the combination differs from that of the other side, the ~~live~~ supply side of the test circuit shall be connected to the side of the combination which gives the more onerous condition. In case of doubt, the test-duty shall be repeated with the supply connections reversed, but for test duties comprising identical tests, one test shall be made with the supply connected to one side and the following test(s) with the supply connected to the other side.

The fuses selected for the tests shall be chosen so that the result of the test duties are deemed valid for all combinations made of the same combination base and any fuse of the reference list. For the tests of take-over current of release-operated combinations, over-current relays or releases (where fitted) shall be of the lowest release-initiated opening time ~~associated with these fuses~~. The tests shall be carried out at ambient temperature and without previous loading, ~~unless otherwise specified~~. If applicable, test shall be performed at the minimum functional pressure for insulation and/or switching.

7.101.2.2 Test frequency

~~Combinations shall be tested at rated frequency with a tolerance of $\pm 8\%$. However, for convenience of testing, some deviations from the above tolerance are allowed; for example, when combinations rated at 50 Hz are tested at 60 Hz and vice versa, care should be taken in the interpretation of the results, taking into account all significant facts such as the type of the combination and the type of tests performed.~~

~~In some cases, the rated characteristics of a combination when used on a 60 Hz system may be different from its rated characteristics when used on a 50 Hz system.~~

Combinations shall be tested at rated frequency, with a tolerance as stated in Table C.1, Annex C.

Combinations may be tested at 50 Hz or 60 Hz to cover both frequencies with the testing conditions given in Table 2.

Table 2 – Summary of the conditions for combining tests and alternative procedures

Test duty	Performed at 50 Hz, and also valid for 60 Hz	Performed at 60 Hz, and also valid for 50 Hz
$TD_{I_{transfer}}$, $TD_{I_{to}}$	If a derating factor of 1,2 ^a is applied to the rated transfer current and to the rated take-over current	yes
$TD_{I_{sc}}$, $TD_{I_{Wmax}}$	yes ^b	yes ^b
^a The factor 1,2 reflects the higher di/dt at 60 Hz. In the case of a switch-fuse combination of a rated transfer current of 1 000 A tested at 50 Hz, a rated transfer current of 833 A may be assigned at 60 Hz without any other additional tests. ^b During $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$, current-limiting fuses reduce significantly the peak current and force the current to zero before the natural zero of the circuit. Within certain limits (from 48 Hz to 62 Hz), frequency is not a critical parameter for current-limiting fuses (see 7.6.1.4 of IEC 60282-1:2020 and 4.2.3.5 of IEC TR 62655:2013) and in such case the current should be cleared only by fuses. Therefore peak factors of 2,6 usually considered for 60 Hz, are irrelevant for switch-fuse combinations.		

7.101.2.3 Power factor

The power factor of the test circuit shall be determined by measurement and shall be taken as the average of the power factors in each phase.

During the tests, the average value shall conform to the values given in 7.101.3.1, 7.101.3.2, 7.101.3.3 and 7.101.3.4.

7.101.2.4 Arrangement of test circuits

For test duties $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$, the combination shall ~~preferably~~ be connected in a circuit having the neutral point of the supply isolated and the neutral point of the three-phase short-circuit earthed, as shown in Figure 1a). When the neutral point of the test supply cannot be isolated, it shall be earthed and the three-phase short-circuit point shall be isolated as shown in Figure 1b).

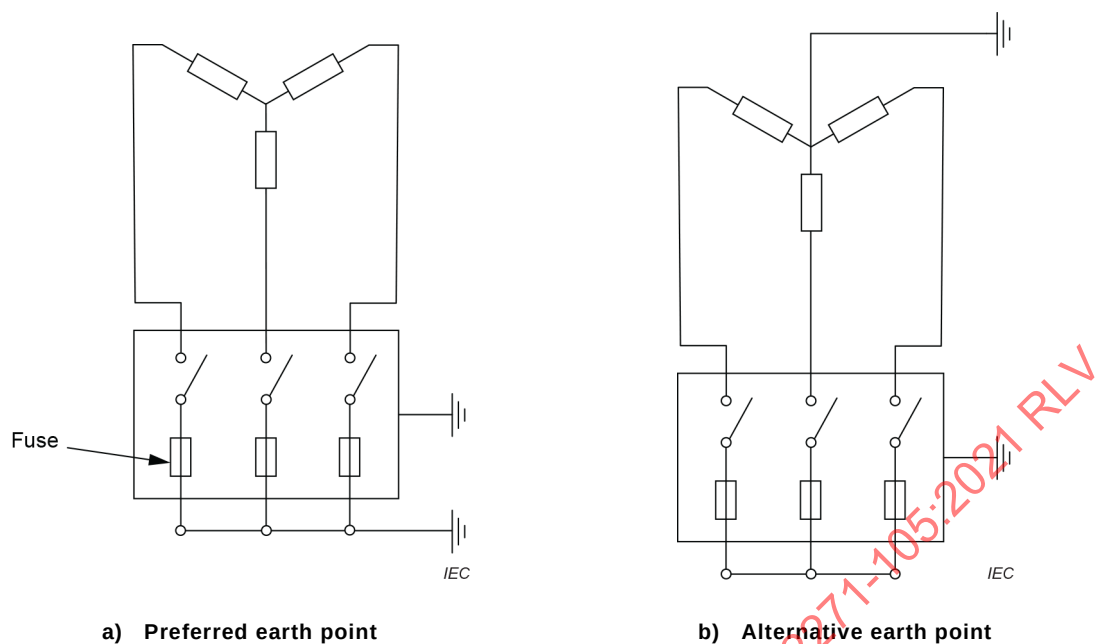


Figure 1 – Arrangement of test circuits for test duties TD_{isc} and TD_{iwmax}

For test duties $TD_{ltransfer}$ and TD_{lto} , the combination shall be connected in a circuit as shown in Figure 2 and Figure 3, respectively.

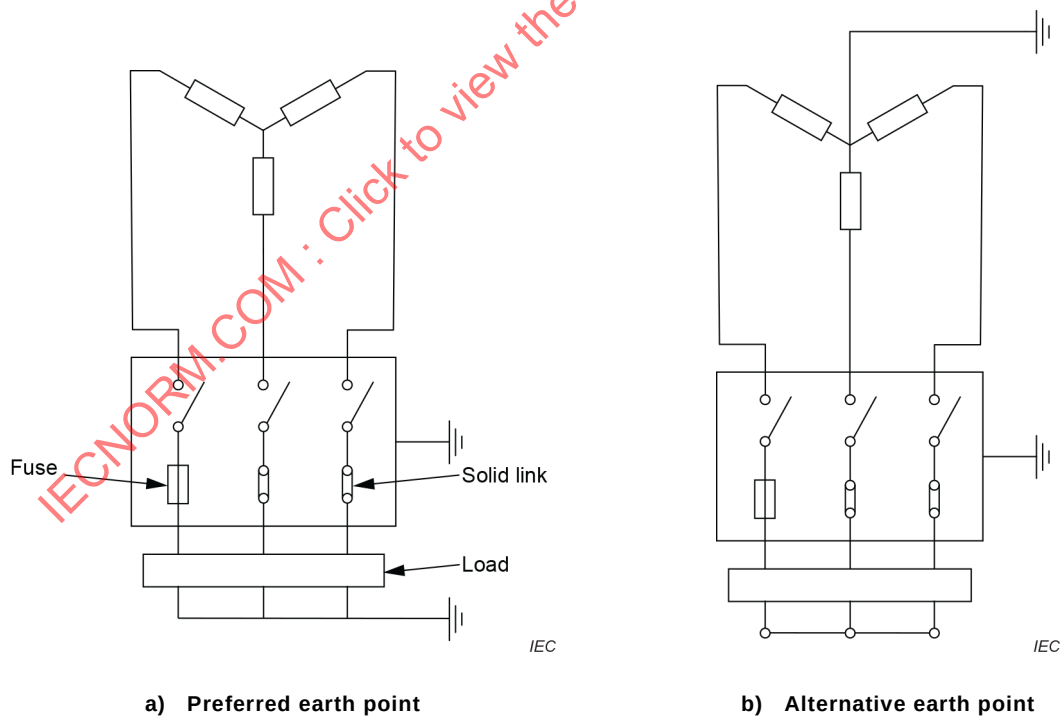


Figure 2 – Arrangement of test circuits for test-duty $TD_{ltransfer}$

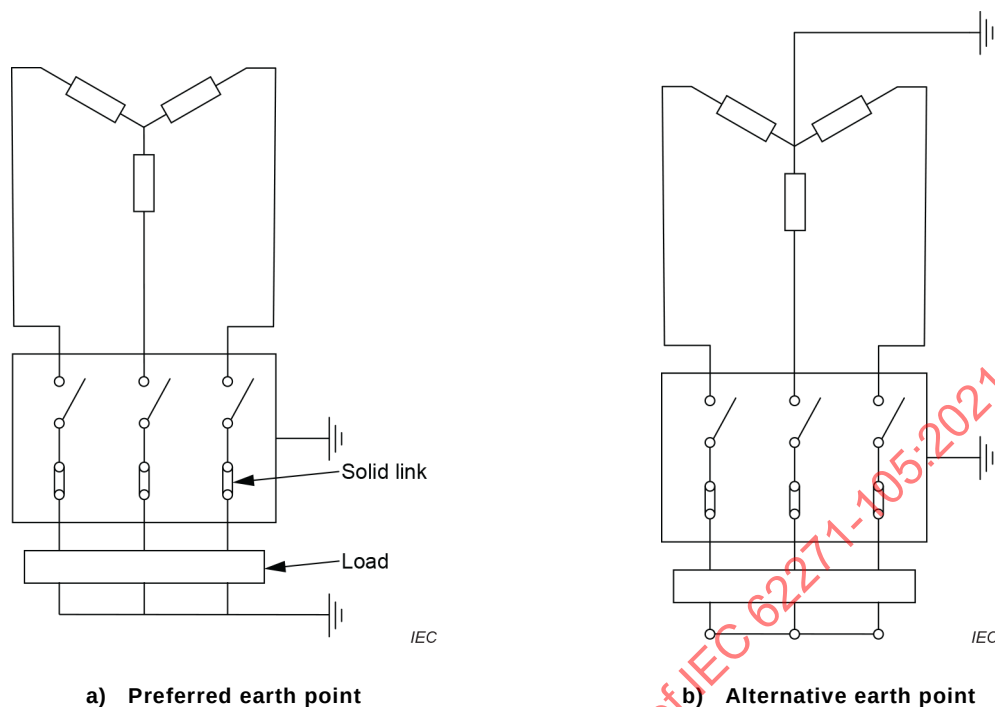


Figure 3 – Arrangement of test circuits for test-duty TD_{It0}

For combinations producing an emission of flame or metallic particles, the tests shall be made with metallic screens placed in the vicinity of the live parts, separated from them by a clearance distance which the manufacturer shall specify.

~~The screens, frame and other normally earthed parts shall be insulated from earth but connected thereto through a fuse consisting of a copper wire of 0,1 mm diameter and 50 mm in length. The fuse wire may also be connected to the secondary side of a 1:1 ratio current transformer. The terminal of the current transformer should be protected by a spark gap or surge arrester. No significant leakage is assumed to have occurred if this wire is intact after the test.~~

The screens, frame and other normally earthed parts shall be insulated and then connected to earth through a current indicating device. The current indicating device can be a fuse consisting of a copper wire of 0,1 mm diameter and 5 cm in length, or a link to earth across a sensor to measure the current. The fuse wire may also be connected to the secondary side of a 1:1 ratio current transformer. The terminals of the current transformer should be protected by a spark gap or surge arrester. No significant leakage is assumed to have occurred if the wire is intact after the test or if the Joule integral of the leakage current is less than 5 A²s from arc establishing up to 100 ms.

7.101.2.5 Test voltage for breaking tests

The test voltage is the average of the phase-to-phase voltages measured at the combination location immediately after the breaking operation.

The voltage shall be measured as close as practicable to the terminals of the combination, i.e. without appreciable impedance between the measuring point and the terminals.

~~The test voltage, in the case of three-phase tests, shall be, as nearly as possible, equal to the rated voltage of the combination.~~

~~The tolerance on the average value is $\pm 5\%$ of the specified value, and the tolerance on any phase to the average value is $\pm 20\%$.~~

The test voltage shall be equal to the rated voltage of the combination with a tolerance on the average value of $\pm 5\%$ and a tolerance on any phase to the average value of $\pm 20\%$.

7.101.2.6 Power-frequency recovery voltage

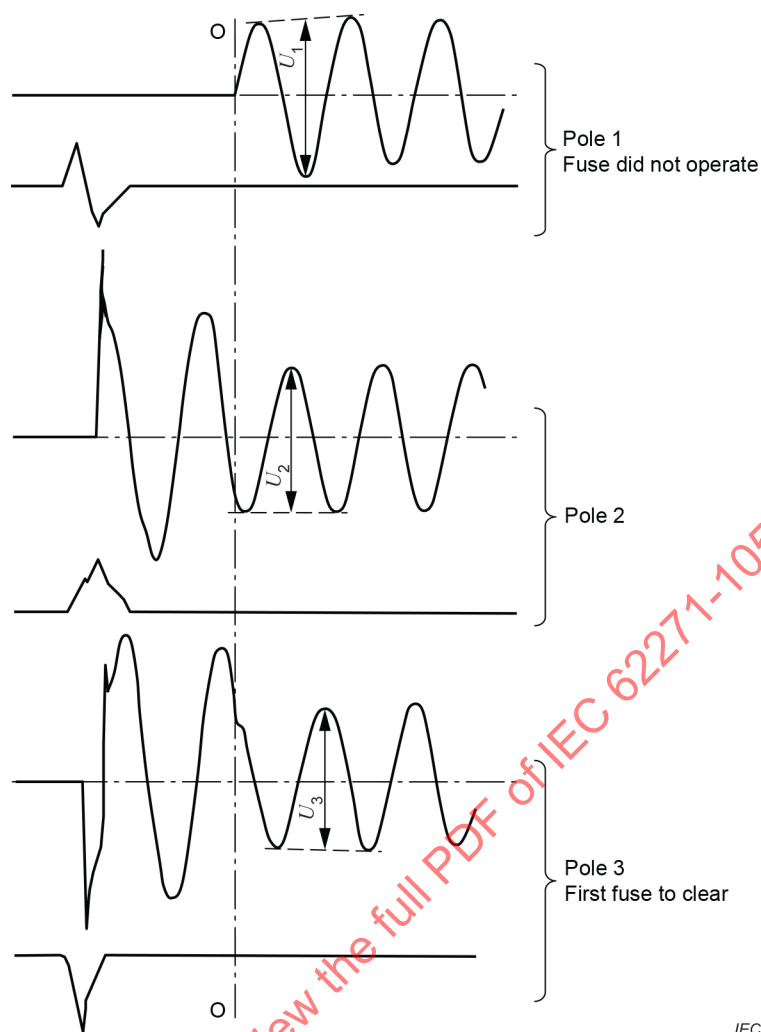
The power-frequency recovery voltage shall be maintained for at least 0,3 s after arc extinction.

The power-frequency recovery voltage of a three-phase test circuit shall be the average value of the power-frequency recovery voltages in all phases measured after the opening of the switch.

The power-frequency recovery voltage of the test circuit shall be measured between the terminals of each pole of the combination in each phase of the test circuit.

The power-frequency recovery voltage shall be measured one cycle after the opening of the switch in accordance with Figure 4.

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Key $U_1/2\sqrt{2}$ voltage of pole 1 $U_2/2\sqrt{2}$ voltage of pole 2 $U_3/2\sqrt{2}$ voltage of pole 3

OO instant of opening of mechanical switching device

$$\text{Average voltage of poles 1, 2 and 3} = \frac{\frac{U_1}{2\sqrt{2}} + \frac{U_2}{2\sqrt{2}} + \frac{U_3}{2\sqrt{2}}}{3}$$

Figure 4 – Determination of power-frequency recovery voltage**7.101.2.7 Applied voltage before short-circuit making tests**

The applied voltage (see ~~3.7.114~~ 3.7.112) before the short-circuit making tests in test duties TD_{ISC} and TD_{IWmax} is the RMS value of the voltage at the pole terminals immediately before the test.

The average value of the applied three-phase voltages shall be not less than the rated voltage of the combination divided by $\sqrt{3}$ and shall not exceed this value by more than 10 % without the consent of the manufacturer.

The difference between the average value and the applied voltages of each phase shall not exceed 5 % of the average value.

7.101.2.8 Breaking current

For test duties TD_{Isc} and TD_{IWmax} , the RMS value of the AC component of the prospective short-circuit breaking current shall be measured one half-cycle after the initiation of the short-circuit in the prospective current test.

For test duties $TD_{Itransfer}$ and TD_{It0} , the breaking current shall be the RMS value of the AC component measured at the initiation of arcing.

For test duties TD_{Isc} , TD_{IWmax} and TD_{It0} , the RMS value of the AC component of the breaking current in any pole shall not vary from the average by more than 10 %. For test-duty $TD_{Itransfer}$, the RMS value of the AC component of the breaking current in the two poles fitted with solid conducting links shall be not less than $(\sqrt{3})/2$, i.e. 87 % of that in the first-pole-to-clear, i.e. the pole fitted with a fuse.

7.101.2.9 Transient recovery voltage TRV

The prospective TRV of a test circuit shall be determined by such a method as will produce and measure the TRV wave without significantly influencing it and shall be measured at the terminals to which the combination will be connected with all necessary test-measuring devices, such as voltage dividers, included. Suitable methods are described in ~~Annex F of IEC 62271-100:2008~~ Annex E of IEC 62271-100:2021. The TRV refers to the first-pole-to-clear, i.e. the voltage across one open pole with the other two poles closed, with the appropriate test circuit arranged in accordance with 7.101.2.4.

The prospective TRV curve of a test circuit is represented by its envelope drawn as shown in Figure 5 and by its initial portion.

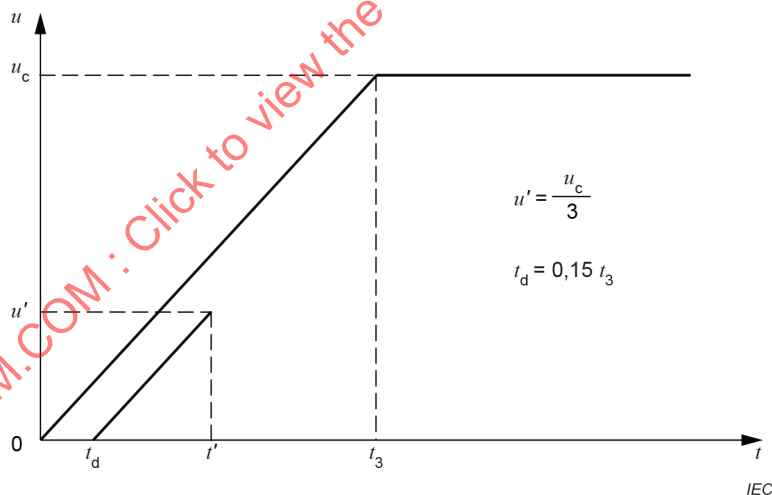


Figure 5 – Representation of a specified TRV by a two-parameter reference line and a delay line

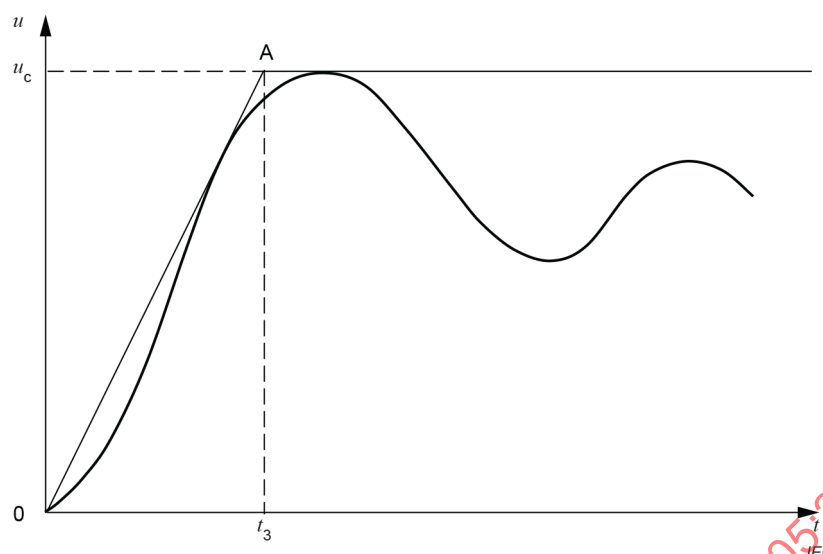


Figure 6 – Example of a two-parameter reference line for a TRV

The prospective TRV wave of the test circuit shall comply with the following requirements (see example in Figure 6):

- a) Its envelope shall at no time be below the specified reference line.

It is stressed that the extent by which the envelope may exceed the specified reference line requires the consent of the manufacturer.

- b) Its initial portion shall not cross the delay line where such a ~~one~~ delay is specified.

7.101.3 Test-duty procedures

7.101.3.1 Test-duty $TD_{I_{sc}}$ – Making and breaking tests at the rated short-circuit current

This test-duty is performed to show that the switch is capable of withstanding and making the cut-off current of the fuse without damage and that the striker will open the switch at this current. The test is carried out with fuses fitted in all three poles of the combination.

One break and then one make-break test shall be made in a three-phase circuit, having prospective current equal to the rated short-circuit breaking current of the combination with a tolerance of $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \%$.

The power factor of the test circuit shall be 0,07 to 0,15 lagging.

The applied voltage shall be in accordance with 7.101.2.7.

The power-frequency recovery voltage (see 7.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is $\pm 5 \%$ of the specified value, and the tolerance on any phase to the average value is $\pm 20 \%$.

~~The prospective transient recovery voltage shall be in accordance with 4.102 and 6.101.2.9.~~

The prospective TRV shall be in accordance with 7.101.2.9 and the values specified in test-duty 1 of IEC 60282-1:2020.

The breaking test of this test-duty shall be made with the initiation of arcing in the fuse in one of the outer poles in accordance with the provisions of test-duty 1 of IEC 60282-1:2020, i.e. to be within the range of 65 to 90 electrical degrees after voltage zero in that pole.

7.101.3.2 Test-duty $TD_{IW_{max}}$ – Making and breaking tests at the maximum breaking I^2t

When carried out, its purpose is to verify the performance of the combination with a prospective current approximating to that producing the maximum I^2t for the switch-fuse combination. The test is carried out with fuses fitted in all three poles of the combination.

~~Combinations in which the switch closes fully home before opening under the action of the fuse striker, and has been subjected, under IEC 62271-103 conditions, to two make tests at a peak current value not less than 2,5 times I_2 (50 Hz) or 2,6 times I_2 (60 Hz), and a short time test for a duration of not less than 0,1 s at a current value not less than I_2 (i.e. the prospective short-circuit current for test duty 2 of IEC 60282-1) are exempt from test-duty $TD_{IW_{max}}$ of this standard.~~

This test-duty may be omitted if all of the following requirements are met:

- combinations in which the switch closes fully home before opening under the action of the fuse striker;
- the switch used has been subjected, under IEC 62271-103:2021 conditions, to two make tests at a peak current value not less than 2,5 times I_2 (50 Hz) or 2,6 times I_2 (60 Hz).

A short-time test for a duration of not less than 0,1 s at a current value not less than I_2 (i.e. the prospective short-circuit current for test-duty 2 of IEC 60282-1:2020).

NOTE For other peak factors/time constants refer to NOTE 2 of 5.102.

This test-duty may be also omitted if the fuse or fuses tested in the combination to test-duty TD_{Isc} of this document have a higher published value of I^2t under test-duty 1 of IEC 60282-1:2020 than under test-duty 2 of IEC 60282-1:2020.

One break and one make-break test shall be made in a three-phase circuit having a prospective current within ± 10 % of that prospective current required ~~to verify the value of I^2t of IEC 60282-1 for the fuse design incorporated in the combination.~~

The power factor of the test circuit shall be between 0,07 to 0,15 lagging.

The applied voltage shall be in accordance with 7.101.2.7. For the breaking test of this test-duty, the operation shall be made with point-on-wave closure of the circuit so that current commences between 0 and 20 electrical degrees after voltage zero on any one phase.

The power-frequency recovery voltage (see 7.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % of the specified value, and the tolerance on any phase to the average value is ± 20 %.

The prospective TRV shall be in accordance with 7.101.2.9 and the values specified in test-duty 2 of IEC 60282-1:2020.

7.101.3.3 Test-duty $TD_{I_{transfer}}$ – Breaking tests at the rated transfer current

This test-duty is performed to prove the correct coordination between the switch and fuses in the current region where the breaking duty is transferred from the fuses to the switch (see 3.7.108 and Annex B).

Test-duty $TD_{I_{transfer}}$ may be omitted in the case of release-operated combinations if the **rated** take-over current is equal to or higher than the **rated** transfer current.

Three break tests shall be made in a three-phase circuit, as shown in Figure 2a) or Figure 2b), with the fuses in two poles replaced by solid links of negligible impedance. The pair of poles with the solid links shall be different on each of the three breaking tests. In the case of fuse-switches, the solid links shall be of the same shape, dimension and mass as those of the fuses they replace.

If this arrangement of one fuse on one pole and two solid links on the two other poles is not practicable for the testing laboratory, then the fuse ~~may~~ **could** be omitted and the switch tripped in some other way. In the case of fuse-switches, the fuse shall be replaced by either a dummy fuse (for example ~~a blown~~ **an operated** fuse-link) or an insulating link of the same shape, dimension and mass as those of the fuse.

The test circuit shall consist of a three-phase supply and load circuit (see Figure 2a) ~~and~~ or Figure 2b)).

The load circuit shall be an R-L series connected circuit.

The supply circuit shall have a power factor not exceeding 0,2 lagging and shall meet the following requirements:

- a) the symmetrical component of the short-circuit breaking current of the supply circuit shall neither exceed the rated short-circuit breaking current of the combination nor be less than 5 % of this current;
- b) the impedance of the supply circuit shall be between 12 % and 18 % of the total impedance of the test circuit for test-duty $TD_{I_{transfer}}$. If, due to limitations of the testing station, this condition cannot be met, the percentage may be lower, but it shall be ensured that the resulting prospective TRV is not less severe;
- c) the prospective TRV of the supply circuit under short-circuit conditions shall be in accordance with **test duty 1** of IEC 60282-1:2020.

NOTE 1 For more information about TRV during tests refer to the notes in Table 8 of IEC 62271-103:2021.

The power factor of the load circuit, determined in accordance with 7.101.2.3, shall be:

- between 0,2 to 0,3 lagging if the breaking current exceeds 400 A;
- between 0,3 to 0,4 lagging if the breaking current is equal to or less than 400 A.

The test voltage shall be in accordance with 7.101.2.5.

The power-frequency recovery voltage shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % and the tolerance on any phase voltage to the average value is ± 20 %.

The prospective TRV of the load circuit, ~~for calibration purposes~~, shall be in accordance with 7.101.2.9 and Table 3 or Table 4, as appropriate. A delay line is not specified.

Table 3 – ~~Standard~~ Values of prospective TRV for test-duty TD_{transfer} based on practice in Europe

Rated voltage U_r kV	TRV peak voltage u_c kV	Time t_3 μs	Rate-of-rise u_c/t_3 kV/ μs
3,6	6,2	80	0,077
7,2	12,3	104	0,115
12	20,6	120	0,167
17,5	30	144	0,208
24	41	176	0,236
36	62	216	0,285
$u_c = 1,4 \times 1,5 \times U_r \frac{\sqrt{2}}{\sqrt{3}}$			

Table 4 – ~~Standard~~ Values of prospective TRV for test-duty TD_{transfer} based on practice in the United States of America ~~and Canada~~

Rated voltage U_r kV	TRV peak voltage u_c kV	Time t_3 μs	Rate-of-rise u_c/t_3 kV/ μs
2,8	4,8	74	0,065
5,5	9,4	92	0,103
8,3	14,2	108	0,132
15	25,7	132	0,195
15,5	26,6	134	0,198
27	46,3	186	0,249
38	65,2	222	0,293
$u_c = 1,4 \times 1,5 \times U_r \frac{\sqrt{2}}{\sqrt{3}}$			

NOTE 1—Tables 2 and 3 give three phase values and refer to the first pole-to-clear, i.e. the pole with the fuse (or dummy fuse/insulating link).

NOTE 2—The values shown in Tables 2 and 3 are applicable to typical installations involving transfer currents of lower value than those arising from solid short-circuits in the transformer secondary terminal zone; the latter are normally cleared by the fuses. However, they may not be appropriate for an application requiring the clearing of such terminal-zone faults by the switch. Such a condition of application is subject to agreement between the user and the manufacturer.

NOTE 2 Table 3 and Table 4 give TRV for the first-pole-to-clear, i.e. the pole with the fuse (or dummy fuse/insulating link).

NOTE 3 For more information about TRV during tests refer to the notes in Table 8 of IEC 62271-103:2021.

NOTE 4 It is recognized that the TRV values obtained during the test will differ from prospective values shown in Table 3 and Table 4, due both to the influence of the supply circuit and the power factor of the load.

7.101.3.4 Test-duty TD_{ItO} – Breaking tests at the rated take-over current (release-operated combinations only)

This test-duty is mandatory for release-operated combinations only and is performed to prove the correct coordination between the release-operated switch and fuses in the current region where the breaking duty is taken over from the fuses by the release-operated switch.

Three break tests shall be made in a three-phase circuit, as shown in Figure 3, with the fuses in all three poles replaced by solid links of negligible impedance. In the case of fuse-switches, the solid links shall be of the same shape, dimension and mass as those of the fuses they replace.

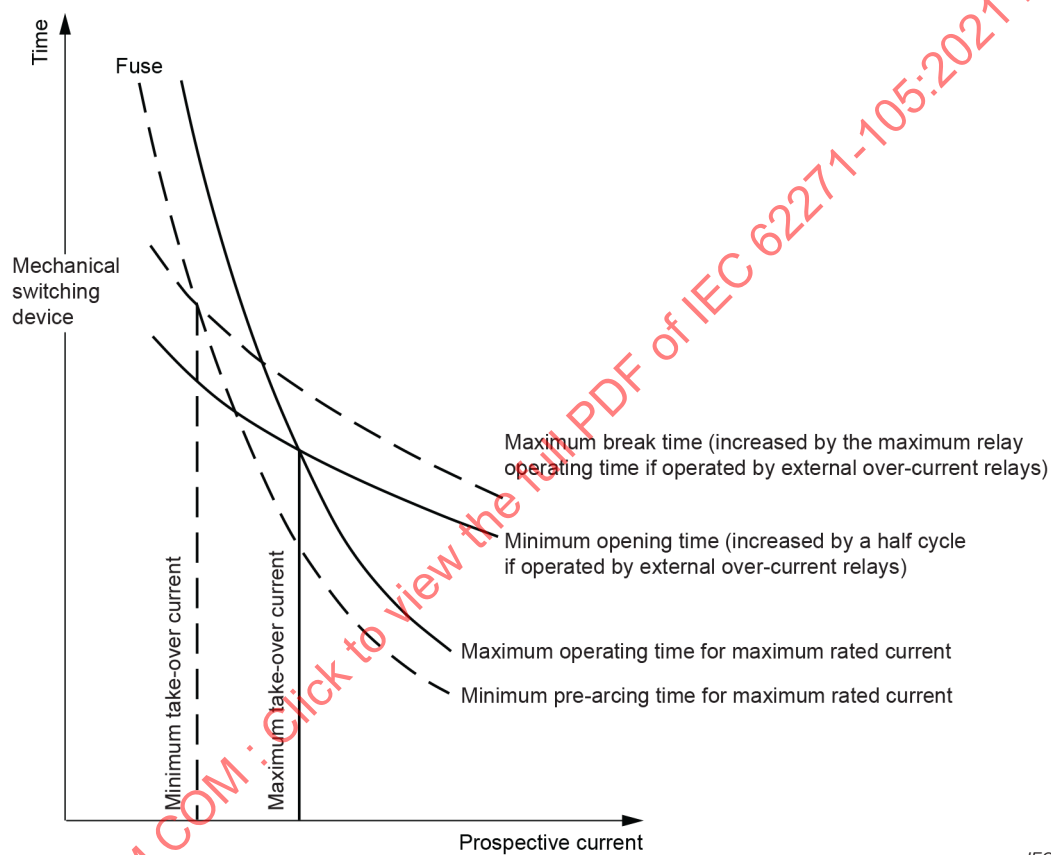
The test circuit shall be the same as for test-duty TD_{transfer} .

The test current value corresponds to

- the minimum release-initiated opening time of the switch plus, ~~where applicable~~, a half cycle time to represent the minimum operating time of an external over-current or an earth-fault relay;
- the maximum operating time of the fuses of highest rated current.

See Figure 7.

NOTE Figure 7 represents for the minimum and maximum release-initiated opening time of the switch, the case of a direct over-current release.



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Figure 7 – Characteristics for determining take-over current

7.101.3.5 Summary of test parameters

A summary of the parameters to be used when performing test duties is given in Table 5.

Table 5 – Summary of test parameters for test duties

Test-duty		Test voltage	Test current/making angle	Test series	Power factor	TRV
No	Circuit					
TD _{Isc}	3-phase Figure 3	U_r	See 6.101.3.1 of this standard	O CO	0,07 to 0,15 lagging	See test-duty 1 of IEC 60282-1
TD _{IWmax}	3-phase Figure 3	U_r	See 6.101.3.2 of this standard	O CO	0,07 to 0,15 lagging	See test-duty 2 of IEC 60282-1
TD _{Itransfer}	3-phase/ 2-phase Figure 2	U_r	$I_{transfer}$ or ($0,87I_{transfer}$) See 6.101.3.3 of this standard	O O O	$I_{transfer} > 400\text{ A}$ 0,2 to 0,3 lagging $I_{transfer} \leq 400\text{ A}$ 0,3 to 0,4 lagging	Tables 2 and 3 of this standard
TD _{Ito}	3-phase Figure 3	U_r	I_{to} See 6.101.3.4 of this standard	O O O	$I_{to} > 400\text{ A}$ 0,2 to 0,3 lagging $I_{to} \leq 400\text{ A}$ 0,3 to 0,4 lagging	Tables 2 and 3 of this standard
NOTE – The power factors relating to test duties TD _{Itransfer} and TD _{Ito} refer to the load circuit.						

Test-duty		Test voltage	Test current/making angle	Test series	Power factor	TRV
No	Circuit					
TD _{Isc}	Figure 1	U_r	See 7.101.3.1	O CO	0,07 to 0,15 lagging	See test-duty 1 of IEC 60282-1:2020.
TD _{IWmax}	Figure 1	U_r	See 7.101.3.2	O CO	0,07 to 0,15 lagging	See test-duty 2 of IEC 60282-1:2020.
TD _{Itransfer}	Figure 2	U_r	$I_{transfer}$ See 7.101.3.3	O O O	$I_{transfer} > 400\text{ A}$ 0,2 to 0,3 lagging $I_{transfer} \leq 400\text{ A}$ 0,3 to 0,4 lagging	Table 3 and Table 4
TD _{Ito}	Figure 3	U_r	I_{to} See 7.101.3.4	O O O	$I_{to} > 400\text{ A}$ 0,2 to 0,3 lagging $I_{to} \leq 400\text{ A}$ 0,3 to 0,4 lagging	Table 3 and Table 4
NOTE The power factors relating to test duties TD _{Itransfer} and TD _{Ito} refer to the load circuit.						

7.101.4 Behaviour of the combination during tests

The combination may be inspected but not reconditioned (apart from the replacement of fuses) between any of the test duties which shall all be done on one ~~sample~~ test object.

During operation, the combination shall show neither signs of ~~excessive~~ electrical or mechanical distress nor phenomena that might endanger an operator, verified as follows.

- From liquid-filled combinations there shall be no outward emission of flame, and the gases produced together with the liquid carried with the gases shall be allowed to escape in such a way as not to cause electrical breakdown.
- For other types of combinations, flame or metallic particles such as might impair the insulation level of the combination shall not be projected beyond the boundaries specified by the manufacturer.
- No significant leakage current is assumed to have flowed if the fuse wire defined in 7.101.2.4 is intact after the test.

During test duties TD_{ISC} and TD_{IWmax} , the switch shall open following the action of the fuse strikers.

For combinations with vacuum switches, non-sustained disruptive discharges (NSDDs) may occur during the recovery voltage period following a breaking operation. However, their occurrence is not a sign of distress of the switching device under test and they do not pose any risk to a system in service. Therefore, their number is of no significance in the interpretation of the performance of the device under test. Where NSDDs are seen during normal testing they shall be reported in order to explain the irregularities in the recovery voltage.

All three fuses should be replaced, regardless of whether they have operated during the test or not.

NOTE In three-phase operations, one fuse and/or its striker may not have operated during testing. This is a normal and not unusual condition which will not invalidate acceptance of the test provided that the fuse shall not have received external damage in any way.

7.101.5 Condition of the apparatus after testing

After testing, fuses shall comply with the requirements of ~~5.1.3 of IEC 60282-1:2009~~ 6.1.3 of IEC 60282-1:2020.

After performing each test-duty:

- The mechanical function and the insulators of the combination shall be practically in the same condition as before the tests. There may be deposits on the insulators caused by the decomposition of the arc-extinguishing medium.
- The combination shall, without reconditioning, be capable of withstanding its rated voltage without dielectric failure.
- For those combinations which incorporate a switch-disconnector, the isolating properties of the switch-disconnector in the open position shall not be reduced below those specified (see ~~4.2 of IEC 62271-1:2007~~ 5.3 of IEC 62271-1:2017) by deterioration of insulating parts in the neighbourhood of, or parallel to, the isolating distance. The requirements for disconnectors given in IEC 62271-102:2018 shall be fulfilled.
- The switch-fuse combination shall be capable of carrying its highest rated ~~normal~~ continuous current continuously, from the reference list, after renewal of fuses.

Visual inspection and no-load operation of the combination after testing are usually sufficient for checking the above requirements.

~~In case of doubt as to the ability of the combination to meet the conditions of 6.101.5 b), it shall be subjected to the relevant power frequency voltage withstand tests in accordance with 6.2.11 of IEC 62271-1:2007. For switch-fuse combinations with sealed for life interrupters, the condition checking test is mandatory unless the sealed interrupter may be disassembled or opened for the purpose of inspection.~~

~~In case of doubt as to the ability of the combination, where applicable, to meet the conditions of 6.101.5 c), it shall be subjected to the relevant power frequency voltage withstand tests in~~

~~accordance with 6.2.11 of IEC 62271-1:2007. For switch-fuse combinations with sealed for life interrupters, the condition checking test is mandatory unless the sealed interrupter may be disassembled or opened for the purpose of inspection.~~

~~National deviations as stated in the foreword of IEC 62271-1 should be considered.~~

~~In case of doubt as to the ability of the combination, where applicable, to meet the conditions of 6.101.5 d), two additional close-open operations shall be made with the rated normal current.~~

In case of doubt on the ability of the switch-fuse combination to meet the conditions of 7.101.5 b) and/or c), it shall be subjected to the relevant power frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:2017.

If vacuum interrupters are used, and they are placed in an insulating fluid other than air at atmospheric pressure (for example a vacuum interrupter in an enclosure filled with SF₆) an integrity check shall also be performed after the making and breaking tests, as follows.

An additional breaking test TD_{lto} shall be performed using a circuit that supplies at least the 50 % rated breaking take-over current with at least 50 % of the rated voltage, having both the neutral points of source side and load circuit, earthed. This additional breaking test shall be made before or after the no-load tests subsequent to the making and breaking test. A successful interruption in each pole evidences that the vacuum interrupter integrity is maintained.

In case of doubt on the capability of the switch-fuse combination, where applicable, to meet the conditions of 7.101.5 d), the requirement is considered to be met if one of the following criteria is satisfied:

1) visual inspection of the main contacts shows evidence of their good condition;

or, if impracticable or unsatisfying,

2) the resistance measurement according to the procedure and the relevant acceptance criteria of 7.4 is satisfying. Before measurement of contact resistance, up to 10 no-load operations may be done,

or, if the condition of b) is not satisfied:

3) a test under the highest rated continuous current demonstrates that no thermal runaway occurs, by monitoring the temperature at the points where resistance measurement was made until stabilization (variation less than 1 K/h). During this test, no other temperature measurement is made inside of the switching device. If stabilization cannot be obtained, then the condition check has failed and the switch-fuse combination is considered to have failed the test duty as well.

7.102 Mechanical operation tests

Tests of the trip linkages shall be performed as follows:

a) To test the mechanical reliability of the linkages between the fuse striker(s) and the switch release, a total of 100 operations shall be made, of which 90 shall be made (30 in each pole) with one striker of minimum energy and 10 with three strikers of maximum energy operating simultaneously.

After performing this test-duty, the mechanical functioning of the trip linkages shall be **practically** the same as before the tests.

b) Using a dummy fuse-link with extended striker, set to the minimum actual travel within the tolerance specified in IEC 60282-1:2020, for each pole in turn it shall be shown that the switch either cannot be closed or cannot remain closed according to its design.

For the purpose of these tests, a device simulating fuse striker operation may be used.

NOTE The switch being in compliance with IEC 62271-103:2021, no additional mechanical operation tests of the switch are required.

7.103 Mechanical shock tests on fuses

During the test of the trip linkages given in 7.102, two fuses shall be fitted in the two poles of the combination not fitted with the fuse striker simulating device for the three sets of 30 operations involved. Each of the two fuses used shall have the lowest rated current of the reference list. If this rating is listed with several fuse types, then the fuses used for the test shall be of different types.

Additionally, in the case of fuse-switches only, 90 close-open operations shall be performed manually with three fuses.

Each of the three fuses used shall have the lowest rated current of the reference list. If this rating is listed with several fuse types, then the fuses used for the test shall be of different types.

After performing this (these) test-duty(ies), the fuses shall show neither signs of mechanical damage nor significant change in resistance. They shall not have become displaced in their contacts.

The satisfactory performance of the above test-duty(ies) can be deemed to be sufficient evidence for justifying the use of fuses other than those tested without further mechanical shock testing.

7.104 Thermal test with long pre-arcing time of fuse

The test conditions are similar to the one used for the ~~temperature-rise~~ continuous current test of 7.5 without measurement of temperature rise. However, the no-load voltage of the supply shall be sufficient to operate the striker.

The test shall be carried out on the fuse, in the reference list, having the highest current rating in each homogeneous series. The test shall be performed at the current giving the highest fuse body temperature, as stated by the fuse manufacturer.

The test is performed by applying a test current of the required value, as stated above, until the striker operates.

The above test need not be repeated for alternative types of fuse having a stated lower peak body temperature than that tested and using the same striker design.

The test is valid if

- a) the striker and the switch have operated correctly,
- b) ~~there is no damage on the fuse as defined in 5.1.3 of IEC 60282-1:2009~~ after visual inspection, no parts of the switch-fuse combination have sustained damage and all parts are in a satisfactory condition (for fuses as defined in 6.1.3 of IEC 60282-1:2020).

NOTE ~~New tests have been introduced in IEC 60282-1 in order to define the highest body temperature of fuse links and corresponding current values.~~

7.105 Extension of validity of type tests

7.105.1 Dielectric

The dielectric properties may be affected when using other diameters than that of the tested fuse. Extension of validity is restricted to fuses with the same overall dimensions.

7.105.2 ~~Temperature-rise~~ Continuous current tests

Compliance with ~~temperature-rise~~ continuous current tests of the combination made ~~of the~~ on a combination base and a given fuse type (referred to as X) demonstrates the compliance of any combination made of the same combination base fitted with another fuse type, at the associated rated ~~normal~~ continuous current of this new combination, provided that the four criteria below are fulfilled:

- the fuses have the same length as the fuse X;
- the fuses have a rated current lower than, or equal to, those of the fuse X ~~fuses~~;
- the fuses have a dissipated power (in accordance with IEC 60282-1:2020) lower than, or equal to, those of the fuse X ~~fuses~~;
- the derating of the fuses within the combination ($I_{r \text{ combination}}/I_{r \text{ fuse}}$) is lower than, or equal to, those of the fuse X ~~fuses~~.

As compliance with the above criteria already includes safety margins, the diameter of the fuses need not be considered.

7.105.3 Making and breaking

Compliance with this document is also achieved by alternative untested or partially tested combinations made of combination base and fuses, provided that the following conditions are met:

- a) any fuse considered ~~shall~~ to comply with its relevant standard (IEC 60282-1:2020);
- b) the same type of striker ~~shall be~~ is fitted, i.e. medium or heavy in accordance with IEC 60282-1:2020;
- c) the alternative type of fuse is such that the cut-off current and operating I^2t of the alternative type, as established by test-duty 1 and/or test-duty 2 of IEC 60282-1:2020, are not greater than those of the tested type similarly established;
- d) for fuse-switches only, any change in fuse-link mass ~~shall not invalidate~~ is not invalidating breaking characteristics due to change in the mechanical operation (i.e. opening speed).

8 Routine tests

~~Clause 7 of IEC 62271-1:2007 is applicable with the following addition:~~

Clause 8 of IEC 62271-1:2017 applies with the following addition:

8.101 Mechanical operating tests

Operating tests shall be carried out to ensure that combinations comply with the ~~prescribed~~ specified operating conditions within the specified voltage and supply pressure limits of their operating devices.

During these tests, it shall be verified, in particular, that the combinations open and close ~~correctly~~ as specified by the manufacturer when their operating devices are energized or under pressure. It shall also be verified that the operation will not cause any damage to the combinations. Fuses of maximum mass and dimensions shall be fitted for fuse-switch testing. For switch-fuse combinations, tests may be made without fuses.

For all switch-fuse combinations the following test shall be carried out:

- a) under the conditions of 7.102 with the action of one fuse striker of minimum energy simulated: one opening operation on each phase.

Additionally, the following tests shall be performed where applicable:

- b) at the specified maximum supply voltage and/or the maximum pressure of the compressed gas supply: five operating cycles;
- c) at the specified minimum supply voltage and/or the minimum pressure of the compressed gas supply: five operating cycles;
- d) if a combination can be operated by hand as well as by its ~~normal~~ electric or pneumatic operating device: five manually operated cycles;
- e) for manually operated combinations only: ten operating cycles;
- f) for release-operated combinations only, at rated supply voltage and/or rated pressure of the compressed gas supply: five operating cycles with a **minimum current for the tripping circuit energized by the closing of the main contacts.**

The tests a), b), c), d) and e) shall be made without current passing through the main circuit.

During all the foregoing routine tests, no adjustments shall be made and the operation shall be faultless. The closed and open positions shall be attained during each operating cycle on tests a), b), c), d) and e).

After the tests, the combination shall be examined to determine that no parts have sustained damage and that all parts are in a satisfactory condition.

9 Guide to the selection of switch-fuse combinations (informative)

~~8.1 Selection of rated values~~

~~Subclause 8.1 of IEC 62271-1:2007 is applicable.~~

~~8.2 Continuous or temporary overload due to changed service conditions~~

~~Subclause 8.2 of IEC 62271-1:2007 is applicable.~~

Clause 9 of IEC 62271-1:2017 applies with the following additions:

9.101 Guide to the selection of switch-fuse combination for transformer protection

9.101.1 General

~~The objective of this application guide, taken in conjunction with that for switches (see Clause 8 of IEC 62271-103:2011) and that for fuses (IEC/TR 60787 deals with choice of fuses for protection of transformers) is to specify criteria for the selection of a combination of switch and fuses which will assure correct performances of the switch-fuse combination, using the parameter values established by tests in accordance with IEC 62271-103, IEC 60282-1 and this standard.~~

~~Criteria for the coordination of high-voltage fuses with other circuit components in transformer applications and guidance for the selection of such fuses with particular reference to their time-current characteristics and ratings are given in IEC/TR 60787.~~

~~Guidance for the selection of switches is given in Clause 8 of IEC 62271-103:2011.~~

~~The test duties specified in this standard, together with the associated guidance as to the application of these tests to other combinations cover most users' requirements. However, in some cases, for example supporting the use of a back-up fuse by type tests carried out on the combination using full range fuses from another manufacturer, may require additional combination testing. Such testing should be subject to agreement between the manufacturer and user.~~

The objective of this application guide, taken in conjunction with that for switches (see Clause 9 of IEC 62271-103:2021) and that for fuses is to specify criteria for the selection of a combination of switch and fuses which will ensure correct performances of the switch-fuse combination.

Criteria for the coordination of high-voltage fuses with other circuit components in transformer applications and guidance for the selection of such fuses with particular reference to their time-current characteristics and ratings are given in 5.2.2.2 of IEC TR 62655:2013.

Guidance for the selection of switches is given in Clause 9 of IEC 62271-103:2021.

9.101.2 Rated short-circuit breaking current

The rated short-circuit breaking current of a combination is largely determined by that of the fuses and shall be equal to or greater than the maximum expected RMS symmetrical fault current level of the point in the distribution system at which the combination is to be located.

9.101.3 Primary fault condition caused by a solid short-circuit on the transformer secondary terminals

The primary side fault condition caused by a solid short-circuit on the transformer secondary terminals corresponds to very high TRV values which the switch (not designed and not tested to that condition) in a combination may not be able to cope with. The fuses, therefore, shall be so chosen that they alone will deal with such a fault condition without throwing any of the breaking duty onto the switch. In practice, this entails ensuring that the transfer current of the combination **under consideration** is less than the foregoing primary fault current expressed by (see Figure 8):

$$I_{sc} = \frac{100I_T}{Z}$$

where

I_T is the rated current of the transformer;

I_{sc} is the primary fault current on the transformer;

Z is the short-circuit percentage impedance of the transformer.

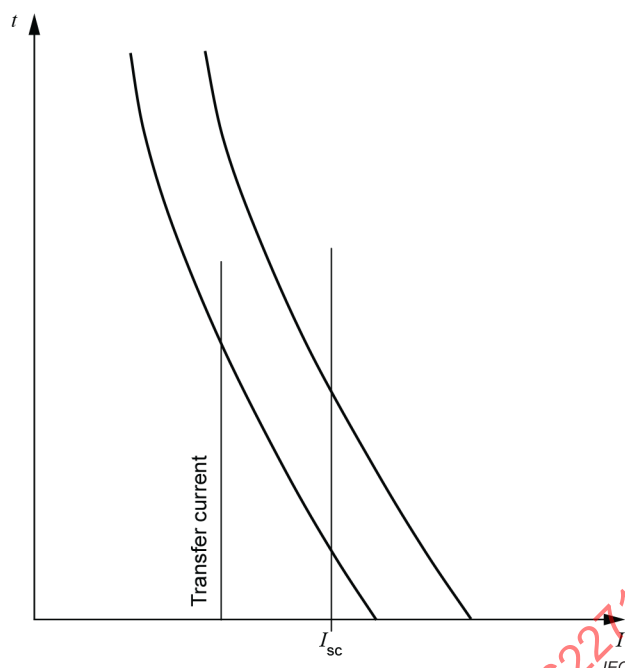


Figure 8 – Transfer current in relation to the primary fault current I_{sc} due to a solid short circuit in the transformer secondary terminal

With this condition being fulfilled, transfer currents correspond to faults for which arc impedance or fault line impedance reduce the magnitude of both the current and the TRV values and increase the power factor.

An example is given in Annex A.

In cases where a system provider considers that the design of the LV connections between transformer and LV switchgear (e.g. inside prefabricated substations in accordance with IEC 62271-202) prevents a solid short-circuit on the secondary transformer terminals, the above fault condition need not be considered in the selection of the fuse-links.

In all other cases where the ~~requirements~~ conditions of this subclause cannot be met, a switch ~~according to IEC 62271-103 shall~~ fuse-combination should not be applied.

9.102 Coordination of switch and fuses for extension of the reference list of fuses

9.102.1 General

In the following paragraphs, strictly speaking, one should refer to the break-time and not to the opening time of the switch. However, the opening time is usually more readily available and is close enough to the break-time for the purposes of this document.

9.102.2 Rated ~~normal~~ continuous current

~~Reference should be made to 9.3.2 of IEC 60282-1:2009 where comment is made on the rated current of fuses and its selection and on how it may be affected by the mounting of the fuses in an enclosure.~~

The rated ~~normal~~ continuous current of a switch-fuse combination is assigned by the switch-fuse manufacturer ~~on the basis of information gained from temperature-rise tests~~ and will depend on the type and ratings of the switch and the fuses. It may have to be reduced where the ambient temperature in service exceeds the ~~prescribed~~ specified ambient temperature.

The rated ~~normal~~ continuous current of a combination is generally less than, but ~~should~~ shall not be in excess of, the rated current of the fuses as assigned by the fuse manufacturer.

9.102.3 Low over-current performance

At values of fault current below the minimum breaking current of the fuses fitted in the combination, correct operation is ensured by the ejection of one or more fuse strikers operating the switch tripping mechanism (and hence causing the switch to open) before the fuse has had time to be damaged by internal arcing (see 6.102). Additionally, over-current relays could be used.

9.102.4 Transfer current

The transfer current of a combination is dependent upon both the fuse-initiated opening time of the switch and the time-current characteristic of the fuse.

Near the transfer point, under a three-phase fault, the fastest fuse to melt clears the first pole and its striker starts to trip the switch.

The other two poles then see a reduced current (87 %) which will be interrupted by either the switch or the remaining fuses. The transfer point is when the switch opens and the fuse elements melt simultaneously.

The transfer current for a given combination, determined as described in Annex B, shall be smaller than the rated transfer current.

9.102.5 Take-over current

The value of the take-over current of a combination is dependent upon both the release-initiated opening time of the switch and the time-current characteristic of the fuse. As its name implies, it is the value of the current at the intersection of the two curves, above which the fuses take over the function of current interruption from the release and switch.

Relay behaviour and fuse characteristics should be such that the take-over current is smaller than the ~~maximum~~ rated take-over current of the combination (see definition 3.7.112 and the test conditions in 7.101.3.4).

9.102.6 Extension of the validity of type tests

As it is recognized that it may well be impractical to test all combinations made of a combination base and fuses and to carry out repeat tests on combinations whenever the fuse is altered, this document specifies conditions (see 7.105) whereby the validity of the ~~temperature rise~~ continuous current test, making and breaking type tests may be extended to cover combinations other than that (those) tested.

The test duties specified in this document, together with the associated guidance as to the application of these tests to other combinations cover most users' requirements. However, in some cases, for example supporting the use of a back-up fuse by type tests carried out on the combination using full range fuses from another manufacturer, may require additional combination testing. Such testing should be subject to agreement between the manufacturer and user.

~~8.103 Operation~~

- ~~a) The three fuses fitted in a given combination shall all be of the same type and current rating, otherwise the breaking performance of the combination could be adversely affected.~~
- ~~b) It is vital, for the correct operation of the combination, that the fuses are inserted with the strikers in the correct orientation.~~
- ~~c) When a switch fuse has operated as a result of a three phase fault, it is possible for~~

- ~~1) only two out of the three fuses to have operated,~~
- ~~2) all three fuses to have operated but for only two out of the three strikers to have ejected.~~
- ~~— Such partial operation of one fuse can occur under three-phase service conditions and is not to be considered abnormal.~~
- ~~d) Where a switch fuse has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses may give an indication as to the type of fault current and its approximate value. Such an investigation is best carried out by the fuse manufacturer.~~
- ~~e) All three fuses shall be discarded and replaced if the fuse(s) in one or two poles of a combination has operated.~~
- ~~f) Before removing or replacing fuses, the operator should satisfy himself that the fuse mount is electrically disconnected from all parts of the combination which could still be electrically energized. This is especially important when the fuse mount is not visibly isolated.~~

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

Subclause 10.1 of IEC 62271-1:2017 applies.

10.2 Information with enquiries and orders

~~Subclause 9.1 of IEC 62271-1:2007 is applicable with the following additions.~~

Subclause 10.2 of IEC 62271-1:2017 applies with the following additions:

In addition to the information listed for the switch in 10.2 of IEC 62271-103:2021, the inquirer should specify the limit of supply, i.e. if the combinations described include the fuse-links (defined as switch-fuse combination) or not (defined as switch-fuse combination base).

10.3 Information with tenders

~~Subclause 9.2 of IEC 62271-1:2007 is applicable with the following additions.~~

Subclause 10.3 of IEC 62271-1:2017 applies with the following additions:

As well as the information given for the switch in 10.3 of IEC 62271-103:2021, the combination manufacturer shall give, in addition to the rated quantities, the following information:

- a) the reference list of fuses, which shall include the designation of the combination base, ~~its maximum demonstrated cut-off current characteristics of the fuse~~ and for each selected fuse, the following information:
 - fuse designation (~~brand~~ manufacturer, type, rating);
 - rated ~~normal~~ continuous current of the combination;
 - rated short-circuit current of the combination;
 - ~~rated~~ maximum cut-off current of the combination;
- b) filling medium (type and amount), when applicable.

~~On request, the relevant information for the extension of the type test validity should be given, i.e.:~~

- ~~— fuse length (6.105.2);~~
- ~~— fuse maximum rated current (6.105.2);~~
- ~~— fuse power dissipation (6.105.2);~~

~~— fuse derating (6.105.2);~~

~~— Joule integral (highest value of the fuse type used in 6.101.3.1 and 6.101.3.2).~~

On request, the following information for the extension of the type test validity should be given:

- fuse length (7.105.2);
- fuse power dissipation (7.105.2);
- Joule integral (highest value of the fuse type used in 7.101.3.1 and 7.101.3.2).

11 Transport, storage, installation, ~~operation~~ operating instructions and maintenance

~~Clause 10 of IEC 62271-1:2007 is applicable with the following addition.~~

Clause 11 of IEC 62271-1:2017 applies with the following additions:

The reference list of fuses shall be given in the instruction book.

High-voltage fuses, although robust in external appearance, may have fuse-elements of relatively fragile construction. Fuses should, therefore, be kept in their protective packaging until ready for installation and should be handled with the same degree of care as a relay, meter or other similar item. Where fuses are already fitted in a switch-fuse unit, they should be temporarily removed while the unit is man-handled into position.

For operation, the following points should be considered:

- a) The three fuses fitted in a given combination shall all be of the same type and current rating, otherwise the breaking performance of the combination could be adversely affected.
- b) It is vital, for the correct operation of the combination, that the fuses are inserted with the strikers in the correct orientation.
- c) When a switch-fuse has operated as a result of a three-phase fault, it is possible for
 - 1) only two out of the three fuses to have operated,
 - 2) all three fuses to have operated but for only two out of the three strikers to have ejected.Such partial operation of one fuse can occur under three-phase service conditions and is not to be considered abnormal.
- d) Where a switch-fuse has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses may give an indication as to the type of fault current and its approximate value. Such an investigation is best carried out by the fuse manufacturer.
- e) All three fuses shall be discarded and replaced if the fuse(s) in one or two poles of a combination has operated.
- f) Before removing or replacing fuses, the operator should satisfy himself that the fuse-mount is electrically disconnected from all parts of the combination which could still be electrically energized. This is especially important when the fuse-mount is not visibly isolated.

12 Safety

~~Clause 11 of IEC 62271-1:2007 is applicable.~~

Clause 12 of IEC 62271-1:2017 applies.

13 Influence of the product on the environment

~~Clause 12 of IEC 62271-1:2007 is applicable.~~

Clause 13 of IEC 62271-1:2017 applies.

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Annex A (informative)

Example of the coordination of fuses, switch and transformer

The transformer is chosen by the user for its particular duty, thus fixing values of the full load current and permissible overload current.

The maximum fault level of the high-voltage system is known.

For the purpose of this example, an 11 kV, 400 kVA transformer on a high-voltage system with maximum fault level of 16 kA is considered:

- a) full load current is approximately 21 A;
- b) permissible periodic overload is assumed to be 150 %, on the "–5 %" tapping of the transformer, i.e. approximately:

$$21 \text{ A} \times 1,05 \times 1,5 = 33 \text{ A}$$

- c) maximum magnetizing inrush current, assumed to be 12 times the rated current, is:

$$21 \text{ A} \times 12 = 252 \text{ A}$$

for a duration of 0,1 s (~~Clause 5 a) of IEC /TR 60787:2007~~ 5.2.2.2.3 a) of IEC TR 62655:2013).

Site ambient air temperature is 45 °C, i.e. 5 °C above standard.

Suppose the user has decided that a 12 kV switch-fuse combination from a certain manufacturer will be used to control and protect the transformer.

The manufacturer shall provide a list of the fuses which can be used in the combination and shall advise which of these are suitable for the application.

This list of fuses will have been drawn up by the switch-fuse manufacturer on the basis of appropriate type tests on the switch-fuse combination in accordance with this document and by the application of its extension of validity clauses (see 9.102).

Suppose he advises that a 12 kV, 40 A, 16 kA (at least) back-up fuse of a given type from a certain fuse manufacturer is suitable. To justify this advice, the switch-fuse manufacturer will have ascertained the following:

- a) The fuse can withstand the 252 A magnetizing inrush current of the transformer for 0,1 s (~~Clause 5 a) of IEC /TR 60787:2007~~ 5.2.2.2.3 a) of IEC TR 62655:2013). He will normally do this by examining the fuse time-current characteristic, i.e. where the 252 A point at 0,1 s has a selectivity distance of 20 % to the time-current curve at this point, and/or by consulting the fuse manufacturer.
- b) The ~~normal~~ continuous current rating of the switch-fuse combination when fitted with the fuses is adequate to allow for periodic overloading of the transformer up to 33 A in ambient air temperature conditions of 45 °C (~~Clause 5 b)1) of IEC /TR 60787:2007~~ 5.2.2.2.3 b)1) of IEC TR 62655:2013).

The ~~normal~~ continuous current rating of the combination when fitted with the fuses may not be more than 40 A, especially in the higher than standard ambient conditions. ~~Temperature-rise~~ Continuous current tests carried out by the switch-fuse manufacturer, or calculations based on such tests, may indicate a ~~normal~~ continuous current rating of, say, 35 A in ambient conditions of 45 °C. This would be adequate for the application.

- c) The pre-arcing current of the fuse is low enough in the 10 s region of the fuse time-current characteristic to ensure satisfactory protection of the transformer (~~Clause 5 c) of~~

~~IEC/TR 60787:2007~~ 5.2.2.2.3 c) of IEC TR 62655:2013). The manufacturer will normally do this by examining the fuse time-current characteristic and/or consulting the fuse manufacturer.

- d) The fuses alone will deal with the condition of a solid short-circuit on the transformer secondary terminals, i.e. that the maximum primary short-circuit current (in this case:

$$\frac{400 \times 100}{11 \times \sqrt{3} \times 5} = 420 \text{ A}$$

based on 5 % transformer impedance) is greater than the transfer current (see 3.7.108) of the combination when fitted with 40 A fuses. He will do this using the method explained in 9.102.3. Reference to Figure A.1 shows that the transfer current thus obtained is only 280 A, the fuse-initiated opening time of the switch assumed to be 0,05 s for the purpose of this example.

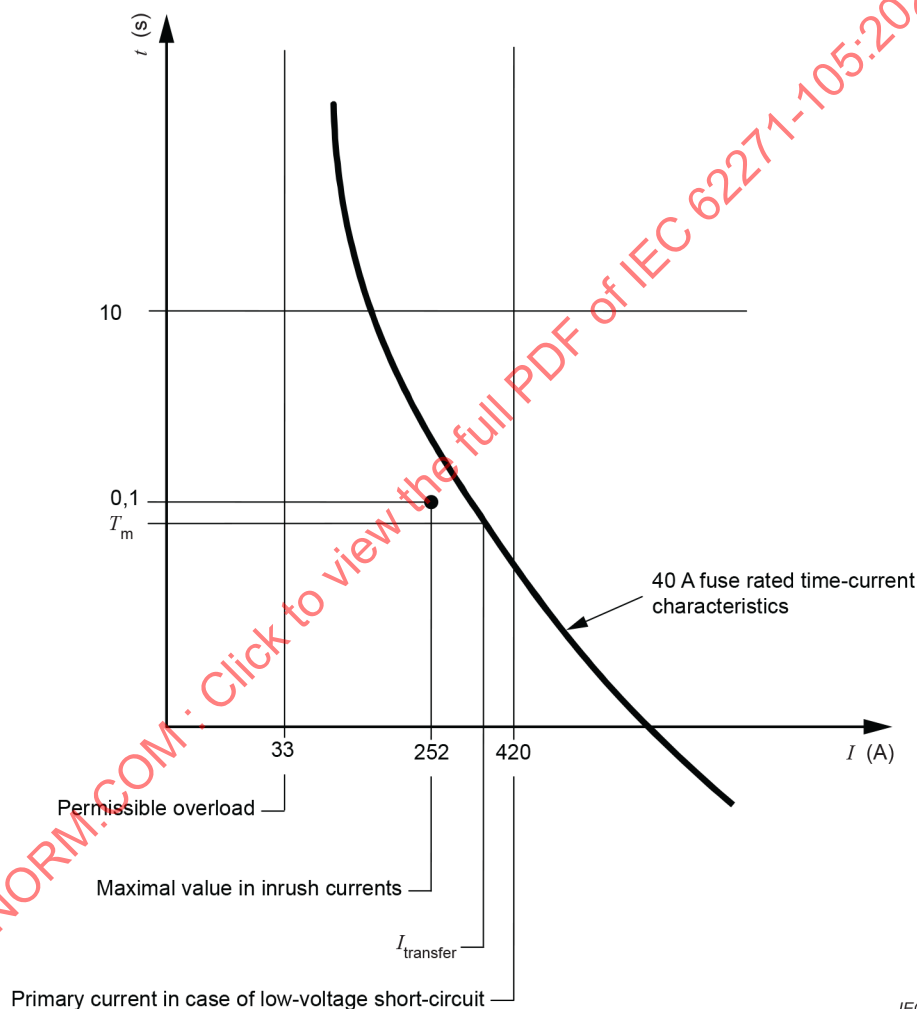


Figure A.1 – Characteristics relating to the protection of an 11 kV, 400 kVA transformer

- e) The transfer current of the combination, when fitted with 40 A fuses, is less than its rated transfer current (see 5.103), which one can suppose to be 1 000 A.

The user shall check that the fuse discriminates with the highest rating of a low-voltage fuse used in the event of a phase-to-phase fault occurring on the low-voltage system.

NOTE This is usually the worst condition for discrimination.

As explained in ~~Clause 5 d) of IEC/TR 60787:2007~~ 5.2.2.2.3 d) of IEC TR 62655:2013, the intersection of the two time-current characteristics of the high-voltage and low-voltage fuses shall occur at a value of current greater than that of the maximum fault current on the load side of the low-voltage fuse (see Figure A.2).

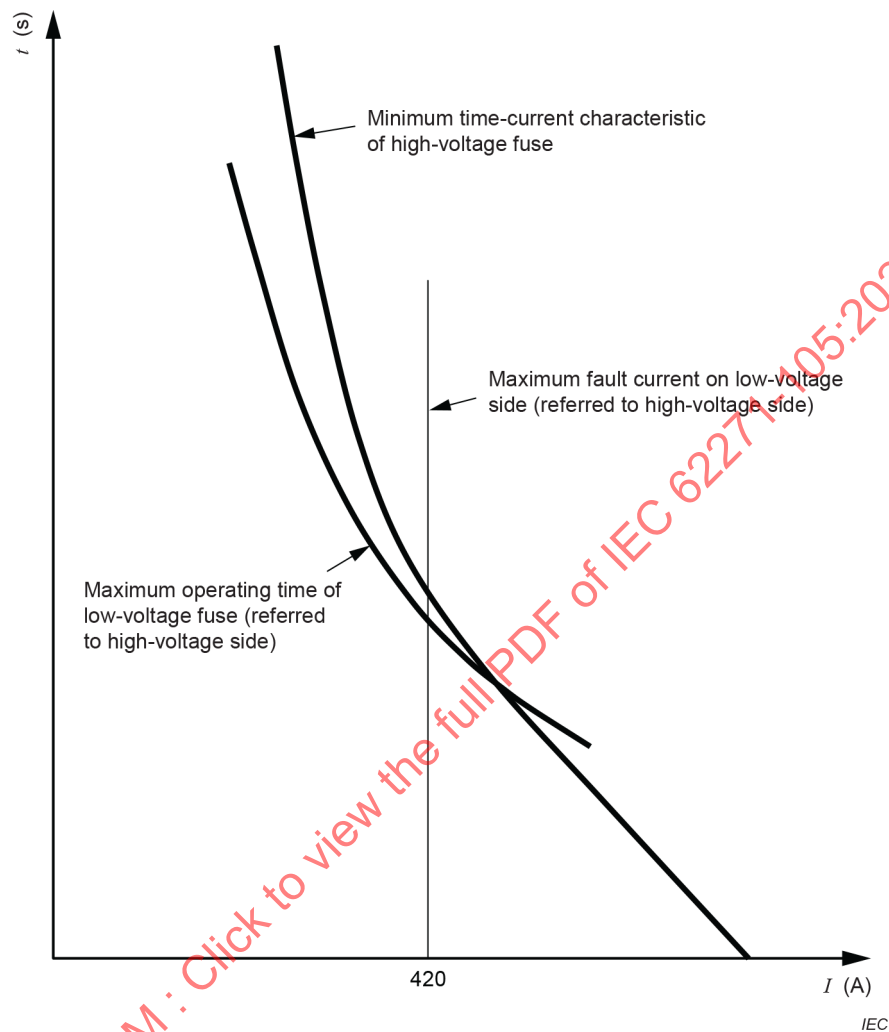


Figure A.2 – Discrimination between HV and LV fuses

Annex B (normative)

Procedures for determining transfer current

B.1 Background

Transfer current I_{transfer} is defined as the current at which, under striker operation, the breaking duty is transferred from the fuses to the switch.

This occurs when, after the melting of a first fuse, the switch opens under striker operation before or at the same time as the melting of the second fuse, there being an inevitable difference between the melting times of fuses.

A knowledge of this difference, ΔT , between the melting times of fuses permits comparison between it and the striker-initiated opening time of the switch-fuse combination.

The following procedures compare, in an intentional simplification, virtual melting times of the fuse-links against the real opening times of the switch-fuse combination. Taking into account the real melting-time values of the fuses, resulting from the interdependent three-phase effects, the value of transfer current may be different. As the calculation already includes some safety margins, these differences may not be taken into consideration.

Calculations proposed in this annex use the assumption of a non-effectively earthed neutral system. Such an assumption leads to consider that the current in the two remaining phases is reduced after a first fuse cleared, possibly extending the melting duration of the remaining fuses. With such an assumption, it could be feared that the two remaining phases should be cleared by the switch-fuse combination with conditions not clearly addressed by this document.

When an effectively earthed neutral system is used, then, after a first fuse cleared the fault, the current in the two remaining phases could keep the value of the three-phase fault. Under such a condition, the requirement expressed in 5.103 ensures that the fuses will melt before the switch-fuse combination can be opened by any tripping device. There is no reason for concern.

B.2 Mathematical determination of ΔT

Figure B.1 shows small segments of the more probable minimum and maximum fuse time-current characteristics in the transfer current region.

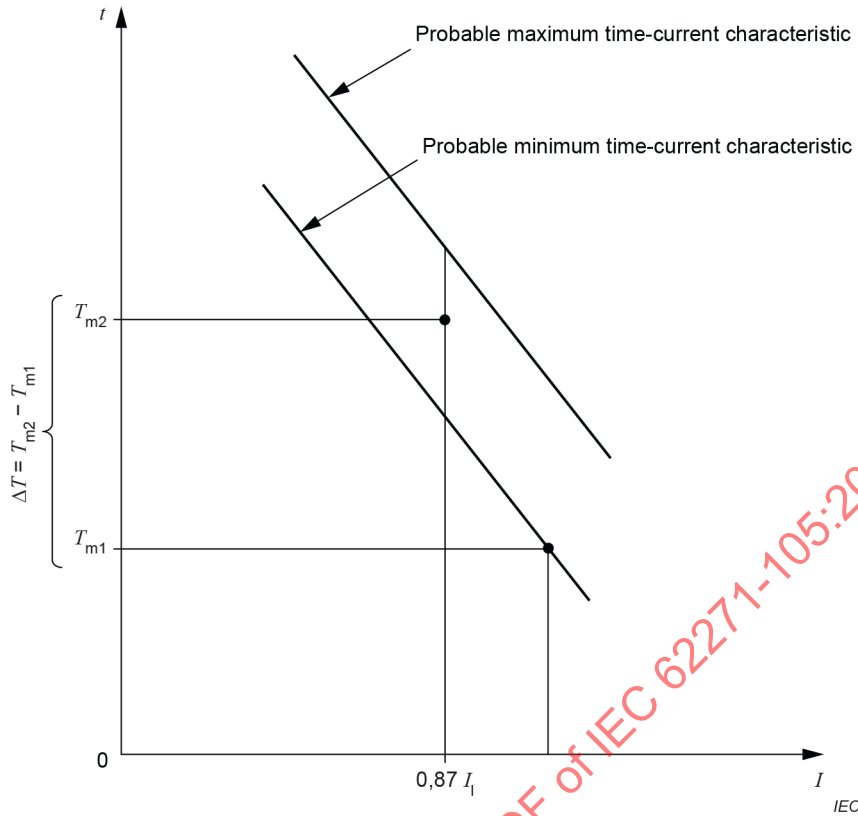


Figure B.1 – Practical determination of the transfer current

The time T_{m1} on the minimum characteristic is the melting time of the first fuse to operate under a three-phase fault current I_1 .

The time T_{m2} is the melting time of the second fuse to operate. It should be noted that this time T_{m2} (see Figure B.1) is shorter than the value indicated for a two-phase current of $0,87I_1$ by the maximum time-current characteristic as this second fuse has already seen the three-phase fault current I_1 for the time T_{m1} .

The small segments of the time-current characteristics can be regarded as straight lines to a close approximation in log-log coordinates, their formula being:

$$\log T_m = -a \log I + \log C$$

defining a relationship between I and T_m such that:

$$I^\alpha \times T_m = C \quad (\text{B.1})$$

where α is the gradient and $\log C$ the intercept with the ordinate axis of the straight line so defined.

Applying Formula (B.1) to the minimum time-current characteristic, the formula for the maximum time-current characteristic will be expressed by:

$$I^\alpha \times T_m = C(1+x)^\alpha \quad (\text{B.2})$$

where x is the tolerance on the current between the two time-current characteristics and defined as $100 x \%$.

The first fuse melts under the three-phase fault current I_1 in a time T_{m1} according to Formula (B.1) for the minimum time-current characteristic such that:

$$I_1^\alpha \times T_{m1} = C \quad (\text{B.3})$$

After having seen the current I_1 for a time T_{m1} , the second fuse will melt under the two-phase fault current, $0,87I_1$, in a time T_{m2} according to Formula (B.2) for the maximum time-current characteristic such that:

$$I_1^\alpha T_{m1} + (0,87 I_1)^\alpha \times (T_{m2} - T_{m1}) = C (1+x)^\alpha \quad (\text{B.4})$$

Combining Formula (B.3) and Formula (B.4) one obtains:

$$\Delta T = T_{m2} - T_{m1} = T_{m1} \left[\frac{(1+x)^\alpha - 1}{0,87^\alpha} \right] \quad (\text{B.5})$$

The transfer point occurs when ΔT is equal to the fuse-initiated opening time T_0 of the switch.

Taking a statistically realistic tolerance for the fuse time-current characteristics of $\pm 6,5 \%$ ($\pm 2\sigma$ of $\pm 10 \%$) then $x = 0,13$. Using this value in Formula (B.5) gives:

$$T_{m1} = T_0 \left[\frac{0,87^\alpha}{(1+0,13)^\alpha - 1} \right] \quad (\text{B.6})$$

The transfer current I_{transfer} is then deduced from the minimum time-current characteristic of the fuse.

As the slope α is dependent on the value T_{m1} (Figure B.2), an iterative calculation shall be made: a first value of T_{m1} shall be taken, for instance $(T_{m1})_0$ equal to $1,2T_0$, for it is normally close to the practical value. Then, a first value of the transfer current $(I_{\text{transfer}})_0$ and of the slope α_0 are deduced from the minimum time-current characteristic.

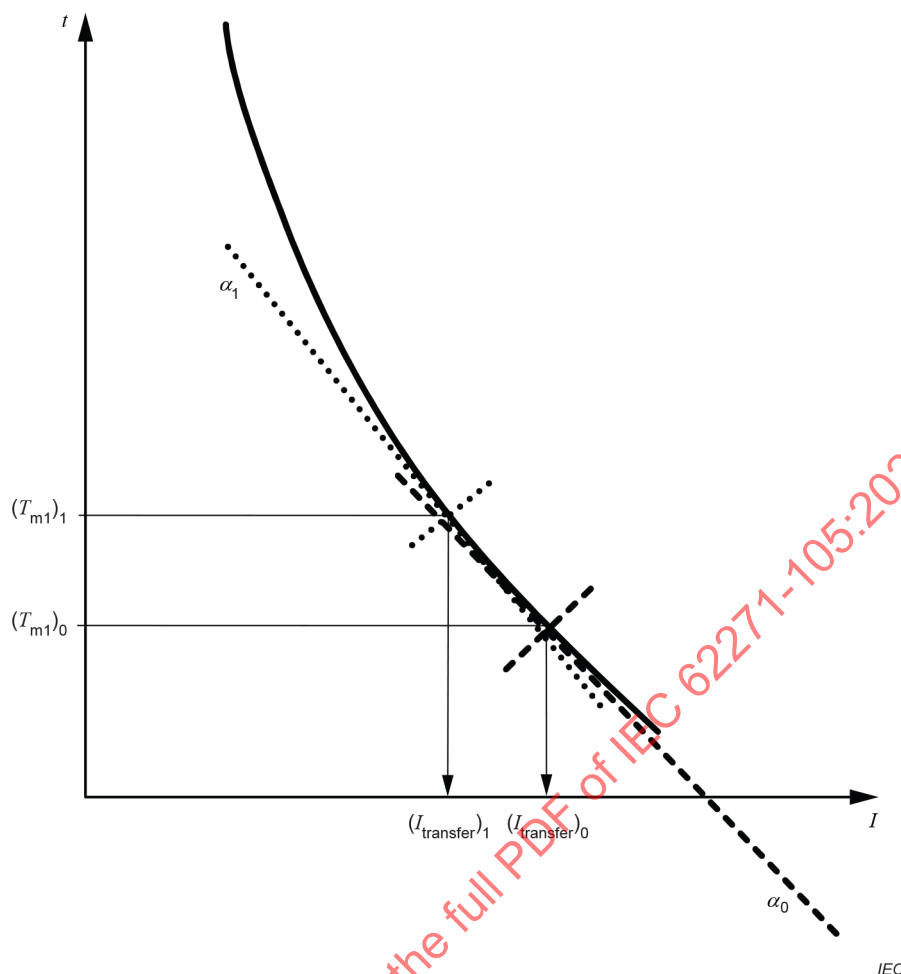


Figure B.2 – Determination of the transfer current with the iterative method

With this value α_0 , a new $(T_{m1})_1$ is calculated with Formula (B.6) and new $(I_{\text{transfer}})_1$ and α_1 are determined as above. If the new value of the transfer current does not differ from the previous one by more than 5 %, then it is taken for I_{transfer} . If not, this calculation shall be re-made successively until the difference between two successive transfer currents is less than 5 %.

B.3 Simplified method for determination of transfer current

Taking $\alpha = 4$, which is on the conservative side with fuse-initiated opening times lying between 0,05 s and 0,3 s, then Formula (B.5) gives:

$$\Delta T = T_{m1} \left(\frac{(1+0,13)^4 - 1}{(0,87)^4} \right) \quad (\text{B.7})$$

The transfer point occurs when the fuse-initiated opening time T_0 of the switch is equal to ΔT :

$$T_0 = \Delta T = 1,1 \times T_{m1}$$

or

$$T_{m1} = 0,9 T_0$$

Thus, the transfer current can be defined as the current which gives a pre-arcing time equal to $0,9 T_0$ for the minimum time-current characteristic of the fuse.

This simplified procedure is based on a slope of the fuse characteristic of $\alpha = 4$. The slope of the characteristics of actually existing fuses may vary from 4, which may lead to different transfer currents and, thus, different fuse rated currents. In case of doubt apply the iterative method (Clause B.2) or consult the switch-fuse manufacturer.

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Annex C (normative)

Tolerances on test quantities for type tests

Table C.1 – Tolerances on test quantities for type tests

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference to
7.101	Making and breaking tests				
7.101.2.2	Test frequency	Test frequency	Rated frequency	±8 %	
7.101.2.5	Test voltage for breaking tests	Power-frequency recovery voltage	Rated voltage	±5 %	Figure 4
		Power-frequency recovery voltage of any phase/average value	1	± 20 %	
7.101.2.7	Applied voltage before short circuit tests	Applied voltage	Rated voltage	+10 % –0 %	
		Applied voltage of any phase /average value	1	±5 %	
7.101.2.8	Breaking current	AC component of test current for TD_{ISC} , TD_{IWmax} and TD_{Ito} in any phase/average	1	±10 %	
		AC component of test current for $TD_{Itransfer}$ in two phases fitted with solid links/phase with fuses	1	≥ √3/2	
7.101.3.1	Short circuit current	Prospective current	Rated value	+5 % –0 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 1	+10 % –0 %	
7.101.3.2	Current with max. I^2t of the fuse	Prospective current	Specified value	±10 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 2	+10 % –0 %	

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference to
7.101.3.3 and 7.101.3.4	Transfer current and take-over current	Prospective current	Rated value	+10 % –0 %	
		Power factor of load circuit	$I_{rtransfer} > 400 \text{ A}$	0,2 to 0,3	
			$I_{rtransfer} \leq 400 \text{ A}$	0,3 to 0,4	
		Power factor of supply circuit		< 0,2	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 1	+10 % –0 %	
		TRV of load circuit	Table 3 and Table 4	+10 % –0 %	
		Impedance of supply circuit/total impedance	0,15	±0,03	

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IEC TR 62655:2013, *Tutorial and application guide for high-voltage fuses*

IEC 62271-202, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**High-voltage switchgear and controlgear –
Part 105: Alternating current switch-fuse combinations for rated voltages above
1 kV up to and including 52 kV**

**Appareillage à haute tension –
Partie 105: Combinés interrupteurs-fusibles pour courant alternatif de tensions
assignées supérieures à 1 kV et jusqu'à 52 kV inclus**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 105: Alternating current switch-fuse combinations
for rated voltages above 1 kV up to and including 52 kV**

FOREWORD

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IEC 62271-105 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

This third edition cancels and replaces the second edition published in 2012. This edition constitutes a technical revision.

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

- a) the document has been updated to be in alignment with the second edition of IEC 62271-1:2017;
- b) rated TRV has been removed (TRV is only a test parameter), as in the latest revision of IEC 62271-100;

- c) differentiation has been introduced between requirements expressed for fulfilling the function expected from a switch-fuse combination, from requirements only relevant when the function is performed by a stand-alone device. The goal is to avoid duplication or conflicts of requirements with a standard dealing with assemblies, when the function is implemented within such an assembly.

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

FDIS	Report on voting
17A/1300/FDIS	17A/1306/RVD

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

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

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

This document is to be read in conjunction with IEC 62271-1:2017, 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 62271-1:2017. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

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

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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV

1 Scope

This part of IEC 62271 applies to three-pole units for public and industrial distribution systems which are functional assemblies of switches composed of switches or switch-disconnectors and current-limiting fuses designed so as to be capable of

- breaking, at the rated voltage, any current up to and including the rated short-circuit breaking current;
- making, at the rated voltage, circuits to which the rated short-circuit breaking current applies.

It does not apply to combinations of fuses with circuit-breakers, contactors or circuit switchers, nor for combinations for motor-circuits nor to combinations incorporating single capacitor bank switches.

This document applies to combinations designed with rated voltages above 1 kV up to and including 52 kV for use on three-phase alternating current systems of either 50 Hz or 60 Hz.

In this document, the word "combination" is used for a combination in which the components constitute a functional assembly. Each association of a given type of switch and a given type of fuse defines one type of switch-fuse combination. Different types of fuses can be combined with one type of switch, which give several combinations with different characteristics, in particular concerning the rated continuous currents.

A switch-fuse combination is therefore defined by its type designation and a list of selected fuses defined by the manufacturer, the so-called "reference list of fuses". Compliance with this document of a given combination means that every combination using one of the selected fuses is proven to be in compliance with this document.

The fuses are incorporated in order to extend the short-circuit breaking rating of the combination beyond that of the switch alone. They are fitted with strikers in order both to open automatically all three poles of the switch on the operation of a fuse and to achieve a correct operation at values of fault current above the minimum melting current but below the minimum breaking current of the fuses. In addition to the fuse strikers, the combination can be fitted with either an over-current release or a shunt release.

NOTE In this document the term "fuse" is used to designate either the fuse or the fuse-link where the general meaning of the text does not result in ambiguity.

Fuses are in accordance with IEC 60282-1:2020.

Devices that require dependent manual operation are not covered by this document.

Switches, including their specific mechanism, are in accordance with IEC 62271-103 except for the short-time current and short-circuit making requirements where the current-limiting effects of the fuses are taken into account.

Earthing switches forming an integral part of a combination are covered by IEC 62271-102.

In addition, switches which include other functions (not covered by IEC 62271-103) are covered by their relevant standards (e.g. IEC 62271-102 for disconnectors and earthing switches).

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.

Clause 2 of IEC 62271-1:2017 applies with the following additions:

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

IEC 60282-1:2020, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

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

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

IEC 62271-103:2021, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

3 Terms and definitions

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

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

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

NOTE Some of the terms given in IEC 60050-441 are listed hereunder.

3.1 General terms and definitions

Subclause 3.1 of IEC 62271-1:2017 applies.

3.2 Assemblies of switchgear and controlgear

Subclause 3.2 of IEC 62271-1:2017 applies.

3.3 Parts of assemblies

Subclause 3.3 of IEC 62271-1:2017 applies.

3.4 Switching devices

Subclause 3.4 of IEC 62271-1:2017 applies, with the following additions:

3.4.101**switch-fuse combination**

combination of a three-pole switch with three fuses provided with strikers, the operation of any striker causing all three poles of the switch to open automatically

Note 1 to entry: The switch-fuse combination includes the fuse-switch combination.

3.4.102**switch-fuse combination base
combination base**

switch-fuse combination without fuse-links mounted

3.4.103**switch-fuse**

switch in which one or more poles have a fuse in series in a composite unit

[SOURCE: IEC 60050-441:2000, 441-14-14]

3.4.104**fuse-switch**

switch in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:2000, 441-14-17]

3.4.105**switch-disconnector**

switch which, in the open position, satisfies the isolating requirements specified for a disconnector

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.4.106**release-operated combination**

combination in which automatic opening of the switch can also be initiated by either an over-current release or a shunt release

3.5 Parts of switchgear and controlgear

Subclause 3.5 of IEC 62271-1:2017 applies, with the following additions:

3.5.101**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 60050-441:2000, 441-15-17]

3.5.102**over-current release**

release which permits a mechanical switching device to open with or without time-delay when the current in the release exceeds a predetermined value

Note 1 to entry: This value can in some cases depend upon the rate-of-rise of current.

[SOURCE: IEC 60050-441:2000, 441-16-33]

3.5.103

shunt release

release energized by a source of voltage

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

[SOURCE: IEC 60050-441:2000, 441-16-41]

3.6 Operational characteristics of switchgear and controlgear

Subclause 3.6 of IEC 62271-1:2017 applies.

3.7 Characteristic quantities

Subclause 3.7 of IEC 62271-1:2017 applies, with the following additions:

3.7.101

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 60050-441:2000, 441-17-01]

3.7.102

prospective peak current

peak value of a prospective current during the transient period following initiation

Note 1 to entry: The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[SOURCE: IEC 60050-441:2000, 441-17-02]

3.7.103

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 60050-441:2000, 441-17-04]

3.7.104

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 60050-441:2000, 441-17-07]

3.7.105**minimum breaking current**

minimum value of prospective current that a fuse-link is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-18-29]

3.7.106**short-circuit making capacity**

making capacity for which the prescribed conditions include a short circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:2000, 441-17-10]

3.7.107**cut-off current****let-through current**

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:2000, 441-17-12]

3.7.108**transfer current**

I_{transfer}

<striker operation> value of the three-phase symmetrical current at which the fuses and the switch exchange breaking duties

Note 1 to entry: Above this value the three-phase current is interrupted by the fuses only. Immediately below this value, the current in the first-pole-to-clear is interrupted by the fuse and the current in the other two poles by the switch, or by the fuses, depending on the tolerances of the fuse time current characteristic and the fuse-initiated opening time of the switch.

3.7.109**take-over current**

current co-ordinate of the intersection between the time-current characteristics of two over-current protective devices

[SOURCE: IEC 60050-441:2000, 441-17-16]

3.7.110**minimum take-over current**

<of a release-operated combination> current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to

- a) the maximum break-time plus, where applicable, the maximum operating time of an external over-current or earth-fault relay,
- b) the minimum pre-arcing time of the fuse

3.7.111**maximum take-over current**

<of a release-operated combination> current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to:

- a) the minimum opening time plus, where applicable, the minimum operating time of an external over-current or earth-fault relay,
- b) the maximum operating time of the fuse

3.7.112

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 60050-441:2000, 441-17-24]

3.7.113

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 60050-441:2000, 441-17-25]

3.7.114

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 voltages 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 60050-441:2000, 441-17-26]

3.7.115

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:2000, 441-17-27]

3.7.116

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 60050-441:2000, 441-17-29]

3.7.117

fuse-initiated opening time

<of the switch-fuse combination> time taken from the instant at which arcing in the fuse commences to the instant when the arcing contacts of the switch of the combination have separated in all poles (including all elements influencing this time)

3.7.118**release-initiated opening time**

<of the switch-fuse combination> release-initiated opening time is defined according to the tripping method as stated below with any time-delay device forming an integral part of the switch adjusted to a specified setting:

- a) for a switch tripped by any form of auxiliary power, interval of time between the instant of energizing the opening release, the switch being in the closed position, and the instant when the arcing contacts have separated in all poles;
- b) for a switch tripped (other than by the striker) by a current in the main circuit without the aid of any form of auxiliary power, interval of time between the instant at which, the switch being in the closed position, the current in the main circuit reaches the operating value of the over-current release and the instant when the arcing contacts have separated in all poles.

3.7.119**minimum release-initiated opening time**

<of the switch-fuse combination> release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its minimum setting

3.7.120**maximum release-initiated opening time**

<of the switch-fuse combination> release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its maximum setting

3.7.121**break-time**

interval of time between the beginning of the opening time of a mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[SOURCE: IEC 60050-441:2000, 441-17-39]

3.7.122**arcing time**

<of a pole or a fuse> interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[SOURCE: IEC 60050-441:2000, 441-17-37]

3.101 Fuses**3.101.1****reference list of fuses**

list of fuses defined by the manufacturer for a given type of switch-fuse combination base, for which compliance to the present document of all corresponding switch-fuse combinations is assessed

Note 1 to entry: Conditions for extending the validity of the type tests are given in 7.105 and 9.102.

3.101.2**fuse-base****fuse mount**

fixed part of a fuse provided with contacts and terminals

[SOURCE: IEC 60050-441:2000, 441-18-02]

3.101.3**striker**

mechanical device forming part of a fuse-link which, when the fuse operates, releases the energy required to cause operation of other apparatus or indicators or to provide interlocking

[SOURCE: IEC 60050-441:2000, 441-18-18]

3.101.4**pre-arcing time****melting time**

interval of time between the beginning of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated

[SOURCE: IEC 60050-441:2000, 441-18-21]

3.101.5**operating time****total clearing time**

sum of the pre-arcing time and the arcing time

[SOURCE: IEC 60050-441:2000, 441-18-22]

3.101.6 **I^2t** **Joule integral**

integral of the square of the current over a given time interval:

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

Note 1 to entry: The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

Note 2 to entry: The operating I^2t is the I^2t integral extended over the operating time of the fuse.

Note 3 to entry: The energy in joules liberated in one ohm of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in A²s.

[SOURCE: IEC 60050-441:2000, 441-18-23]

4 Normal and special service conditions

Clause 4 of IEC 62271-1:2017 applies.

5 Ratings**5.1 General**

Subclause 5.1 of IEC 62271-1:2017 applies with the following additions:

- k) rated short-circuit breaking current;
- l) rated short-circuit making current;
- m) rated transfer current for striker operation;
- n) rated take-over current for a release-operated combination.

If the switch-fuse combination is not used as a stand-alone device, the influences to the different ratings are covered by the relevant standards (e.g. if it is used as a part of switchgear and controlgear assembly).

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 applies.

5.3 Rated insulation level (U_d , U_p , U_s)

Subclause 5.3 of IEC 62271-1:2017 applies.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 applies.

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 applies with the following additions:

The rated continuous current applies to the complete switch-fuse combination.

Each combination of a given type of switch and a given type of fuse defines one type of switch-fuse combination. Different types of fuses may be combined with one type of switch, which give several switch-fuse combinations with different rated continuous currents.

It is not required that the rated continuous current is selected from the R10 series.

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 does not apply.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 does not apply.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 does not apply.

5.9 Rated supply voltage of auxiliary and control circuits (U_a)

Subclause 5.9 of IEC 62271-1:2017 applies.

5.10 Rated supply frequency of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 applies.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 applies.

5.101 Rated short-circuit breaking current

The rated short-circuit breaking current is the highest prospective short-circuit current which the combination shall be capable of breaking under the conditions of use and behaviour defined in this document in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the combination and having a prospective TRV as specified in 7.101.2.8 and the values specified in test-duty 1 of IEC 60282-1:2020. The rated short-circuit breaking current is expressed by the RMS value of its AC component.

The rated short-circuit breaking currents shall be selected from the R10 series.

NOTE 1 The R10 series comprises the numbers: 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n .

NOTE 2 It is recognized that the series impedance of the combination or rapid operation of the fuses or switch can cause one or both of the following effects:

- a) a reduction of short-circuit current to a value appreciably below that which would otherwise be reached;
- b) such rapid operation that the short-circuit current wave is distorted from its normal form.

This is why the term "prospective current" is used when assessing breaking and making performances.

5.102 Rated short-circuit making current

The rated short-circuit making current is the highest prospective peak current which the switch-fuse combination shall be capable of making under the conditions of use and behaviour defined in this document in a circuit having a power-frequency voltage corresponding to the rated voltage of the switch-fuse combination. It shall be at least 2,5 times (50 Hz) or 2,6 times (60 Hz) the value of the rated short-circuit breaking current.

NOTE 1 See also Note 2 in 5.101.

NOTE 2 A higher peak factor, linked with possible long time constant of the network, does not influence the performance of the switch-fuse combination under short-circuit conditions, thanks to the current-limiting behaviour of the fuses. That is stated in IEC 60282-1:2020, 6.1.2.

5.103 Rated transfer current (striker operation) (I_{transfer})

The rated transfer current is the maximum RMS value of the transfer current which the switch in the combination is able to interrupt.

5.104 Rated take-over current for release-operated combinations (I_{rto})

The rated take-over current is the maximum RMS value of the take-over current which the switch in the combination is able to interrupt.

6 Design and construction

6.1 Requirements for liquids in switch-fuse combinations

Subclause 6.1 of IEC 62271-1:2017 applies.

6.2 Requirements for gases in switch-fuse combinations

Subclause 6.2 of IEC 62271-1:2017 applies.

6.3 Earthing of switch-fuse combinations

Subclause 6.3 of IEC 62271-1:2017 applies.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 applies.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 applies with the following addition:

Dependent manual operation is not allowed.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 applies.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 applies with the following addition:

NOTE The switch-fuse combination is able to break the fault current, without need of a time delay.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 applies.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 applies.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 applies.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 applies with the following modifications:

The nameplate of a switch-fuse combination shall contain information in accordance with Table 1.

Table 1 – Nameplate information

(1)	Abbreviation (2) ^a	Unit (3)	Switch-fuse combination (4)	Operating device (5)	Condition for marking required (6)
Manufacturer			X	Y	Only if not integral with the combination and/or if manufacturers are different.
Type designation			X	Y	Only if not integral with the combination and/or if manufacturers are different.
Serial number			X	(Y)	Only if not integral with the combination and/or if manufacturers are different.
Number of this document			X		
Instruction book reference			X		
Rated voltage	U_r	kV	X		
Rated lightning impulse withstand voltage	U_p	kV	X		
Rated frequency	f_r	Hz	X		
Rated continuous current with fuses	See reference list		X		
Filling pressure for operation(*)	P_{rm}	kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for operation(*)	p_{mm}	kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Alarm pressure for operation(*)	P_{am}	kPa		Y	If applicable. Information to be put on the nameplate or in the instructions book.
Filling pressure for insulation(*)	P_{re}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for insulation(*)	p_{me}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Minimum functional pressure for switching(*)	p_{sw}	kPa	Y		If applicable. Information to be put on the nameplate or in the instructions book.
Rated supply voltage of auxiliary and control circuits	U_a	V		Y	If applicable.
Year of manufacture			X		
Minimum and maximum ambient air temperature		°C	Y		If different from –5 °C and/or 40 °C.
Insulating fluid and mass	M_f	kg	Y		If applicable.
Key (*) Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate or in the instruction book. X The marking of these values is mandatory; blank spaces indicate zero values. Y The marking of these values is mandatory, subject to the conditions in column (6). (Y) The marking of these values is optional and subject to the conditions in column (6). ^a Abbreviations in column (2) may be used instead of terms in column (1). When terms of column (1) are used, the word "rated" need not appear.					

6.12 Locking devices

Subclause 6.12 of IEC 62271-1:2017 applies.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 applies.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 applies.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 applies.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 applies.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 applies.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 applies.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 applies.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 applies.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 applies.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 applies.

6.101 Linkages between the fuse striker(s) and the switch release

The linkages between the fuse striker(s) and the switch release shall be such that the switch operates satisfactorily under both three-phase and single-phase conditions at the minimum and maximum requirements of a given type of striker (medium or heavy) irrespective of the method of striker operation (spring or explosive). The requirements for strikers are given in IEC 60282-1:2020. This requirement is considered to be demonstrated by the tests specified for test duties TD_{Isc} and TD_{IWmax} and mechanical operation tests.

6.102 Low over-current conditions (long fuse-pre-arcing time conditions)

The switch-fuse combination shall be designed so that the combination will perform satisfactorily at all values of breaking current from the rated maximum breaking current of the fuse down to the minimum melting current under low over-current conditions. This is achieved by compliance with the following:

- a) time coordination between switch and fuse is provided by either 1), 2) or 3) below:
- 1) the fuse-initiated opening time of the switch-fuse combination shall be shorter than the maximum arcing time the fuse can withstand as specified in IEC 60282-1:2020;
- NOTE Tests have been introduced in IEC 60282-1 in order to assess that the maximum arcing withstand time of the fuse under long pre-arcing conditions is at least 100 ms.
- 2) where the fuse manufacturer can show that the fuse has been satisfactorily proven at all values of breaking current from the rated maximum breaking current of the fuse down to the rated minimum melting current of the fuse in the combination (i.e. full range fuses) then the fuse-initiated opening time of the switch-fuse combination is deemed not relevant;
 - 3) where it can be shown that the thermal release of the fuse striker makes the switch clear the current before arcing in the fuse can occur, for all currents below I_3 (minimum breaking current of the fuse in accordance with IEC 60282-1:2020);
- b) temperature rise under these conditions does not impair the performances of the combination as proven by the test described in 7.104.

7 Type tests

7.1 General

7.1.1 Basics

Subclause 7.1.1 of IEC 62271-1:2017 applies with the following additions:

The purpose of type tests is to prove the characteristics of switch-fuse combinations, their operating devices and their operating equipment.

It is required that the switch of the combination has been tested as an individual component for compliance with IEC 62271-103:2021, except for the short-time withstand current and short-circuit making current requirements, because these parameters will be influenced by the fuses.

Furthermore, it is required that the fuses have been tested to the applicable requirements of IEC 60282-1:2020.

For combinations, three groups of tests are involved:

- a) tests on the switch in accordance with IEC 62271-103:2021; these tests may be carried out on a combination other than that used for tests c);
- b) tests on the fuse in accordance with IEC 60282-1:2020;
- c) tests on the combination in accordance with this document.

In the case of a fuse-switch, the tests of IEC 62271-103:2021 and the tests of 7.102 of this document shall be carried out after replacing, as specified, the fuses with solid links of the same shape, dimension and mass as that of the fuses.

The combination submitted for test shall be in new condition with clean contact parts and fitted with the appropriate fuses.

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC 62271-1:2017 applies.

7.1.3 Information to be included in type-test reports

Subclause 7.1.3 of IEC 62271-1:2017 applies.

7.2 Dielectric tests

Subclause 7.2 of IEC 62271-1:2017 and 7.4 of IEC 60282-1:2020 apply.

7.3 Radio interference voltage (RIV) test

RIV tests are not required.

7.4 Resistance measurement

Subclause 7.4 of IEC 62271-1:2017 applies with the following addition:

Solid links of negligible resistance shall be used instead of fuses and the resistance of the links shall be recorded.

7.5 Continuous current tests

Subclause 7.5 of IEC 62271-1:2017 applies with the following additions:

The continuous current tests of the combination shall be carried out at the rated continuous currents of the combination with all fuses of the reference list. However, the number of tests may be reduced by applying the criteria of 7.105.2.

The power (in W) dissipated by each individual (1-phase) fuse-link just before the end of the test period shall be recorded in the type test report.

NOTE 1 The power dissipated by the fuse is defined by the product of the applied AC continuous test current (RMS value) and the measured steady voltage drop across the fuse-link.

NOTE 2 The voltage drop is measured on the fuse-link contacts as close as possible to the point of contact with the immediate mating contact piece.

Reference of fuse-links used for the test, or tests, shall be recorded in the test report.

As long as IEC 60282-1:2020 provide different temperature rise limits compared to IEC 62271-1:2017, the lower values are applicable.

7.6 Short-time withstand current and peak withstand current tests

Subclause 7.6 of IEC 62271-1:2017 does not apply.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 applies.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 applies.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 applies.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-103:2021 applies.

7.11 X-radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 applies.

7.101 Making and breaking tests

7.101.1 General

Subclause 7.101.1 describes four independent test duties:

- TD_{Isc} : making and breaking tests at the rated short-circuit current;
- TD_{IWmax} : making and breaking tests at the maximum breaking I^2t ;
- $TD_{Itransfer}$: breaking tests at the rated transfer current;
- TD_{Ito} : breaking tests at the rated take-over current.

7.101.2 Conditions for performing the tests

7.101.2.1 Condition of the combination before testing

The combination under test shall be mounted in accordance with the manufacturer's instructions, on a specified or equivalent support. Its operating device shall be operated in the manner specified and in particular, if it is electrically or pneumatically operated, it shall be operated at the minimum voltage or gas pressure respectively as specified in 5.9 and 5.11 of IEC 62271-1:2017, unless current chopping influences the test results. In the latter case, the combination shall be operated at a voltage or gas pressure within the tolerances specified in 5.9 and 5.11 of IEC 62271-1:2017, chosen so as to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

It shall be shown that the combination will operate satisfactorily under the above conditions on no-load.

Combinations with independent unlatched operation may be operated by an arrangement provided for the purpose of making remote control possible.

Due consideration shall be given to the choice of the supply side connections. When the combination is intended for power supply from either side, and the physical arrangement of one side of the break, or breaks, of the combination differs from that of the other side, the supply side of the test circuit shall be connected to the side of the combination which gives the more onerous condition. In case of doubt, the test-duty shall be repeated with the supply connections reversed, but for test duties comprising identical tests, one test shall be made with the supply connected to one side and the following test(s) with the supply connected to the other side.

The fuses selected for the tests shall be chosen so that the result of the test duties are deemed valid for all combinations made of the same combination base and any fuse of the reference list. For the tests of take-over current of release-operated combinations, over-current relays or releases (where fitted) shall be of the lowest release-initiated opening time. The tests shall be carried out at ambient temperature and without previous loading. If applicable, test shall be performed at the minimum functional pressure for insulation and/or switching.

7.101.2.2 Test frequency

Combinations shall be tested at rated frequency, with a tolerance as stated in Table C.1, Annex C.

Combinations may be tested at 50 Hz or 60 Hz to cover both frequencies with the testing conditions given in Table 2.

Table 2 – Summary of the conditions for combining tests and alternative procedures

Test duty	Performed at 50 Hz, and also valid for 60 Hz	Performed at 60 Hz, and also valid for 50 Hz
$TD_{I_{transfer}}$, $TD_{I_{to}}$	If a derating factor of 1,2 ^a is applied to the rated transfer current and to the rated take-over current	yes
$TD_{I_{sc}}$, $TD_{I_{Wmax}}$	yes ^b	yes ^b
^a The factor 1,2 reflects the higher di/dt at 60 Hz. In the case of a switch-fuse combination of a rated transfer current of 1 000 A tested at 50 Hz, a rated transfer current of 833 A may be assigned at 60 Hz without any other additional tests. ^b During $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$, current-limiting fuses reduce significantly the peak current and force the current to zero before the natural zero of the circuit. Within certain limits (from 48 Hz to 62 Hz), frequency is not a critical parameter for current-limiting fuses (see 7.6.1.4 of IEC 60282-1:2020 and 4.2.3.5 of IEC TR 62655:2013) and in such case the current should be cleared only by fuses. Therefore peak factors of 2,6 usually considered for 60 Hz, are irrelevant for switch-fuse combinations.		

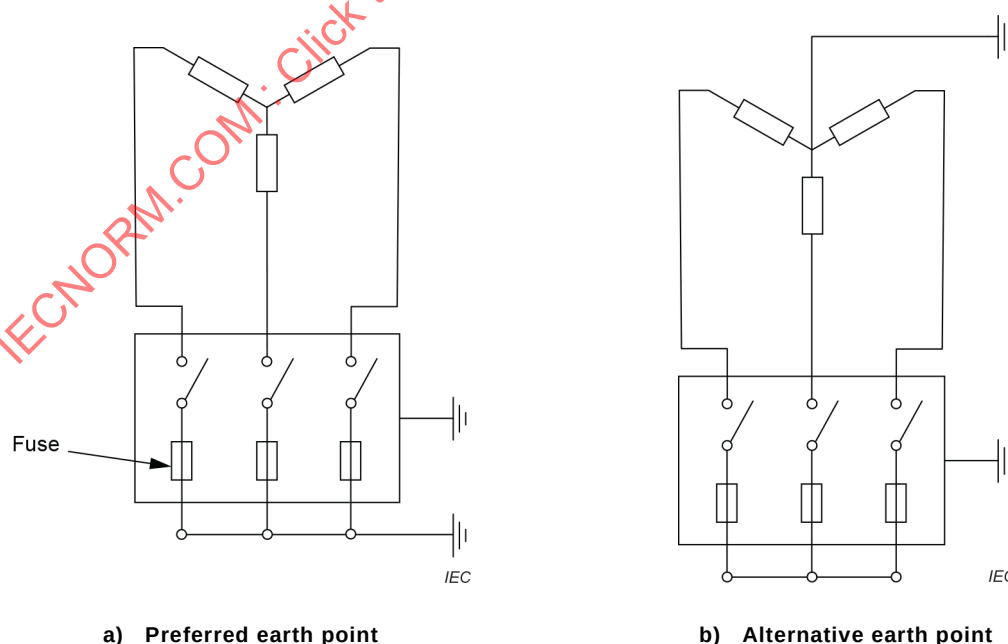
7.101.2.3 Power factor

The power factor of the test circuit shall be determined by measurement and shall be taken as the average of the power factors in each phase.

During the tests, the average value shall conform to the values given in 7.101.3.1, 7.101.3.2, 7.101.3.3 and 7.101.3.4.

7.101.2.4 Arrangement of test circuits

For test duties $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$, the combination shall be connected in a circuit having the neutral point of the supply isolated and the neutral point of the three-phase short-circuit earthed, as shown in Figure 1a). When the neutral point of the test supply cannot be isolated, it shall be earthed and the three-phase short-circuit point shall be isolated as shown in Figure 1b).

**Figure 1 – Arrangement of test circuits for test duties $TD_{I_{sc}}$ and $TD_{I_{Wmax}}$**

For test duties $TD_{I_{transfer}}$ and $TD_{I_{to}}$, the combination shall be connected in a circuit as shown in Figure 2 and Figure 3, respectively.

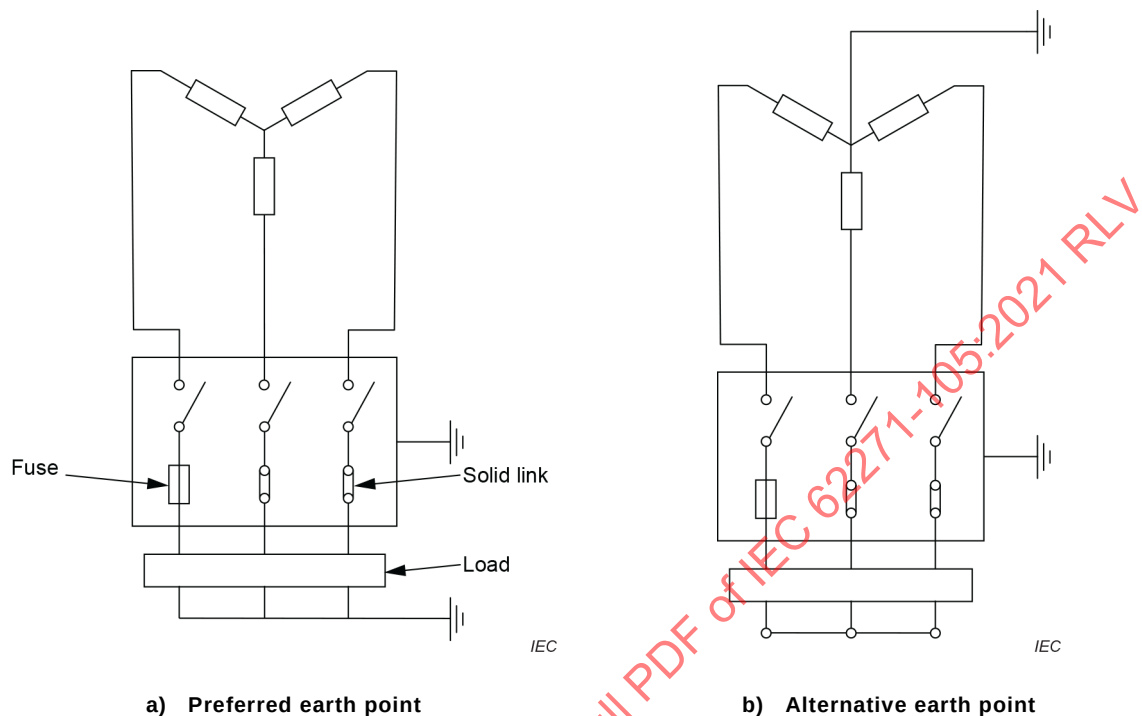


Figure 2 – Arrangement of test circuits for test-duty $TD_{I_{transfer}}$

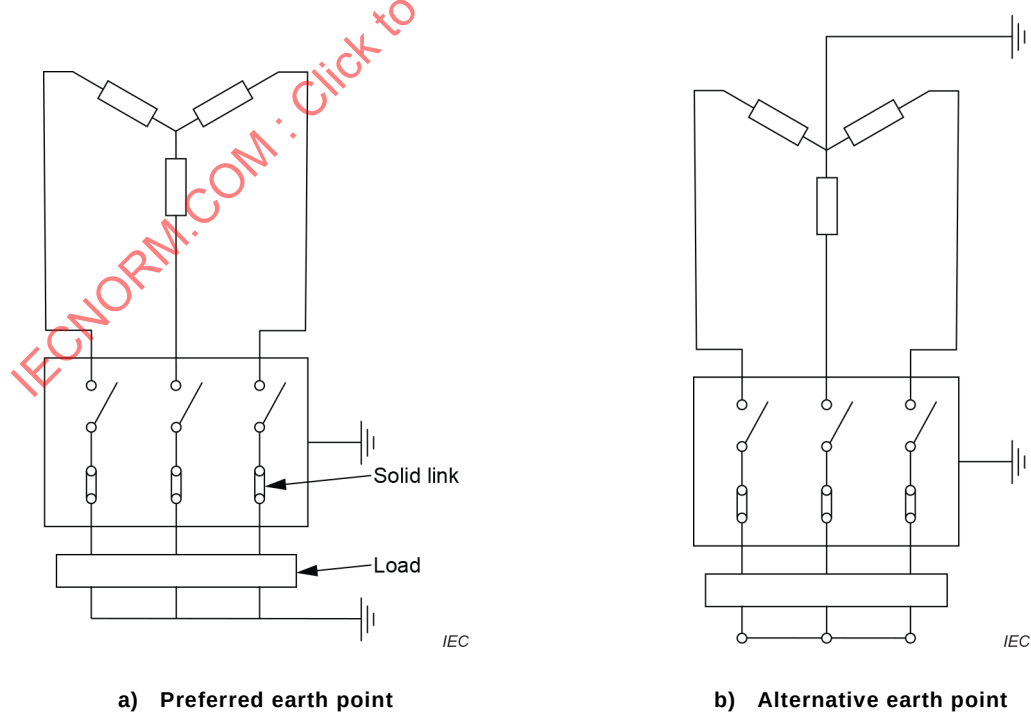


Figure 3 – Arrangement of test circuits for test-duty $TD_{I_{to}}$

For combinations producing an emission of flame or metallic particles, the tests shall be made with metallic screens placed in the vicinity of the live parts, separated from them by a clearance distance which the manufacturer shall specify.

The screens, frame and other normally earthed parts shall be insulated and then connected to earth through a current indicating device. The current indicating device can be a fuse consisting of a copper wire of 0,1 mm diameter and 5 cm in length, or a link to earth across a sensor to measure the current. The fuse wire may also be connected to the secondary side of a 1:1 ratio current transformer. The terminals of the current transformer should be protected by a spark gap or surge arrester. No significant leakage is assumed to have occurred if the wire is intact after the test or if the Joule integral of the leakage current is less than 5 A²s from arc establishing up to 100 ms.

7.101.2.5 Test voltage for breaking tests

The test voltage is the average of the phase-to-phase voltages measured at the combination location immediately after the breaking operation.

The voltage shall be measured as close as practicable to the terminals of the combination, i.e. without appreciable impedance between the measuring point and the terminals.

The test voltage shall be equal to the rated voltage of the combination with a tolerance on the average value of $\pm 5\%$ and a tolerance on any phase to the average value of $\pm 20\%$.

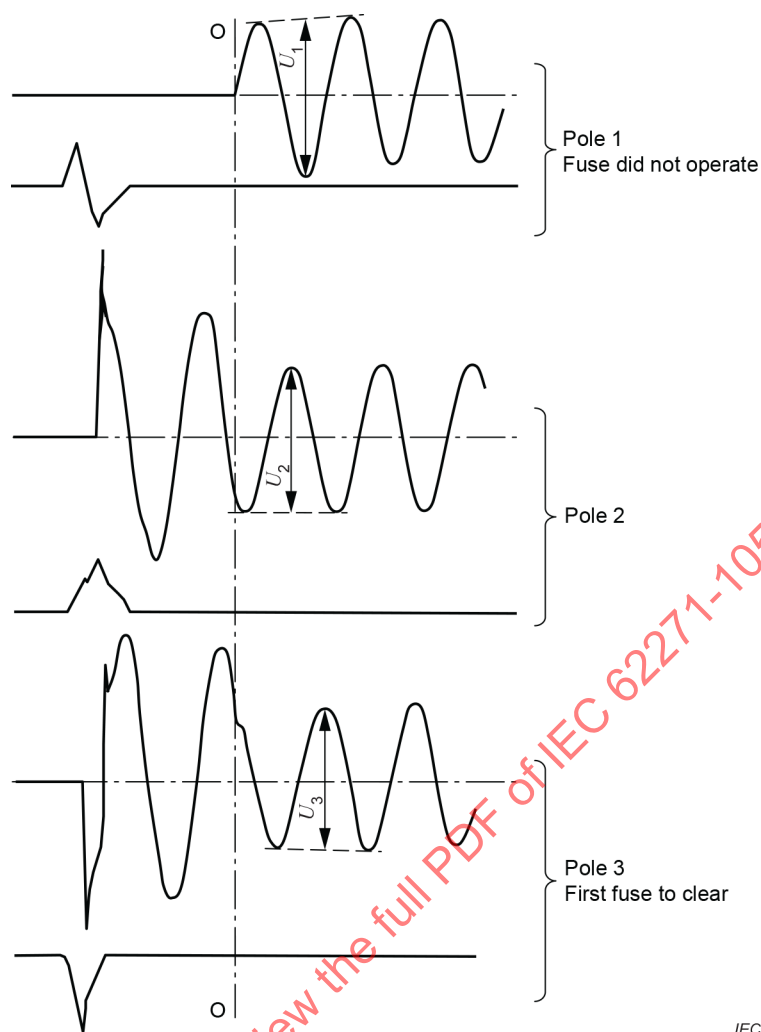
7.101.2.6 Power-frequency recovery voltage

The power-frequency recovery voltage shall be maintained for at least 0,3 s after arc extinction.

The power-frequency recovery voltage of a three-phase test circuit shall be the average value of the power-frequency recovery voltages in all phases measured after the opening of the switch.

The power-frequency recovery voltage of the test circuit shall be measured between the terminals of each pole of the combination in each phase of the test circuit.

The power-frequency recovery voltage shall be measured one cycle after the opening of the switch in accordance with Figure 4.



IEC

Key

$U_1/2\sqrt{2}$ voltage of pole 1

$U_2/2\sqrt{2}$ voltage of pole 2

$U_3/2\sqrt{2}$ voltage of pole 3

OO instant of opening of mechanical switching device

$$\text{Average voltage of poles 1, 2 and 3} = \frac{\frac{U_1}{2\sqrt{2}} + \frac{U_2}{2\sqrt{2}} + \frac{U_3}{2\sqrt{2}}}{3}$$

Figure 4 – Determination of power-frequency recovery voltage

7.101.2.7 Applied voltage before short-circuit making tests

The applied voltage (see 3.7.112) before the short-circuit making tests in test duties TD_{ISC} and $TD_{I_{Wmax}}$ is the RMS value of the voltage at the pole terminals immediately before the test.

The average value of the applied three-phase voltages shall be not less than the rated voltage of the combination divided by $\sqrt{3}$ and shall not exceed this value by more than 10 % without the consent of the manufacturer.

The difference between the average value and the applied voltages of each phase shall not exceed 5 % of the average value.

7.101.2.8 Breaking current

For test duties TD_{ISC} and TD_{IWmax} , the RMS value of the AC component of the prospective short-circuit breaking current shall be measured one half-cycle after the initiation of the short-circuit in the prospective current test.

For test duties $TD_{Itransfer}$ and TD_{It0} , the breaking current shall be the RMS value of the AC component measured at the initiation of arcing.

For test duties TD_{ISC} , TD_{IWmax} and TD_{It0} , the RMS value of the AC component of the breaking current in any pole shall not vary from the average by more than 10 %. For test-duty $TD_{Itransfer}$, the RMS value of the AC component of the breaking current in the two poles fitted with solid conducting links shall be not less than $(\sqrt{3})/2$, i.e. 87 % of that in the first-pole-to-clear, i.e. the pole fitted with a fuse.

7.101.2.9 TRV

The prospective TRV of a test circuit shall be determined by such a method as will produce and measure the TRV wave without significantly influencing it and shall be measured at the terminals to which the combination will be connected with all necessary test-measuring devices, such as voltage dividers, included. Suitable methods are described in Annex E of IEC 62271-100:2021. The TRV refers to the first-pole-to-clear, i.e. the voltage across one open pole with the other two poles closed, with the appropriate test circuit arranged in accordance with 7.101.2.4.

The prospective TRV curve of a test circuit is represented by its envelope drawn as shown in Figure 5 and by its initial portion.

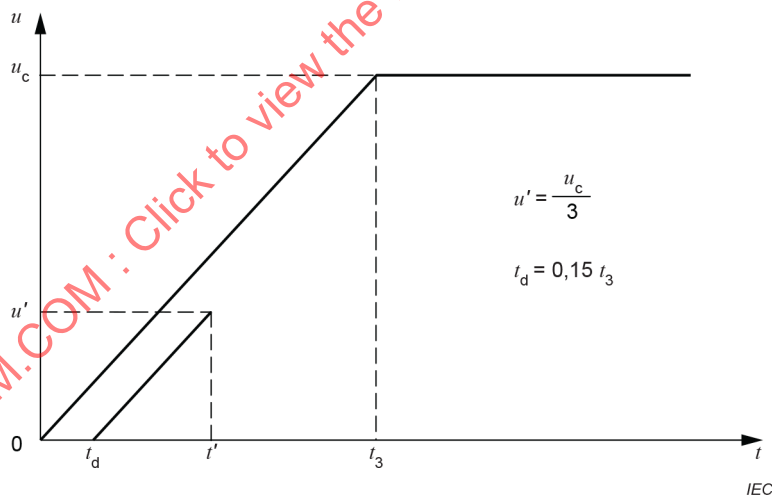


Figure 5 – Representation of a specified TRV by a two-parameter reference line and a delay line

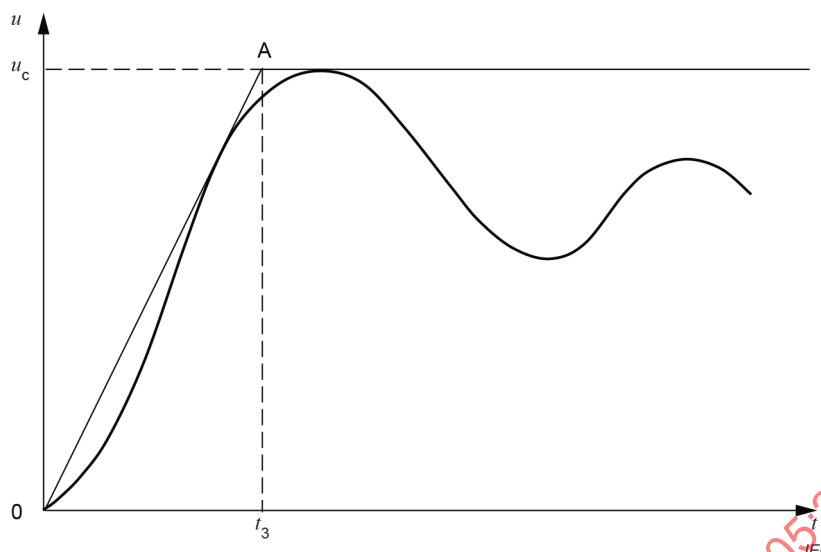


Figure 6 – Example of a two-parameter reference line for a TRV

The prospective TRV wave of the test circuit shall comply with the following requirements (see example in Figure 6):

- a) Its envelope shall at no time be below the specified reference line.

It is stressed that the extent by which the envelope may exceed the specified reference line requires the consent of the manufacturer.

- b) Its initial portion shall not cross the delay line where such a delay is specified.

7.101.3 Test-duty procedures

7.101.3.1 Test-duty $TD_{I_{sc}}$ – Making and breaking tests at the rated short-circuit current

This test-duty is performed to show that the switch is capable of withstanding and making the cut-off current of the fuse without damage and that the striker will open the switch at this current. The test is carried out with fuses fitted in all three poles of the combination.

One break and then one make-break test shall be made in a three-phase circuit, having prospective current equal to the rated short-circuit breaking current of the combination with a tolerance of $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \%$.

The power factor of the test circuit shall be 0,07 to 0,15 lagging.

The applied voltage shall be in accordance with 7.101.2.7.

The power-frequency recovery voltage (see 7.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is $\pm 5 \%$ of the specified value, and the tolerance on any phase to the average value is $\pm 20 \%$.

The prospective TRV shall be in accordance with 7.101.2.9 and the values specified in test-duty 1 of IEC 60282-1:2020.

The breaking test of this test-duty shall be made with the initiation of arcing in the fuse in one of the outer poles in accordance with the provisions of test-duty 1 of IEC 60282-1:2020, i.e. to be within the range of 65 to 90 electrical degrees after voltage zero in that pole.

7.101.3.2 Test-duty $TD_{IW_{max}}$ – Making and breaking tests at the maximum breaking I^2t

When carried out, its purpose is to verify the performance of the combination with a prospective current approximating to that producing the maximum I^2t for the switch-fuse combination. The test is carried out with fuses fitted in all three poles of the combination.

This test-duty may be omitted if all of the following requirements are met:

- combinations in which the switch closes fully home before opening under the action of the fuse striker;
- the switch used has been subjected, under IEC 62271-103:2021 conditions, to two make tests at a peak current value not less than 2,5 times I_2 (50 Hz) or 2,6 times I_2 (60 Hz).

A short-time test for a duration of not less than 0,1 s at a current value not less than I_2 (i.e. the prospective short-circuit current for test-duty 2 of IEC 60282-1:2020).

NOTE For other peak factors/time constants refer to NOTE 2 of 5.102.

This test-duty may be also omitted if the fuse or fuses tested in the combination to test-duty TD_{ISC} of this document have a higher published value of I^2t under test-duty 1 of IEC 60282-1:2020 than under test-duty 2 of IEC 60282-1:2020.

One break and one make-break test shall be made in a three-phase circuit having a prospective current within ± 10 % of that prospective current required.

The power factor of the test circuit shall be between 0,07 to 0,15 lagging.

The applied voltage shall be in accordance with 7.101.2.7. For the breaking test of this test-duty, the operation shall be made with point-on-wave closure of the circuit so that current commences between 0 and 20 electrical degrees after voltage zero on any one phase.

The power-frequency recovery voltage (see 7.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % of the specified value, and the tolerance on any phase to the average value is ± 20 %.

The prospective TRV shall be in accordance with 7.101.2.9 and the values specified in test-duty 2 of IEC 60282-1:2020.

7.101.3.3 Test-duty $TD_{I_{transfer}}$ – Breaking tests at the rated transfer current

This test-duty is performed to prove the correct coordination between the switch and fuses in the current region where the breaking duty is transferred from the fuses to the switch (see 3.7.108 and Annex B).

Test-duty $TD_{I_{transfer}}$ may be omitted in the case of release-operated combinations if the rated take-over current is equal to or higher than the rated transfer current.

Three break tests shall be made in a three-phase circuit, as shown in Figure 2a) or Figure 2b), with the fuses in two poles replaced by solid links of negligible impedance. The pair of poles with the solid links shall be different on each of the three breaking tests. In the case of fuse-switches, the solid links shall be of the same shape, dimension and mass as those of the fuses they replace.

If this arrangement of one fuse on one pole and two solid links on the two other poles is not practicable for the testing laboratory, then the fuse could be omitted and the switch tripped in some other way. In the case of fuse-switches, the fuse shall be replaced by either a dummy fuse (for example an operated fuse-link) or an insulating link of the same shape, dimension and mass as those of the fuse.

The test circuit shall consist of a three-phase supply and load circuit (see Figure 2a) or Figure 2b)).

The load circuit shall be an R-L series connected circuit.

The supply circuit shall have a power factor not exceeding 0,2 lagging and shall meet the following requirements:

- the symmetrical component of the short-circuit breaking current of the supply circuit shall neither exceed the rated short-circuit breaking current of the combination nor be less than 5 % of this current;
- the impedance of the supply circuit shall be between 12 % and 18 % of the total impedance of the test circuit for test-duty TD_{transfer} . If, due to limitations of the testing station, this condition cannot be met, the percentage may be lower, but it shall be ensured that the resulting prospective TRV is not less severe;
- the prospective TRV of the supply circuit under short-circuit conditions shall be in accordance with test duty 1 of IEC 60282-1:2020.

NOTE 1 For more information about TRV during tests refer to the notes in Table 8 of IEC 62271-103:2021.

The power factor of the load circuit, determined in accordance with 7.101.2.3, shall be:

- between 0,2 to 0,3 lagging if the breaking current exceeds 400 A;
- between 0,3 to 0,4 lagging if the breaking current is equal to or less than 400 A.

The test voltage shall be in accordance with 7.101.2.5.

The power-frequency recovery voltage shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % and the tolerance on any phase voltage to the average value is ± 20 %.

The prospective TRV of the load circuit shall be in accordance with 7.101.2.9 and Table 3 or Table 4, as appropriate. A delay line is not specified.

Table 3 – Values of prospective TRV for test-duty TD_{transfer} based on practice in Europe

Rated voltage U_r kV	TRV peak voltage u_c kV	Time t_3 μs	Rate-of-rise u_c/t_3 kV/ μs
3,6	6,2	80	0,077
7,2	12,3	104	0,115
12	20,6	120	0,167
17,5	30	144	0,208
24	41	176	0,236
36	62	216	0,285
$u_c = 1,4 \times 1,5 \times U_r \frac{\sqrt{2}}{\sqrt{3}}$			

Table 4 – Values of prospective TRV for test-duty $TD_{Itransfer}$ based on practice in the United States of America

Rated voltage U_r kV	TRV peak voltage u_c kV	Time t_3 μs	Rate-of-rise u_c/t_3 kV/μs
2,8	4,8	74	0,065
5,5	9,4	92	0,103
8,3	14,2	108	0,132
15	25,7	132	0,195
15,5	26,6	134	0,198
27	46,3	186	0,249
38	65,2	222	0,293
$u_c = 1,4 \times 1,5 \times U_r \frac{\sqrt{2}}{\sqrt{3}}$			

NOTE 2 Table 3 and Table 4 give TRV for the first-pole-to-clear, i.e. the pole with the fuse (or dummy fuse/insulating link).

NOTE 3 For more information about TRV during tests refer to the notes in Table 8 of IEC 62271-103:2021.

NOTE 4 It is recognized that the TRV values obtained during the test will differ from prospective values shown in Table 3 and Table 4, due both to the influence of the supply circuit and the power factor of the load.

7.101.3.4 Test-duty TD_{Ito} – Breaking tests at the rated take-over current (release-operated combinations only)

This test-duty is mandatory for release-operated combinations only and is performed to prove the correct coordination between the release-operated switch and fuses in the current region where the breaking duty is taken over from the fuses by the release-operated switch.

Three break tests shall be made in a three-phase circuit, as shown in Figure 3, with the fuses in all three poles replaced by solid links of negligible impedance. In the case of fuse-switches, the solid links shall be of the same shape, dimension and mass as those of the fuses they replace.

The test circuit shall be the same as for test-duty $TD_{Itransfer}$.

The test current value corresponds to

- the minimum release-initiated opening time of the switch plus a half cycle time to represent the minimum operating time of an external over-current or an earth-fault relay;
- the maximum operating time of the fuses of highest rated current.

See Figure 7.

NOTE Figure 7 represents for the minimum and maximum release-initiated opening time of the switch, the case of a direct over-current release.

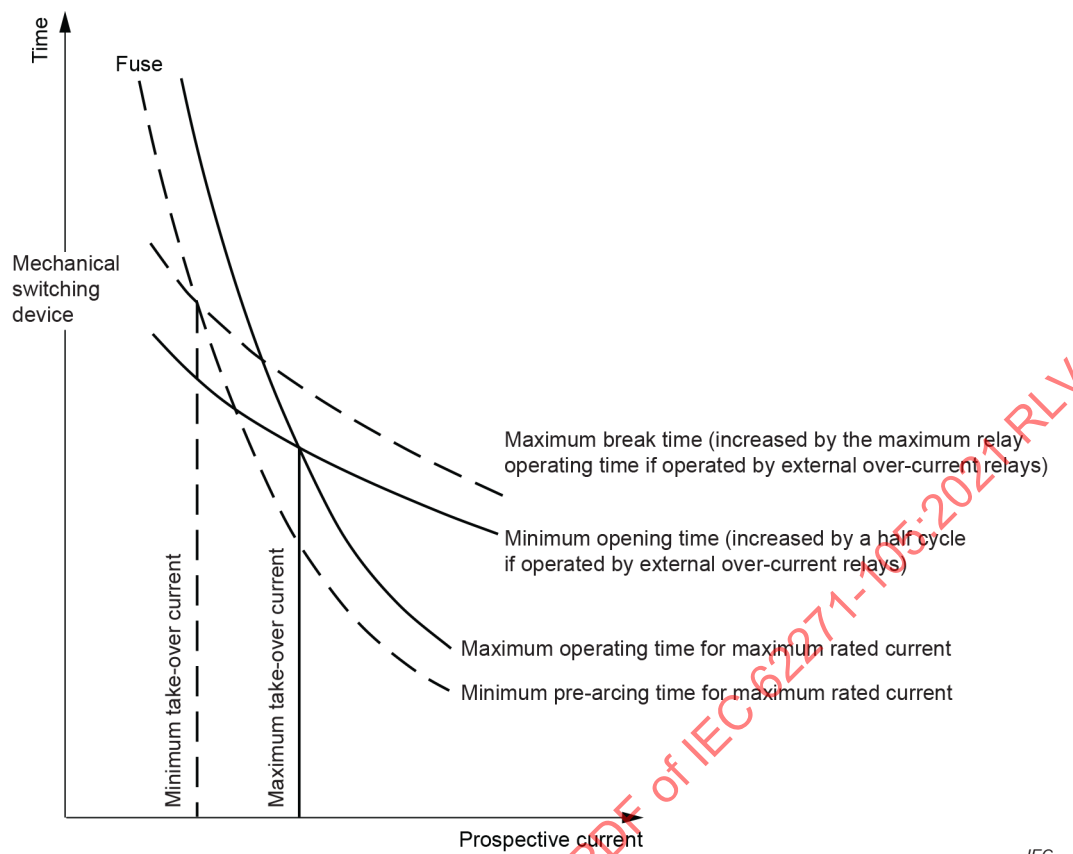


Figure 7 – Characteristics for determining take-over current

7.101.3.5 Summary of test parameters

A summary of the parameters to be used when performing test duties is given in Table 5.

Table 5 – Summary of test parameters for test duties

Test-duty		Test voltage	Test current/making angle	Test series	Power factor	TRV
No	Circuit					
TD _{Isc}	Figure 1	U_r	See 7.101.3.1	O CO	0,07 to 0,15 lagging	See test-duty 1 of IEC 60282-1:2020.
TD _{IWmax}	Figure 1	U_r	See 7.101.3.2	O CO	0,07 to 0,15 lagging	See test-duty 2 of IEC 60282-1:2020.
TD _{Itransfer}	Figure 2	U_r	$I_{transfer}$ See 7.101.3.3	O O O	$I_{transfer} > 400$ A 0,2 to 0,3 lagging $I_{transfer} \leq 400$ A 0,3 to 0,4 lagging	Table 3 and Table 4
TD _{Ito}	Figure 3	U_r	I_{to} See 7.101.3.4	O O O	$I_{to} > 400$ A 0,2 to 0,3 lagging $I_{to} \leq 400$ A 0,3 to 0,4 lagging	Table 3 and Table 4
NOTE The power factors relating to test duties TD _{Itransfer} and TD _{Ito} refer to the load circuit.						

7.101.4 Behaviour of the combination during tests

The combination may be inspected but not reconditioned (apart from the replacement of fuses) between any of the test duties which shall all be done on one test object.

During operation, the combination shall show neither signs of electrical or mechanical distress nor phenomena that might endanger an operator, verified as follows.

- From liquid-filled combinations there shall be no outward emission of flame, and the gases produced together with the liquid carried with the gases shall be allowed to escape in such a way as not to cause electrical breakdown.
- For other types of combinations, flame or metallic particles such as might impair the insulation level of the combination shall not be projected beyond the boundaries specified by the manufacturer.
- No significant leakage current is assumed to have flowed if the fuse wire defined in 7.101.2.4 is intact after the test.

During test duties TD_{Isc} and TD_{IWmax}, the switch shall open following the action of the fuse strikers.

For combinations with vacuum switches, non-sustained disruptive discharges (NSDDs) may occur during the recovery voltage period following a breaking operation. However, their occurrence is not a sign of distress of the switching device under test and they do not pose any risk to a system in service. Therefore, their number is of no significance in the interpretation of the performance of the device under test. Where NSDDs are seen during normal testing they shall be reported in order to explain the irregularities in the recovery voltage.

All three fuses should be replaced, regardless of whether they have operated during the test or not.

In three-phase operations, one fuse and/or its striker may not have operated during testing. This is a normal and not unusual condition which will not invalidate acceptance of the test provided that the fuse shall not have received external damage in any way.

7.101.5 Condition of the apparatus after testing

After testing, fuses shall comply with the requirements of 6.1.3 of IEC 60282-1:2020.

After performing each test-duty:

- a) The mechanical function and the insulators of the combination shall be practically in the same condition as before the tests. There may be deposits on the insulators caused by the decomposition of the arc-extinguishing medium.
- b) The combination shall, without reconditioning, be capable of withstanding its rated voltage without dielectric failure.
- c) For those combinations which incorporate a switch-disconnector, the isolating properties of the switch-disconnector in the open position shall not be reduced below those specified (see 5.3 of IEC 62271-1:2017) by deterioration of insulating parts in the neighbourhood of, or parallel to, the isolating distance. The requirements for disconnectors given in IEC 62271-102:2018 shall be fulfilled.
- d) The switch-fuse combination shall be capable of carrying its highest rated continuous current continuously, from the reference list, after renewal of fuses.

Visual inspection and no-load operation of the combination after testing are usually sufficient for checking the above requirements.

In case of doubt on the ability of the switch-fuse combination to meet the conditions of 7.101.5 b) and/or c), it shall be subjected to the relevant power frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:2017.

If vacuum interrupters are used, and they are placed in an insulating fluid other than air at atmospheric pressure (for example a vacuum interrupter in an enclosure filled with SF₆) an integrity check shall also be performed after the making and breaking tests, as follows.

An additional breaking test ID_{lto} shall be performed using a circuit that supplies at least the 50 % rated breaking take-over current with at least 50 % of the rated voltage, having both the neutral points of source side and load circuit, earthed. This additional breaking test shall be made before or after the no-load tests subsequent to the making and breaking test. A successful interruption in each pole evidences that the vacuum interrupter integrity is maintained.

In case of doubt on the capability of the switch-fuse combination, where applicable, to meet the conditions of 7.101.5 d), the requirement is considered to be met if one of the following criteria is satisfied:

- 1) visual inspection of the main contacts shows evidence of their good condition;

or, if impracticable or unsatisfying,

- 2) the resistance measurement according to the procedure and the relevant acceptance criteria of 7.4 is satisfying. Before measurement of contact resistance, up to 10 no-load operations may be done,

or, if the condition of b) is not satisfied:

- 3) a test under the highest rated continuous current demonstrates that no thermal runaway occurs, by monitoring the temperature at the points where resistance measurement was made until stabilization (variation less than 1 K/h). During this test, no other temperature measurement is made inside of the switching device. If stabilization cannot be obtained, then the condition check has failed and the switch-fuse combination is considered to have failed the test duty as well.

7.102 Mechanical operation tests

Tests of the trip linkages shall be performed as follows:

- a) To test the mechanical reliability of the linkages between the fuse striker(s) and the switch release, a total of 100 operations shall be made, of which 90 shall be made (30 in each pole) with one striker of minimum energy and 10 with three strikers of maximum energy operating simultaneously.

After performing this test-duty, the mechanical functioning of the trip linkages shall be the same as before the tests.

- b) Using a dummy fuse-link with extended striker, set to the minimum actual travel within the tolerance specified in IEC 60282-1:2020, for each pole in turn it shall be shown that the switch either cannot be closed or cannot remain closed according to its design.

For the purpose of these tests, a device simulating fuse striker operation may be used.

NOTE The switch being in compliance with IEC 62271-103:2021, no additional mechanical operation tests of the switch are required.

7.103 Mechanical shock tests on fuses

During the test of the trip linkages given in 7.102, two fuses shall be fitted in the two poles of the combination not fitted with the fuse striker simulating device for the three sets of 30 operations involved. Each of the two fuses used shall have the lowest rated current of the reference list. If this rating is listed with several fuse types, then the fuses used for the test shall be of different types.

Additionally, in the case of fuse-switches only, 90 close-open operations shall be performed manually with three fuses.

Each of the three fuses used shall have the lowest rated current of the reference list. If this rating is listed with several fuse types, then the fuses used for the test shall be of different types.

After performing this (these) test-duty(ies), the fuses shall show neither signs of mechanical damage nor significant change in resistance. They shall not have become displaced in their contacts.

The satisfactory performance of the above test-duty(ies) can be deemed to be sufficient evidence for justifying the use of fuses other than those tested without further mechanical shock testing.

7.104 Thermal test with long pre-arcing time of fuse

The test conditions are similar to the one used for the continuous current test of 7.5 without measurement of temperature rise. However, the no-load voltage of the supply shall be sufficient to operate the striker.

The test shall be carried out on the fuse, in the reference list, having the highest current rating in each homogeneous series. The test shall be performed at the current giving the highest fuse body temperature, as stated by the fuse manufacturer.

The test is performed by applying a test current of the required value, as stated above, until the striker operates.

The above test need not be repeated for alternative types of fuse having a stated lower peak body temperature than that tested and using the same striker design.

The test is valid if

- a) the striker and the switch have operated correctly,
- b) after visual inspection, no parts of the switch-fuse combination have sustained damage and all parts are in a satisfactory condition (for fuses as defined in 6.1.3 of IEC 60282-1:2020).

7.105 Extension of validity of type tests

7.105.1 Dielectric

The dielectric properties may be affected when using other diameters than that of the tested fuse. Extension of validity is restricted to fuses with the same overall dimensions.

7.105.2 Continuous current tests

Compliance with continuous current tests of the combination made on a combination base and a given fuse type (referred to as X) demonstrates the compliance of any combination made of the same combination base fitted with another fuse type, at the associated rated continuous current of this new combination, provided that the four criteria below are fulfilled:

- the fuses have the same length as the fuse X;
- the fuses have a rated current lower than, or equal to, those of the fuse X;
- the fuses have a dissipated power (in accordance with IEC 60282-1:2020) lower than, or equal to, those of the fuse X;
- the derating of the fuses within the combination ($I_{r \text{ combination}}/I_{r \text{ fuse}}$) is lower than, or equal to, those of the fuse X.

As compliance with the above criteria already includes safety margins, the diameter of the fuses need not be considered.

7.105.3 Making and breaking

Compliance with this document is also achieved by alternative untested or partially tested combinations made of combination base and fuses, provided that the following conditions are met:

- a) any fuse considered to comply with its relevant standard (IEC 60282-1:2020);
- b) the same type of striker is fitted, i.e. medium or heavy in accordance with IEC 60282-1:2020;
- c) the alternative type of fuse is such that the cut-off current and operating I^2t of the alternative type, as established by test-duty 1 and/or test-duty 2 of IEC 60282-1:2020, are not greater than those of the tested type similarly established;
- d) for fuse-switches only, any change in fuse-link mass is not invalidating breaking characteristics due to change in the mechanical operation (i.e. opening speed).

8 Routine tests

Clause 8 of IEC 62271-1:2017 applies with the following addition:

8.101 Mechanical operating tests

Operating tests shall be carried out to ensure that combinations comply with the specified operating conditions within the specified voltage and supply pressure limits of their operating devices.

During these tests, it shall be verified, in particular, that the combinations open and close as specified by the manufacturer when their operating devices are energized or under pressure. It shall also be verified that the operation will not cause any damage to the combinations. Fuses of maximum mass and dimensions shall be fitted for fuse-switch testing. For switch-fuse combinations, tests may be made without fuses.

For all switch-fuse combinations the following test shall be carried out:

- a) under the conditions of 7.102 with the action of one fuse striker of minimum energy simulated: one opening operation on each phase.

Additionally, the following tests shall be performed where applicable:

- b) at the specified maximum supply voltage and/or the maximum pressure of the compressed gas supply: five operating cycles;
- c) at the specified minimum supply voltage and/or the minimum pressure of the compressed gas supply: five operating cycles;
- d) if a combination can be operated by hand as well as by its electric or pneumatic operating device: five manually operated cycles;
- e) for manually operated combinations only: ten operating cycles;
- f) for release-operated combinations only, at rated supply voltage and/or rated pressure of the compressed gas supply: five operating cycles with a minimum current for the tripping circuit energized by the closing of the main contacts.

The tests a), b), c), d) and e) shall be made without current passing through the main circuit.

During all the foregoing routine tests, no adjustments shall be made and the operation shall be faultless. The closed and open positions shall be attained during each operating cycle on tests a), b), c), d) and e).

After the tests, the combination shall be examined to determine that no parts have sustained damage and that all parts are in a satisfactory condition.

9 Guide to the selection of switch-fuse combinations (informative)

Clause 9 of IEC 62271-1:2017 applies with the following additions:

9.101 Guide to the selection of switch-fuse combination for transformer protection

9.101.1 General

The objective of this application guide, taken in conjunction with that for switches (see Clause 9 of IEC 62271-103:2021) and that for fuses is to specify criteria for the selection of a combination of switch and fuses which will ensure correct performances of the switch-fuse combination.

Criteria for the coordination of high-voltage fuses with other circuit components in transformer applications and guidance for the selection of such fuses with particular reference to their time-current characteristics and ratings are given in 5.2.2.2 of IEC TR 62655:2013.

Guidance for the selection of switches is given in Clause 9 of IEC 62271-103:2021.

9.101.2 Rated short-circuit breaking current

The rated short-circuit breaking current of a combination is largely determined by that of the fuses and shall be equal to or greater than the maximum expected RMS symmetrical fault current level of the point in the distribution system at which the combination is to be located.

9.101.3 Primary fault condition caused by a solid short-circuit on the transformer secondary terminals

The primary side fault condition caused by a solid short-circuit on the transformer secondary terminals corresponds to very high TRV values which the switch (not designed and not tested to that condition) in a combination may not be able to cope with. The fuses, therefore, shall be so chosen that they alone will deal with such a fault condition without throwing any of the breaking duty onto the switch. In practice, this entails ensuring that the transfer current of the combination under consideration is less than the foregoing primary fault current expressed by (see Figure 8):

$$I_{sc} = \frac{100I_T}{Z}$$

where

- I_T is the rated current of the transformer;
- I_{sc} is the primary fault current on the transformer;
- Z is the short-circuit percentage impedance of the transformer.

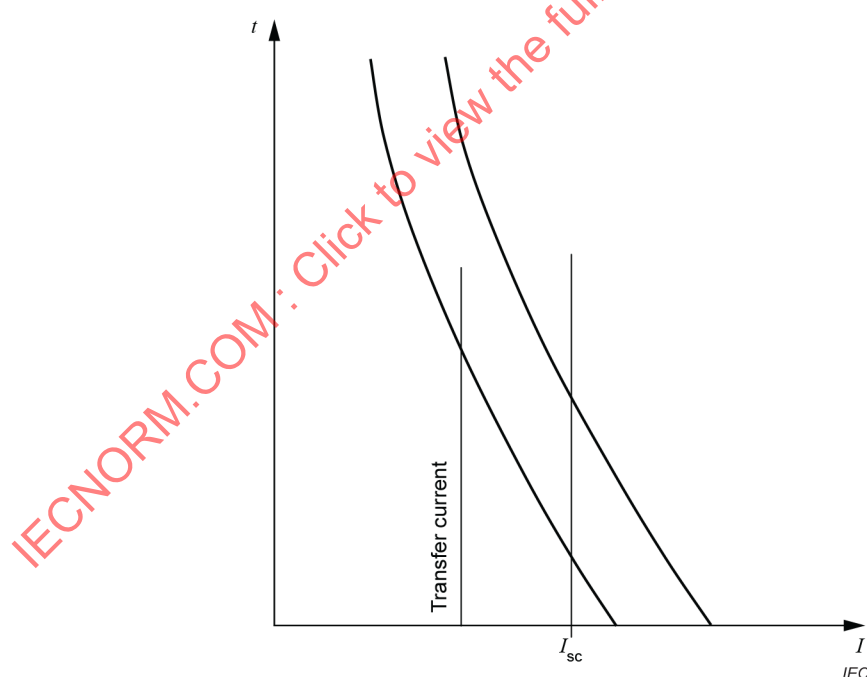


Figure 8 – Transfer current in relation to the primary fault current I_{sc} due to a solid short circuit in the transformer secondary terminal

With this condition being fulfilled, transfer currents correspond to faults for which arc impedance or fault line impedance reduce the magnitude of both the current and the TRV values and increase the power factor.

An example is given in Annex A.

In cases where a system provider considers that the design of the LV connections between transformer and LV switchgear (e.g. inside prefabricated substations in accordance with IEC 62271-202) prevents a solid short-circuit on the secondary transformer terminals, the above fault condition need not be considered in the selection of the fuse-links.

In all other cases where the conditions of this subclause cannot be met, a switch fuse-combination should not be applied.

9.102 Coordination of switch and fuses for extension of the reference list of fuses

9.102.1 General

In the following paragraphs, strictly speaking, one should refer to the break-time and not to the opening time of the switch. However, the opening time is usually more readily available and is close enough to the break-time for the purposes of this document.

9.102.2 Rated continuous current

The rated continuous current of a switch-fuse combination is assigned by the switch-fuse manufacturer and will depend on the type and ratings of the switch and the fuses. It may have to be reduced where the ambient temperature in service exceeds the specified ambient temperature.

The rated continuous current of a combination is generally less than, but shall not be in excess of, the rated current of the fuses as assigned by the fuse manufacturer.

9.102.3 Low over-current performance

At values of fault current below the minimum breaking current of the fuses fitted in the combination, correct operation is ensured by the ejection of one or more fuse strikers operating the switch tripping mechanism (and hence causing the switch to open) before the fuse has had time to be damaged by internal arcing (see 6.102). Additionally, over-current relays could be used.

9.102.4 Transfer current

The transfer current of a combination is dependent upon both the fuse-initiated opening time of the switch and the time-current characteristic of the fuse.

Near the transfer point, under a three-phase fault, the fastest fuse to melt clears the first pole and its striker starts to trip the switch.

The other two poles then see a reduced current (87 %) which will be interrupted by either the switch or the remaining fuses. The transfer point is when the switch opens and the fuse elements melt simultaneously.

The transfer current for a given combination, determined as described in Annex B, shall be smaller than the rated transfer current.

9.102.5 Take-over current

The value of the take-over current of a combination is dependent upon both the release-initiated opening time of the switch and the time-current characteristic of the fuse. As its name implies, it is the value of the current at the intersection of the two curves, above which the fuses take over the function of current interruption from the release and switch.

Relay behaviour and fuse characteristics should be such that the take-over current is smaller than the rated take-over current of the combination (see definition 3.7.112 and the test conditions in 7.101.3.4).

9.102.6 Extension of the validity of type tests

As it is recognized that it may well be impractical to test all combinations made of a combination base and fuses and to carry out repeat tests on combinations whenever the fuse is altered, this document specifies conditions (see 7.105) whereby the validity of the continuous current test, making and breaking type tests may be extended to cover combinations other than that (those) tested.

The test duties specified in this document, together with the associated guidance as to the application of these tests to other combinations cover most users' requirements. However, in some cases, for example supporting the use of a back-up fuse by type tests carried out on the combination using full range fuses from another manufacturer, may require additional combination testing. Such testing should be subject to agreement between the manufacturer and user.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

Subclause 10.1 of IEC 62271-1:2017 applies.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC 62271-1:2017 applies with the following additions:

In addition to the information listed for the switch in 10.2 of IEC 62271-103:2021, the inquirer should specify the limit of supply, i.e. if the combinations described include the fuse-links (defined as switch-fuse combination) or not (defined as switch-fuse combination base).

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 applies with the following additions:

As well as the information given for the switch in 10.3 of IEC 62271-103:2021, the combination manufacturer shall give, in addition to the rated quantities, the following information:

- a) the reference list of fuses, which shall include the designation of the combination base, and for each selected fuse, the following information:
 - fuse designation (manufacturer, type, rating);
 - rated continuous current of the combination;
 - rated short-circuit current of the combination;
 - maximum cut-off current of the combination;
- b) filling medium (type and amount), when applicable.

On request, the following information for the extension of the type test validity should be given:

- fuse length (7.105.2);
- fuse power dissipation (7.105.2);
- Joule integral (highest value of the fuse type used in 7.101.3.1 and 7.101.3.2).

11 Transport, storage, installation, operating instructions and maintenance

Clause 11 of IEC 62271-1:2017 applies with the following additions:

The reference list of fuses shall be given in the instruction book.

High-voltage fuses, although robust in external appearance, may have fuse-elements of relatively fragile construction. Fuses should, therefore, be kept in their protective packaging until ready for installation and should be handled with the same degree of care as a relay, meter or other similar item. Where fuses are already fitted in a switch-fuse unit, they should be temporarily removed while the unit is man-handled into position.

For operation, the following points should be considered:

- a) The three fuses fitted in a given combination shall all be of the same type and current rating, otherwise the breaking performance of the combination could be adversely affected.
- b) It is vital, for the correct operation of the combination, that the fuses are inserted with the strikers in the correct orientation.
- c) When a switch-fuse has operated as a result of a three-phase fault, it is possible for
 - 1) only two out of the three fuses to have operated,
 - 2) all three fuses to have operated but for only two out of the three strikers to have ejected.Such partial operation of one fuse can occur under three-phase service conditions and is not to be considered abnormal.
- d) Where a switch-fuse has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses may give an indication as to the type of fault current and its approximate value. Such an investigation is best carried out by the fuse manufacturer.
- e) All three fuses shall be discarded and replaced if the fuse(s) in one or two poles of a combination has operated.
- f) Before removing or replacing fuses, the operator should satisfy himself that the fuse-mount is electrically disconnected from all parts of the combination which could still be electrically energized. This is especially important when the fuse-mount is not visibly isolated.

12 Safety

Clause 12 of IEC 62271-1:2017 applies.

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:2017 applies.

Annex A (informative)

Example of the coordination of fuses, switch and transformer

The transformer is chosen by the user for its particular duty, thus fixing values of the full load current and permissible overload current.

The maximum fault level of the high-voltage system is known.

For the purpose of this example, an 11 kV, 400 kVA transformer on a high-voltage system with maximum fault level of 16 kA is considered:

- a) full load current is approximately 21 A;
- b) permissible periodic overload is assumed to be 150 %, on the "–5 %" tapping of the transformer, i.e. approximately:

$$21 \text{ A} \times 1,05 \times 1,5 = 33 \text{ A}$$

- c) maximum magnetizing inrush current, assumed to be 12 times the rated current, is:

$$21 \text{ A} \times 12 = 252 \text{ A}$$

for a duration of 0,1 s (5.2.2.2.3 a) of IEC TR 62655:2013).

Site ambient air temperature is 45 °C, i.e. 5 °C above standard.

Suppose the user has decided that a 12 kV switch-fuse combination from a certain manufacturer will be used to control and protect the transformer.

The manufacturer shall provide a list of the fuses which can be used in the combination and shall advise which of these are suitable for the application.

This list of fuses will have been drawn up by the switch-fuse manufacturer on the basis of appropriate type tests on the switch-fuse combination in accordance with this document and by the application of its extension of validity clauses (see 9.102).

Suppose he advises that a 12 kV, 40 A, 16 kA (at least) back-up fuse of a given type from a certain fuse manufacturer is suitable. To justify this advice, the switch-fuse manufacturer will have ascertained the following:

- a) The fuse can withstand the 252 A magnetizing inrush current of the transformer for 0,1 s (5.2.2.2.3 a) of IEC TR 62655:2013). He will normally do this by examining the fuse time-current characteristic, i.e. where the 252 A point at 0,1 s has a selectivity distance of 20 % to the time-current curve at this point, and/or by consulting the fuse manufacturer.
- b) The continuous current rating of the switch-fuse combination when fitted with the fuses is adequate to allow for periodic overloading of the transformer up to 33 A in ambient air temperature conditions of 45 °C (5.2.2.2.3 b)1) of IEC TR 62655:2013).

The continuous current rating of the combination when fitted with the fuses may not be more than 40 A, especially in the higher than standard ambient conditions. Continuous current tests carried out by the switch-fuse manufacturer, or calculations based on such tests, may indicate a continuous current rating of, say, 35 A in ambient conditions of 45 °C. This would be adequate for the application.

- c) The pre-arcing current of the fuse is low enough in the 10 s region of the fuse time-current characteristic to ensure satisfactory protection of the transformer (5.2.2.2.3 c) of IEC TR 62655:2013). The manufacturer will normally do this by examining the fuse time-current characteristic and/or consulting the fuse manufacturer.

- d) The fuses alone will deal with the condition of a solid short-circuit on the transformer secondary terminals, i.e. that the maximum primary short-circuit current (in this case:

$$\frac{400 \times 100}{11 \times \sqrt{3} \times 5} = 420 \text{ A}$$

based on 5 % transformer impedance) is greater than the transfer current (see 3.7.108) of the combination when fitted with 40 A fuses. He will do this using the method explained in 9.102.3. Reference to Figure A.1 shows that the transfer current thus obtained is only 280 A, the fuse-initiated opening time of the switch assumed to be 0,05 s for the purpose of this example.

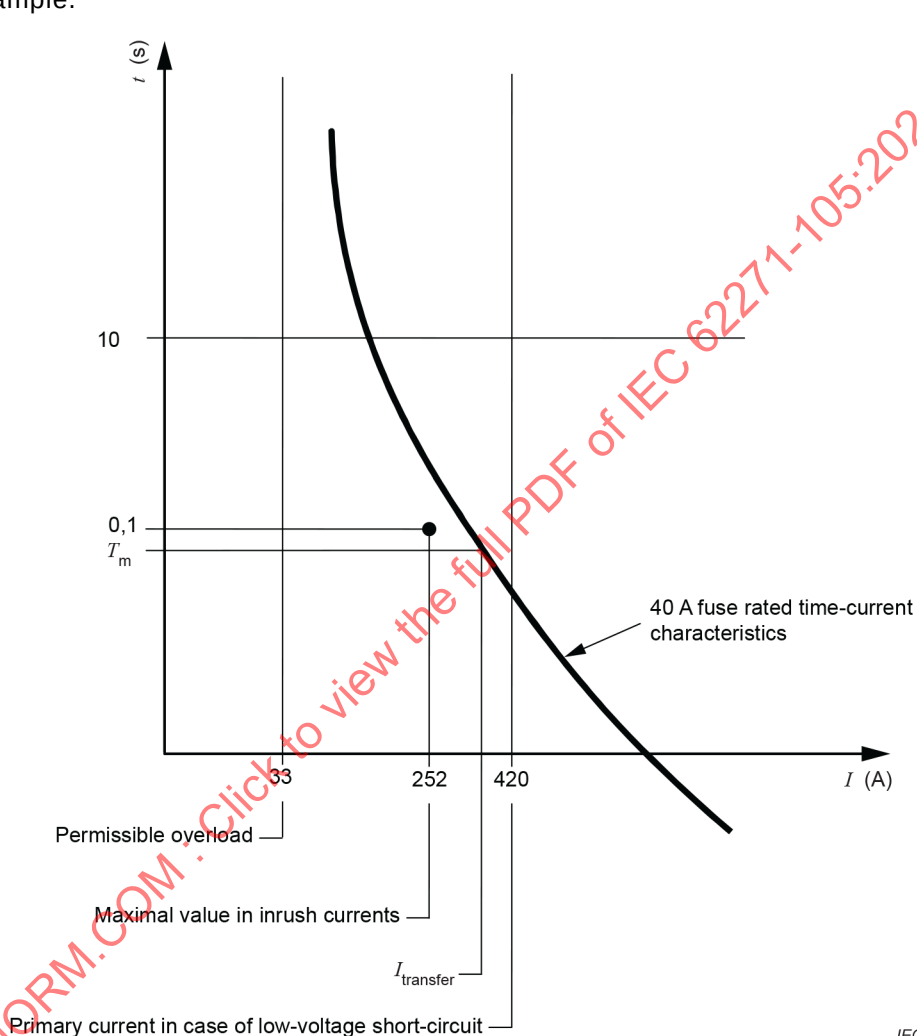


Figure A.1 – Characteristics relating to the protection of an 11 kV, 400 kVA transformer

- e) The transfer current of the combination, when fitted with 40 A fuses, is less than its rated transfer current (see 5.103), which one can suppose to be 1 000 A.

The user shall check that the fuse discriminates with the highest rating of a low-voltage fuse used in the event of a phase-to-phase fault occurring on the low-voltage system.

NOTE This is usually the worst condition for discrimination.

As explained in 5.2.2.2.3 d) of IEC TR 62655:2013, the intersection of the two time-current characteristics of the high-voltage and low-voltage fuses shall occur at a value of current greater than that of the maximum fault current on the load side of the low-voltage fuse (see Figure A.2).

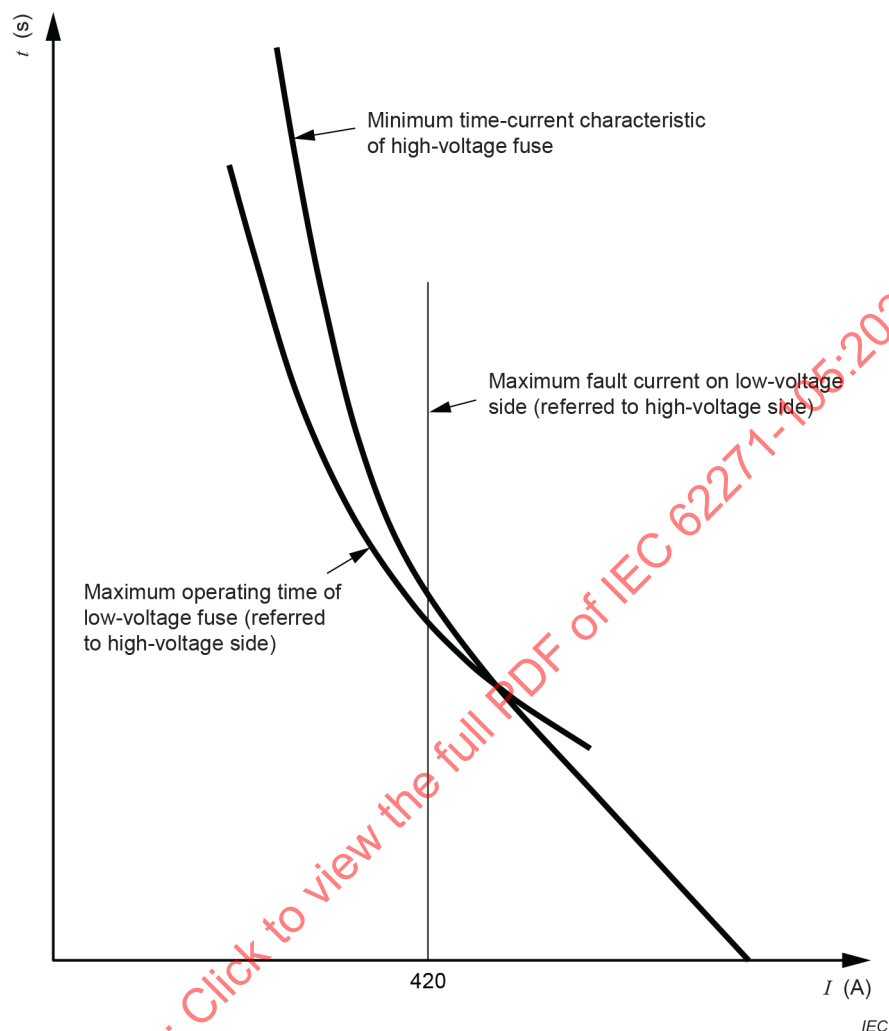


Figure A.2 – Discrimination between HV and LV fuses

Annex B (normative)

Procedures for determining transfer current

B.1 Background

Transfer current I_{transfer} is defined as the current at which, under striker operation, the breaking duty is transferred from the fuses to the switch.

This occurs when, after the melting of a first fuse, the switch opens under striker operation before or at the same time as the melting of the second fuse, there being an inevitable difference between the melting times of fuses.

A knowledge of this difference, ΔT , between the melting times of fuses permits comparison between it and the striker-initiated opening time of the switch-fuse combination.

The following procedures compare, in an intentional simplification, virtual melting times of the fuse-links against the real opening times of the switch-fuse combination. Taking into account the real melting-time values of the fuses, resulting from the interdependent three-phase effects, the value of transfer current may be different. As the calculation already includes some safety margins, these differences may not be taken into consideration.

Calculations proposed in this annex use the assumption of a non-effectively earthed neutral system. Such an assumption leads to consider that the current in the two remaining phases is reduced after a first fuse cleared, possibly extending the melting duration of the remaining fuses. With such an assumption, it could be feared that the two remaining phases should be cleared by the switch-fuse combination with conditions not clearly addressed by this document.

When an effectively earthed neutral system is used, then, after a first fuse cleared the fault, the current in the two remaining phases could keep the value of the three-phase fault. Under such a condition, the requirement expressed in 5.103 ensures that the fuses will melt before the switch-fuse combination can be opened by any tripping device. There is no reason for concern.

B.2 Mathematical determination of ΔT

Figure B.1 shows small segments of the more probable minimum and maximum fuse time-current characteristics in the transfer current region.

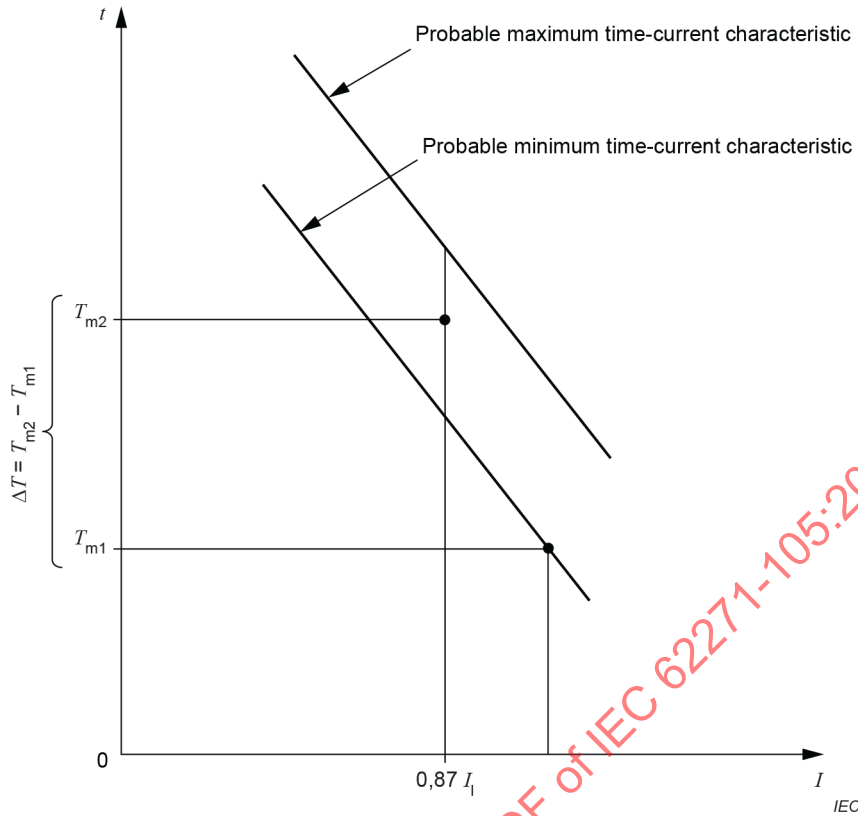


Figure B.1 – Practical determination of the transfer current

The time T_{m1} on the minimum characteristic is the melting time of the first fuse to operate under a three-phase fault current I_1 .

The time T_{m2} is the melting time of the second fuse to operate. It should be noted that this time T_{m2} (see Figure B.1) is shorter than the value indicated for a two-phase current of $0,87I_1$ by the maximum time-current characteristic as this second fuse has already seen the three-phase fault current I_1 for the time T_{m1} .

The small segments of the time-current characteristics can be regarded as straight lines to a close approximation in log-log coordinates, their formula being:

$$\log T_m = -a \log I + \log C$$

defining a relationship between I and T_m such that:

$$I^\alpha \times T_m = C \quad (\text{B.1})$$

where α is the gradient and $\log C$ the intercept with the ordinate axis of the straight line so defined.

Applying Formula (B.1) to the minimum time-current characteristic, the formula for the maximum time-current characteristic will be expressed by:

$$I^\alpha \times T_m = C(1+x)^\alpha \quad (\text{B.2})$$

where x is the tolerance on the current between the two time-current characteristics and defined as $100 x \%$.

The first fuse melts under the three-phase fault current I_1 in a time T_{m1} according to Formula (B.1) for the minimum time-current characteristic such that:

$$I_1^\alpha \times T_{m1} = C \quad (B.3)$$

After having seen the current I_1 for a time T_{m1} , the second fuse will melt under the two-phase fault current, $0,87I_1$, in a time T_{m2} according to Formula (B.2) for the maximum time-current characteristic such that:

$$I_1^\alpha T_{m1} + (0,87 I_1)^\alpha \times (T_{m2} - T_{m1}) = C (1+x)^\alpha \quad (B.4)$$

Combining Formula (B.3) and Formula (B.4) one obtains:

$$\Delta T = T_{m2} - T_{m1} = T_{m1} \left[\frac{(1+x)^\alpha - 1}{0,87^\alpha} \right] \quad (B.5)$$

The transfer point occurs when ΔT is equal to the fuse-initiated opening time T_0 of the switch.

Taking a statistically realistic tolerance for the fuse time-current characteristics of $\pm 6,5 \%$ ($\pm 2\sigma$ of $\pm 10 \%$) then $x = 0,13$. Using this value in Formula (B.5) gives:

$$T_{m1} = T_0 \left[\frac{0,87^\alpha}{(1+0,13)^\alpha - 1} \right] \quad (B.6)$$

The transfer current I_{transfer} is then deduced from the minimum time-current characteristic of the fuse.

As the slope α is dependent on the value T_{m1} (Figure B.2), an iterative calculation shall be made: a first value of T_{m1} shall be taken, for instance $(T_{m1})_0$ equal to $1,2T_0$, for it is normally close to the practical value. Then, a first value of the transfer current $(I_{\text{transfer}})_0$ and of the slope α_0 are deduced from the minimum time-current characteristic.

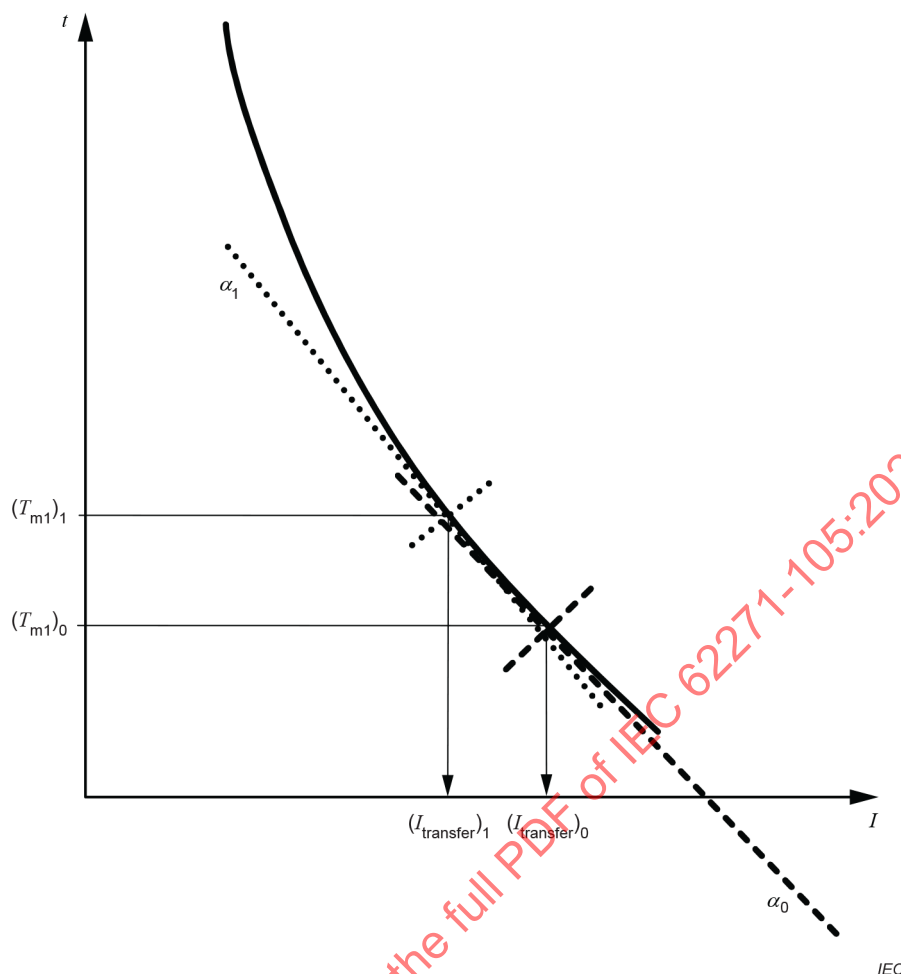


Figure B.2 – Determination of the transfer current with the iterative method

With this value α_0 , a new $(T_{m1})_1$ is calculated with Formula (B.6) and new $(I_{\text{transfer}})_1$ and α_1 are determined as above. If the new value of the transfer current does not differ from the previous one by more than 5 %, then it is taken for I_{transfer} . If not, this calculation shall be re-made successively until the difference between two successive transfer currents is less than 5 %.

B.3 Simplified method for determination of transfer current

Taking $\alpha = 4$, which is on the conservative side with fuse-initiated opening times lying between 0,05 s and 0,3 s, then Formula (B.5) gives:

$$\Delta T = T_{m1} \left(\frac{(1 + 0,13)^4 - 1}{(0,87)^4} \right) \quad (\text{B.7})$$

The transfer point occurs when the fuse-initiated opening time T_0 of the switch is equal to ΔT :

$$T_0 = \Delta T = 1,1 \times T_{m1}$$

or

$$T_{m1} = 0,9 T_0$$

Thus, the transfer current can be defined as the current which gives a pre-arcing time equal to $0,9 T_0$ for the minimum time-current characteristic of the fuse.

This simplified procedure is based on a slope of the fuse characteristic of $\alpha = 4$. The slope of the characteristics of actually existing fuses may vary from 4, which may lead to different transfer currents and, thus, different fuse rated currents. In case of doubt apply the iterative method (Clause B.2) or consult the switch-fuse manufacturer.

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Annex C (normative)

Tolerances on test quantities for type tests

Table C.1 – Tolerances on test quantities for type tests

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference to
7.101	Making and breaking tests				
7.101.2.2	Test frequency	Test frequency	Rated frequency	±8 %	
7.101.2.5	Test voltage for breaking tests	Power-frequency recovery voltage	Rated voltage	±5 %	Figure 4
		Power-frequency recovery voltage of any phase/average value	1	± 20 %	
7.101.2.7	Applied voltage before short circuit tests	Applied voltage	Rated voltage	+10 % –0 %	
		Applied voltage of any phase /average value	1	±5 %	
7.101.2.8	Breaking current	AC component of test current for TD_{ISC} , TD_{IWmax} and TD_{Ito} in any phase/average	1	±10 %	
		AC component of test current for $TD_{Itransfer}$ in two phases fitted with solid links/phase with fuses	1	≥ $\sqrt{3}/2$	
7.101.3.1	Short circuit current	Prospective current	Rated value	+5 % –0 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 1	+10 % –0 %	
7.101.3.2	Current with max. I^2t of the fuse	Prospective current	Specified value	±10 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 2	+10 % –0 %	

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference to
7.101.3.3 and 7.101.3.4	Transfer current and take-over current	Prospective current	Rated value	+10 % –0 %	
		Power factor of load circuit	$I_{rtransfer} > 400 \text{ A}$	0,2 to 0,3	
			$I_{rtransfer} \leq 400 \text{ A}$	0,3 to 0,4	
		Power factor of supply circuit		< 0,2	
		TRV of supply circuit	See IEC 60282-1: 2020 test-duty 1	+10 % –0 %	
		TRV of load circuit	Table 3 and Table 4	+10 % –0 %	
		Impedance of supply circuit/total impedance	0,15	±0,03	

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPAREILLAGE À HAUTE TENSION –

Partie 105: Combinés interrupteurs-fusibles pour courant alternatif de tensions assignées supérieures à 1 kV et jusqu'à 52 kV inclus

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L'IEC 62271-105 a été établie par le sous-comité 17A: Appareils de connexion, du comité d'études 17 de l'IEC: Appareillage haute tension. Il s'agit d'une norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2012. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) le document a été mis à jour conformément à la 2e édition de l'IEC 62271-1:2017;
- b) la TTR assignée est supprimée (la TTR n'est qu'un paramètre d'essai) comme dans la dernière édition de l'IEC 62271-100;

- c) une distinction est désormais faite entre les exigences spécifiées pour l'exécution de la fonction attendue d'un combiné interrupteur-fusibles, et les exigences qui ne sont pertinentes que lorsque la fonction est exécutée par un appareil autonome. Cette distinction a pour but d'éviter des répétitions ou des contradictions d'exigences avec une norme traitant d'ensembles, lorsque la fonction est mise en œuvre au sein d'un tel ensemble.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
17A/1300/FDIS	17A/1306/RVD

Le rapport de vote indiqué dans le Tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La version française de la norme n'a pas été soumise au vote.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Ce document doit être lu conjointement avec l'IEC 62271-1:2017, à laquelle il fait référence et qui est applicable, sauf spécification contraire. Pour faciliter le repérage des exigences correspondantes, cette norme utilise une numérotation identique des articles et des paragraphes à celle de l'IEC 62271-1:2017. Les modifications à ces articles et paragraphes sont indiquées sous la même numérotation, alors que les paragraphes additionnels sont numérotés à partir de 101.

Une liste de toutes les parties de la série IEC 62271, publiées sous le titre général *Appareillage à haute tension*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

APPAREILLAGE À HAUTE TENSION –

Partie 105: Combinés interrupteurs-fusibles pour courant alternatif de tensions assignées supérieures à 1 kV et jusqu'à 52 kV inclus

1 Domaine d'application

La présente partie de l'IEC 62271 est applicable aux appareils tripolaires utilisés dans les réseaux de distribution publics ou les installations industrielles. Ces derniers forment des ensembles fonctionnels composés d'interrupteurs ou d'interrupteurs-sectionneurs et de fusibles limiteurs de courant, conçus pour être capables de

- couper, à la tension assignée, tous les courants jusqu'au pouvoir de coupure assigné en court-circuit inclus;
- établir, à la tension assignée, des circuits pour lesquels le pouvoir de coupure assigné en court-circuit s'applique.

Elle ne s'applique ni aux combinés de fusibles avec des disjoncteurs, des contacteurs ou des circuits-switchers, ni aux combinés destinés à la manœuvre et à la protection des moteurs, ni aux combinés destinés à la manœuvre et à la protection des batteries de condensateurs.

Le présent document s'applique aux combinés prévus pour des tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV, et destinés à être utilisés sur des réseaux triphasés à courant alternatif à 50 Hz ou 60 Hz.

Dans le présent document, le mot "combiné" désigne un combiné dans lequel les composants forment un ensemble fonctionnel. Chaque association d'un type donné d'interrupteur avec un type donné de fusible définit un type de combiné interrupteur-fusibles. Différents types de fusibles peuvent être combinés avec un type donné d'interrupteur, ce qui donne plusieurs combinés de caractéristiques différentes, en particulier pour ce qui concerne les courants permanents assignés.

Un combiné interrupteur-fusibles est donc défini par sa désignation de type, ainsi qu'une liste de fusibles utilisables définie par le fabricant appelée "liste des fusibles de référence". Un combiné est réputé satisfaire au présent document dans la mesure où la conformité à celui-ci a été démontrée pour tous les combinés équipés de l'un des fusibles utilisables.

Les fusibles sont introduits dans le combiné en vue d'obtenir des caractéristiques de coupure assignées en court-circuit supérieures à celles du seul interrupteur. Ces fusibles comportent des percuteurs destinés à provoquer l'ouverture automatique des trois pôles de l'interrupteur par suite du fonctionnement d'un fusible, permettant ainsi d'assurer le bon fonctionnement du combiné pour des valeurs de courant de défaut supérieures au courant minimal de fusion et inférieures au courant minimal de coupure de ces fusibles. En plus des percuteurs des fusibles, les combinés peuvent également être équipés soit d'un déclencheur à maximum de courant, soit d'un déclencheur shunt.

NOTE Dans le présent document, le terme "fusible" est utilisé pour désigner soit le fusible, soit l'élément de remplacement, quand le sens général du texte ne comporte aucune ambiguïté.

Les fusibles sont conformes à l'IEC 60282-1:2020.

Les dispositifs qui exigent une manœuvre dépendante manuelle ne sont pas traités par le présent document.

Les interrupteurs, y compris leurs mécanismes de manœuvre, sont conformes à l'IEC 62271-103, sauf en ce qui concerne les exigences relatives au courant de courte durée admissible et au pouvoir de fermeture sur court-circuit, pour lesquelles l'effet limiteur des fusibles est pris en compte.

Les sectionneurs de terre incorporés dans le combiné répondent aux spécifications de l'IEC 62271-102.

Les interrupteurs qui incluent d'autres fonctions (non couvertes par l'IEC 62271-103) sont couverts par leurs normes applicables (par exemple, IEC 62271-102 Sectionneurs et sectionneurs de terre).

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

L'Article 2 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

IEC 60050-441, *Vocabulaire Electrotechnique International (IEV) – Part 441: Appareillage et fusibles* (disponible à l'adresse <http://www.electropedia.org>)

IEC 60282-1:2020, *Fusibles à haute tension – Partie 1: Fusibles limiteurs de courant*

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-100:2021, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers* (disponible en anglais seulement)

IEC 62271-102:2018, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

IEC 62271-103:2021, *High-voltage switchgear and controlgear – Part 103: Alternating current switches for rated voltages above 1 kV up to and including 52 kV* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-441, ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

NOTE Une partie des termes de l'IEC 60050-441 est énumérée ci-dessous.

3.1 Termes et définitions généraux

Le paragraphe 3.1 de l'IEC 62271-1:2017 s'applique.

3.2 Ensembles d'appareillages

Le paragraphe 3.2 de l'IEC 62271-1:2017 s'applique.

3.3 Parties d'ensembles

Le paragraphe 3.3 de l'IEC 62271-1:2017 s'applique.

3.4 Appareils de connexion

Le paragraphe 3.4 de l'IEC 62271-1:2017 s'applique, avec les ajouts suivants:

3.4.101

combiné interrupteur-fusibles

combinaison d'un interrupteur tripolaire et de trois fusibles équipés de percuteurs, tels que le fonctionnement de n'importe quel percuteur provoque l'ouverture automatique des trois pôles de l'interrupteur

Note 1 à l'Article: Le combiné interrupteur-fusibles comprend le combiné fusible-interrupteur.

3.4.102

socle de combiné interrupteur-fusibles

socle de combiné

combiné interrupteur-fusibles dans lequel les éléments de remplacement ne sont pas installés

3.4.103

interrupteur à fusibles

interrupteur dans lequel un ou plusieurs pôles comportent un fusible en série dans un appareil combiné

[SOURCE: IEC 60050-441:2000, 441-14-14]

3.4.104

fusible-interrupteur

interrupteur dans lequel un élément de remplacement ou un porte-fusible avec son élément de remplacement forme le contact mobile

[SOURCE: IEC 60050-441:2000, 441-14-17]

3.4.105

interrupteur-sectionneur

interrupteur qui, dans sa position d'ouverture, satisfait aux conditions d'isolement spécifiées pour un sectionneur

[SOURCE: IEC 60050-441:2000, 441-14-12]

3.4.106

combiné actionné par déclencheur

combiné dans lequel l'ouverture automatique de l'interrupteur peut aussi être provoquée par un déclencheur à maximum de courant ou par un déclencheur shunt

3.5 Parties d'appareillages

Le paragraphe 3.5 de l'IEC 62271-1:2017 s'applique, avec les ajouts suivants:

3.5.101

déclencheur

<d'un appareil mécanique de connexion> dispositif raccordé mécaniquement à un appareil mécanique de connexion dont il libère les organes de retenue et qui permet l'ouverture ou la fermeture de l'appareil

[SOURCE: IEC 60050-441:2000, 441-15-17]

3.5.102

déclencheur à maximum de courant

déclencheur qui permet l'ouverture, avec ou sans retard, d'un appareil mécanique de connexion, lorsque le courant dans le déclencheur dépasse une valeur prédéterminée

Note 1 à l'Article: Cette valeur peut, dans certains cas, dépendre de la vitesse d'accroissement du courant.

[SOURCE: IEC 60050-441:2000, 441-16-33]

3.5.103

déclencheur shunt

déclencheur alimenté par une source de tension

Note 1 à l'Article: La source de tension peut être indépendante de la tension du circuit principal.

[SOURCE: IEC 60050-441:2000, 441-16-41]

3.6 Caractéristiques opérationnelles de l'appareillage

Le paragraphe 3.6 de l'IEC 62271-1:2017 s'applique.

3.7 Grandeurs caractéristiques

Le paragraphe 3.7 de l'IEC 62271-1:2017 s'applique, avec les ajouts suivants:

3.7.101

courant présumé

<d'un circuit et relatif à un appareil de connexion ou à un fusible> courant qui circulerait dans le circuit si chaque pôle de l'appareil de connexion ou le fusible était remplacé par un conducteur d'impédance négligeable

Note 1 à l'Article: La méthode à employer pour évaluer et pour exprimer le courant présumé doit être spécifiée dans les publications particulières.

[SOURCE: IEC 60050-441:2000, 441-17-01]

3.7.102

valeur de crête du courant présumé

valeur de crête d'un courant présumé pendant la période transitoire qui suit son établissement

Note 1 à l'Article: La définition implique que le courant est établi par un appareil de connexion idéal, c'est-à-dire passant instantanément d'une impédance infinie à une impédance nulle. Pour un circuit ayant plusieurs voies, par exemple un circuit polyphasé, il est entendu en outre que le courant est établi simultanément dans tous les pôles même si on ne considère que le courant dans un seul pôle.

[SOURCE: IEC 60050-441:2000, 441-17-02]

3.7.103

valeur maximale de crête du courant présumé

<d'un circuit à courant alternatif> valeur de crête du courant présumé quand l'établissement du courant a lieu à l'instant qui conduit à la plus grande valeur possible

Note 1 à l'Article: Pour un appareil multipolaire dans un circuit polyphasé, la valeur maximale de crête du courant présumé ne se rapporte qu'à un seul pôle.

[SOURCE: IEC 60050-441:2000, 441-17-04]

3.7.104

courant coupé

<d'un appareil de connexion ou d'un fusible> courant dans un pôle d'un appareil de connexion ou dans un fusible évalué à l'instant de l'amorçage de l'arc au cours d'une coupure

[SOURCE: IEC 60050-441:2000, 441-17-07]

3.7.105

courant minimal de coupure

valeur minimale de courant présumé qu'un élément de remplacement peut couper sous une tension donnée et dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:2000, 441-18-29]

3.7.106

pouvoir de fermeture en court-circuit

pouvoir de fermeture pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

[SOURCE: IEC 60050-441:2000, 441-17-10]

3.7.107

courant coupé limité

valeur instantanée maximale du courant atteinte au cours de la coupure effectuée par un appareil de connexion ou un fusible

Note 1 à l'Article: Cette notion est d'importance particulière si l'appareil de connexion ou le fusible fonctionne de telle manière que la valeur de crête du courant présumé du circuit n'est pas atteinte.

[SOURCE: IEC 60050-441:2000, 441-17-12]

3.7.108

courant de transition

I_{transfer}

<sur fonctionnement provoqué par percuteur> valeur du courant triphasé symétrique pour laquelle les fusibles et l'interrupteur échangent la fonction de coupure

Note 1 à l'Article: Au-dessus de cette valeur, le courant dans les trois phases n'est interrompu que par les fusibles. Immédiatement en dessous de cette valeur, le courant dans le premier pôle qui coupe est interrompu par le fusible, et le courant dans les deux autres pôles par l'interrupteur; ou par les fusibles selon les tolérances de la caractéristique temps-courant des fusibles et de la durée d'ouverture de l'interrupteur provoquée par le percuteur des fusibles.

3.7.109

courant d'intersection

valeur du courant correspondant à l'intersection des caractéristiques temps-courant de deux dispositifs de protection à maximum de courant

[SOURCE: IEC 60050-441:2000, 441-17-16]

3.7.110**courant minimal d'intersection**

<d'un combiné actionné par déclencheur> courant déterminé par le point d'intersection des caractéristiques temps-courant du fusible et de l'interrupteur, correspondant à:

- a) la durée de coupure maximale de l'interrupteur plus, s'il y a lieu, la durée de fonctionnement maximale d'un relais à maximum de courant ou d'un relais de terre externe à l'appareil,
- b) la durée de préarc minimale du fusible

3.7.111**courant maximal d'intersection**

<d'un combiné actionné par déclencheur> courant déterminé par le point d'intersection des caractéristiques temps-courant du fusible et de l'interrupteur, correspondant à:

- a) la durée d'ouverture minimale de l'interrupteur plus, s'il y a lieu, la durée de fonctionnement minimale d'un relais à maximum de courant ou d'un relais de terre externe à l'appareil,
- b) la durée de fonctionnement maximale du fusible

3.7.112**tension appliquée**

<pour un appareil de connexion> tension qui existe entre les bornes d'un pôle d'un appareil de connexion immédiatement avant l'établissement du courant

[SOURCE: IEC 60050-441:2000, 441-17-24]

3.7.113**tension de rétablissement**

tension qui apparaît entre les bornes d'un appareil de connexion ou d'un fusible après l'interruption du courant

Note 1 à l'Article: Cette tension peut être considérée durant deux intervalles de temps consécutifs, l'un durant lequel existe une tension transitoire, suivi par un second intervalle durant lequel la tension de rétablissement à fréquence industrielle ou en régime établi existe seule.

[SOURCE: IEC 60050-441:2000, 441-17-25]

3.7.114**tension transitoire de rétablissement****TTR**

tension de rétablissement pendant le temps où elle présente un caractère transitoire appréciable

Note 1 à l'Article: La tension transitoire de rétablissement peut être oscillatoire ou non oscillatoire ou être une combinaison de celles-ci selon les caractéristiques du circuit et de l'appareil de connexion. Elle tient compte de la variation du potentiel du point neutre du circuit polyphasé.

Note 2 à l'Article: Sauf spécification contraire, la tension transitoire de rétablissement pour les circuits triphasés est la tension aux bornes du premier pôle qui coupe, car cette tension est généralement plus élevée que celle qui apparaît aux bornes de chacun des deux autres pôles.

[SOURCE: IEC 60050-441:2000, 441-17-26]

3.7.115**tension de rétablissement à fréquence industrielle**

tension de rétablissement après la disparition des phénomènes transitoires de tension

[SOURCE: IEC 60050-441:2000, 441-17-27]

3.7.116

tension transitoire de rétablissement présumée

<d'un circuit> tension transitoire de rétablissement présumée qui suit la coupure du courant présumé symétrique par un appareil de connexion idéal

Note 1 à l'Article: La définition implique que l'appareil de connexion ou le fusible, pour lequel la tension transitoire de rétablissement est recherchée, est remplacé par un appareil de connexion idéal, c'est-à-dire dont l'impédance passe instantanément de la valeur zéro à la valeur infinie à l'instant du zéro de courant, c'est-à-dire au zéro "naturel". Pour des circuits ayant plusieurs voies, par exemple un circuit polyphasé, on suppose en outre que la coupure du courant par l'appareil de connexion idéal n'a lieu que sur le pôle considéré.

[SOURCE: IEC 60050-441:2000, 441-17-29]

3.7.117

durée d'ouverture provoquée par le percuteur des fusibles

<du combiné interrupteur-fusibles> intervalle de temps compris entre l'instant du début de l'arc dans le fusible jusqu'à l'instant de la séparation des contacts d'arc de l'interrupteur du combiné sur tous les pôles (comprenant tous les éléments ayant une influence sur cet intervalle de temps)

3.7.118

durée d'ouverture provoquée par le déclencheur

<du combiné interrupteur-fusibles> durée d'ouverture provoquée par le déclencheur qui est définie, selon la méthode de déclenchement, comme cela est indiqué ci-dessous; tout dispositif de retard faisant partie intégrante de l'interrupteur étant réglé à une valeur spécifiée:

- a) pour un interrupteur déclenché à l'aide d'une forme quelconque d'énergie auxiliaire: l'intervalle de temps depuis l'instant d'application de la source d'énergie auxiliaire sur le déclencheur, l'interrupteur étant en position fermée, jusqu'à l'instant de la séparation des contacts d'arc sur tous les pôles;
- b) pour un interrupteur déclenché (autrement que par les percuteurs des fusibles) par le courant du circuit principal sans l'aide d'aucune forme d'énergie auxiliaire: l'intervalle de temps depuis l'instant où l'interrupteur étant en position fermée, le courant dans le circuit principal atteint la valeur de fonctionnement du déclencheur à maximum de courant jusqu'à l'instant de la séparation des contacts d'arc sur tous les pôles

3.7.119

durée d'ouverture minimale provoquée par le déclencheur

<du combiné interrupteur-fusibles> durée d'ouverture provoquée par le déclencheur lorsque le réglage spécifié d'un dispositif de retard quelconque faisant partie intégrante de l'interrupteur est à sa valeur minimale

3.7.120

durée d'ouverture maximale provoquée par le déclencheur

<du combiné interrupteur-fusibles> durée d'ouverture provoquée par le déclencheur lorsque le réglage spécifié d'un dispositif de retard quelconque faisant partie intégrante de l'interrupteur est à sa valeur maximale

3.7.121

durée de coupure

intervalle de temps entre le début de la durée d'ouverture d'un appareil mécanique de connexion, ou le début de la durée de préarc d'un fusible, et la fin de la durée d'arc

[SOURCE: IEC 60050-441:2000, 441-17-39]

3.7.122

durée d'arc

<d'un pôle ou d'un fusible> intervalle de temps entre l'instant de début de l'arc sur un pôle ou sur un fusible et l'instant de l'extinction finale de l'arc sur ce pôle ou ce fusible

[SOURCE: IEC 60050-441:2000, 441-17-37]

3.101 Fusibles

3.101.1

liste des fusibles de référence

liste de fusibles définie par le fabricant pour un type donné de socle de combiné interrupteur-fusibles et pour lesquels la conformité au présent document de tous les combinés interrupteurs-fusibles correspondants est établie

Note 1 à l'Article: Les conditions d'extension de validité des essais de type sont données en 7.105 et 9.102.

3.101.2

socle

partie fixe d'un fusible munie de contacts et de bornes

[SOURCE: IEC 60050-441:2000, 441-18-02]

3.101.3

percuteur

dispositif mécanique faisant partie d'un élément de remplacement qui, lors du fonctionnement du fusible, libère l'énergie requise pour faire fonctionner d'autres appareils, des dispositifs indicateurs ou pour effectuer un verrouillage

[SOURCE: IEC 60050-441:2000, 441-18-18]

3.101.4

durée de préarc

durée de fusion

intervalle de temps qui s'écoule à partir du moment où commence à circuler un courant suffisant pour provoquer une coupure dans le ou les éléments fusibles jusqu'à l'instant où un arc commence à se former

[SOURCE: IEC 60050-441:2000, 441-18-21]

3.101.5

durée de fonctionnement

somme de la durée de préarc et de la durée d'arc

[SOURCE: IEC 60050-441:2000, 441-18-22]

3.101.6

I^2t

intégrale de Joule

intégrale du carré du courant pour un intervalle de temps donné:

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

Note 1 à l'Article: L' I^2t de préarc est l'intégrale I^2t pour la durée de préarc du fusible.

Note 2 à l'Article: L' I^2t de fonctionnement est l'intégrale I^2t pour la durée de fonctionnement du fusible.

Note 3 à l'Article: L'énergie en joules libérée dans une portion ayant une résistance de un ohm d'un circuit protégé par un fusible est égale à la valeur de I^2t de fonctionnement exprimée en A²s.

[SOURCE: IEC 60050-441:2000, 441-18-23]

4 Conditions normales et spéciales de service

L'Article 4 de l'IEC 62271-1:2017 s'applique.

5 Caractéristiques assignées

5.1 Généralités

Le paragraphe 5.1 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

- k) pouvoir de coupure assigné en court-circuit;
- l) pouvoir d'établissement assigné en court-circuit;
- m) courant de transition assigné sur fonctionnement provoqué par percuteur;
- n) courant d'intersection assigné pour un combiné actionné par déclencheur.

Lorsque le combiné interrupteur-fusibles n'est pas utilisé comme un appareil autonome (s'il est utilisé, par exemple, comme un composant d'un ensemble d'appareillages), les influences sur les différentes caractéristiques assignées sont couvertes par les normes applicables.

5.2 Tension assignée (U_r)

Le paragraphe 5.2 de l'IEC 62271-1:2017 s'applique.

5.3 Niveau d'isolement assigné (U_d , U_p , U_s)

Le paragraphe 5.3 de l'IEC 62271-1:2017 s'applique.

5.4 Fréquence assignée (f_r)

Le paragraphe 5.4 de l'IEC 62271-1:2017 s'applique.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

Le courant permanent assigné s'applique au combiné interrupteur-fusibles complet.

Chaque combiné d'un type donné d'interrupteur et d'un type donné de fusibles définit un type de combiné interrupteur-fusibles. Différents types de fusibles peuvent être combinés avec un type donné d'interrupteur, ce qui donne plusieurs combinés interrupteurs-fusibles ayant différents courants permanents assignés.

Il n'est pas exigé de choisir le courant permanent assigné dans la série R10.

5.6 Courant de courte durée admissible assigné (I_k)

Le paragraphe 5.6 de l'IEC 62271-1:2017 ne s'applique pas.

5.7 Valeur de crête du courant admissible assignée (I_p)

Le paragraphe 5.7 de l'IEC 62271-1:2017 ne s'applique pas.

5.8 Durée de court-circuit assignée (t_k)

Le paragraphe 5.8 de l'IEC 62271-1:2017 ne s'applique pas.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le paragraphe 5.9 de l'IEC 62271-1:2017 s'applique.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le paragraphe 5.10 de l'IEC 62271-1:2017 s'applique.

5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue

Le paragraphe 5.11 de l'IEC 62271-1:2017 s'applique.

5.101 Pouvoir de coupure assigné en court-circuit

Le pouvoir de coupure assigné en court-circuit est le plus grand courant de court-circuit présumé que le combiné doit être capable de couper, dans les conditions d'utilisation et de fonctionnement fixées dans le présent document, dans un circuit dont la tension de rétablissement à fréquence industrielle correspond à la tension assignée du combiné et ayant une TTR présumée telle que définie au 7.101.2.8 et les valeurs spécifiées dans la série d'essais 1 de l'IEC 60282-1:2020. Le pouvoir de coupure assigné en court-circuit s'exprime par la valeur efficace de la composante alternative du courant.

Les pouvoirs de coupure assignés en court-circuit doivent être choisis dans la série R10.

NOTE 1 La série R10 comprend les nombres: 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 et leurs produits par 10^n .

NOTE 2 Il est reconnu que l'impédance série du combiné ou le fonctionnement rapide des fusibles ou de l'interrupteur peut provoquer l'un des deux ou les deux effets suivants:

- a) la réduction du courant de court-circuit à une valeur notablement plus faible que celle qu'il atteint autrement;
- b) un fonctionnement suffisamment rapide pour déformer l'onde du courant de court-circuit.

C'est la raison pour laquelle le terme "courant présumé" est utilisé pour définir les performances de fermeture et de coupure.

5.102 Pouvoir d'établissement assigné en court-circuit

Le pouvoir d'établissement assigné en court-circuit est la valeur maximale de crête du courant présumé que le combiné interrupteur-fusibles doit être capable d'établir, dans les conditions d'utilisation et de comportement définies dans le présent document, dans un circuit dont la tension à fréquence industrielle correspond à la tension assignée du combiné interrupteur-fusibles. Il doit être égal à 2,5 fois (50 Hz) ou 2,6 fois (60 Hz) la valeur efficace du pouvoir de coupure assignée en court-circuit.

NOTE 1 Voir également la note 2 de 5.101.

NOTE 2 Un facteur de crête plus élevé, associé à une constante de temps éventuelle élevée du réseau n'influence pas les performances du combiné interrupteur-fusibles dans les conditions de court-circuit, en raison du comportement limiteur de courant des fusibles. Cette situation est indiquée en 6.1.2 de l'IEC 60282-1:2020.

5.103 Courant de transition assigné (sur fonctionnement provoqué par percuteurs) ($I_{rtransfer}$)

Le courant de transition assigné est la valeur efficace maximale du courant de transition que l'interrupteur du combiné est capable d'interrompre.

5.104 Courant d'intersection assigné pour combinés actionnés par déclencheur (I_{rto})

Le courant d'intersection assigné est la valeur efficace maximale du courant d'intersection que l'interrupteur du combiné est capable d'interrompre.

6 Conception et construction

6.1 Exigences pour les liquides utilisés dans les combinés interrupteurs-fusibles

Le paragraphe 6.1 de l'IEC 62271-1:2017 s'applique.

6.2 Exigences pour les gaz utilisés dans les combinés interrupteurs-fusibles

Le paragraphe 6.2 de l'IEC 62271-1:2017 s'applique.

6.3 Raccordement à la terre des combinés interrupteur-fusibles

Le paragraphe 6.3 de l'IEC 62271-1:2017 s'applique.

6.4 Équipements et circuits auxiliaires et de commande

Le paragraphe 6.4 de l'IEC 62271-1:2017 s'applique.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Les manœuvres manuelles dépendantes ne sont pas admises.

6.6 Manœuvre à accumulation d'énergie

Le paragraphe 6.6 de l'IEC 62271-1:2017 s'applique.

6.7 Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)

Le paragraphe 6.7 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

NOTE Le combiné interrupteur-fusibles est capable de couper le courant de défaut, sans nécessiter de retard.

6.8 Organes de commande à manœuvre manuelle

Le paragraphe 6.8 de l'IEC 62271-1:2017 s'applique.

6.9 Fonctionnement des déclencheurs

Le paragraphe 6.9 de l'IEC 62271-1:2017 s'applique.

6.10 Indication de la pression/du niveau

Le paragraphe 6.10 de l'IEC 62271-1:2017 s'applique.

6.11 Plaques signalétiques

Le paragraphe 6.11 de l'IEC 62271-1:2017 s'applique avec les modifications suivantes:

La plaque signalétique d'un combiné interrupteur-fusibles doit contenir les renseignements indiqués dans le Tableau 1.

Tableau 1 – Informations sur la plaque signalétique

(1)	Abréviation (2) ^a	Unité (3)	Combiné interrupteur- fusibles (4)	Dispositif de manœuvre (5)	Condition de marquage exigée (6)
Fabricant			X	Y	Seulement si indépendant du combiné et/ou fabricants différents.
Désignation de type			X	Y	Seulement si indépendant du combiné et/ou fabricants différents.
Numéro de série			X	(Y)	Seulement si indépendant du combiné et/ou fabricants différents.
Numéro du présent document			X		
Référence du manuel d'instructions			X		
Tension assignée	U_r	kV	X		
Tension de tenue assignée aux chocs de foudre	U_p	kV	X		
Fréquence assignée	f_r	Hz	X		
Courant permanent assigné avec fusibles	Voir la liste de référence		X		
Pression de remplissage pour la manœuvre (*)	P_{rm}	kPa		Y	Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Pression fonctionnelle minimale pour la manœuvre (*)	p_{mm}	kPa		Y	Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Pression d'alarme pour la manœuvre(*)	P_{am}	kPa		Y	Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Pression de remplissage pour l'isolement (*)	P_{re}	kPa	Y		Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Pression fonctionnelle minimale pour l'isolement (*)	p_{me}	kPa	Y		Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Pression fonctionnelle minimale pour la coupure (*)	p_{sw}	kPa	Y		Si applicable. Informations à inscrire sur la plaque signalétique ou dans le manuel d'instructions.
Tension assignée d'alimentation des circuits auxiliaires et de commande	U_a	V		Y	Si applicable.
Année de fabrication			X		
Température minimale et maximale de l'air ambiant		°C	Y		Si différent de –5 °C et/ou 40 °C.
Fluide isolant et masse	M_f	kg	Y		Si applicable.
Key (*) Pression absolue (abs.) ou pression relative (rel.) à indiquer sur la plaque signalétique ou dans le manuel d'instructions. X Le marquage de ces valeurs est obligatoire; les cases vides correspondent à des valeurs nulles. Y Le marquage de ces valeurs est obligatoire et dépend des conditions figurant à la colonne (6). (Y) Le marquage de ces valeurs est facultatif et dépend des conditions figurant à la colonne (6). ^a Les abréviations de la colonne (2) peuvent être utilisées à la place des termes de la colonne (1). Quand les termes de la colonne (1) sont utilisés, il n'est pas nécessaire de faire apparaître le mot "assigné".					

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 s'applique.

6.13 Indicateur de position

Le paragraphe 6.13 de l'IEC 62271-1:2017 s'applique.

6.14 Degrés de protection procurés par les enveloppes

Le paragraphe 6.14 de l'IEC 62271-1:2017 s'applique.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le paragraphe 6.15 de l'IEC 62271-1:2017 s'applique.

6.16 Étanchéité au gaz et au vide

Le paragraphe 6.16 de l'IEC 62271-1:2017 s'applique.

6.17 Étanchéité des systèmes de liquide

Le paragraphe 6.17 de l'IEC 62271-1:2017 s'applique.

6.18 Risque de feu (inflammabilité)

Le paragraphe 6.18 de l'IEC 62271-1:2017 s'applique.

6.19 Compatibilité électromagnétique (CEM)

Le paragraphe 6.19 de l'IEC 62271-1:2017 s'applique.

6.20 Émission de rayons X

Le paragraphe 6.20 de l'IEC 62271-1:2017 s'applique.

6.21 Corrosion

Le paragraphe 6.21 de l'IEC 62271-1:2017 s'applique.

6.22 Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre

Le paragraphe 6.22 de l'IEC 62271-1:2017 s'applique.

6.101 Liaisons entre le ou les percuteurs des fusibles et le déclencheur de l'interrupteur

Les liaisons entre le ou les percuteurs des fusibles et le déclencheur de l'interrupteur doivent être conçues de telle sorte que l'interrupteur fonctionne convenablement, aussi bien en triphasé qu'en monophasé, aux exigences minimale et maximale d'un type de percuteur donné (moyen ou fort) indépendamment du mode de fonctionnement de ce percuteur (à ressort ou à charge explosive). Les exigences relatives aux percuteurs sont spécifiées dans l'IEC 60282-1:2020. Ces exigences sont considérées comme étant vérifiées par les essais spécifiés pour les séries d'essais TD_{ISC} et $TD_{IWM_{max}}$ et par les essais de manœuvre mécanique.

6.102 Conditions de faible courant de défaut (conditions de longue durée de préarc des fusibles)

Le combiné interrupteur-fusibles doit être conçu de manière à fonctionner de façon satisfaisante à toutes les valeurs de courants de coupure, depuis le courant maximal de coupure assigné jusqu'au courant minimal de fusion, dans des conditions de faibles courants de défaut. Cela est réalisé si les conditions suivantes sont satisfaites:

a) la coordination entre l'interrupteur et les fusibles est assurée par les conditions 1), 2) ou 3) ci-dessous:

- 1) la durée d'ouverture de l'interrupteur provoquée par le percuteur des fusibles du combiné interrupteur-fusibles doit être plus courte que la durée d'arc maximale que les fusibles peuvent supporter, comme cela est spécifié dans l'IEC 60282-1:2020;

NOTE Des essais ont été introduits dans l'IEC 60282-1 pour vérifier que la durée d'arc maximale que le fusible peut supporter, dans des conditions de longue durée de préarc des fusibles, est supérieure à 100 ms.

- 2) quand le fabricant des fusibles peut prouver que le fusible a été éprouvé avec succès à toutes les valeurs de courants de coupure, depuis le courant maximal de coupure assigné jusqu'au courant minimal de fusion assigné du fusible dans le combiné (fusibles à coupure intégrale), alors la durée d'ouverture de l'interrupteur provoquée par le percuteur des fusibles des combinés interrupteurs-fusibles est réputée non applicable;
- 3) quand il peut être prouvé que le déclencheur thermique du percuteur des fusibles entraîne la coupure du courant avant que l'arc dans ceux-ci puisse apparaître, pour tous les courants inférieurs à I_3 (courant minimal de coupure du fusible selon l'IEC 60282-1:2020);

b) dans ces conditions, la montée en température du combiné ne diminue pas ses performances, comme cela est démontré dans l'essai décrit en 7.104.

7 Essais de type

7.1 Généralités

7.1.1 Principes fondamentaux

Le paragraphe 7.1.1 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants:

L'objectif des essais de type est de démontrer les caractéristiques des combinés interrupteurs-fusibles, de leurs dispositifs de manœuvre et de leurs équipements auxiliaires.

L'interrupteur du combiné doit être soumis aux essais en tant que constituant individuel, en conformité avec l'IEC 62271-103:2021, excepté pour les exigences de courant de courte durée admissible et de pouvoir d'établissement en court-circuit, car ces paramètres sont influencés par les fusibles.

De plus, les fusibles doivent avoir été soumis aux essais selon les exigences applicables de l'IEC 60282-1:2020.

Ainsi, pour les combinés, trois groupes d'essais sont effectués:

- a) essais de l'interrupteur conformément à l'IEC 62271-103:2021; ces essais peuvent être effectués sur un autre combiné que celui utilisé pour les essais c);
- b) essais des fusibles conformément à l'IEC 60282-1:2020;
- c) essais du combiné conformément au présent document.

Dans le cas des fusibles-interrupteurs, les essais de l'IEC 62271-103:2021 et les essais décrits en 7.102 du présent document doivent être effectués après avoir remplacé, comme il a été spécifié, les fusibles par des connexions rigides de mêmes forme, dimension et masse que ces fusibles.