IEC 62271-107

Edition 3.0 2019-05
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

High-voltage switchgear and controlgear – Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV

IEC 62271-107:2019-05 RLV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 29.130.10

ISBN 978-2-8322-7026-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 107: Alternating current fused circuit-switchers 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. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 62271-107 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear

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) technical changes introduced by the second edition of IEC 62271-1 are applied, where relevant;
b) rated TRV is removed and TRV is now treated as a test parameter, as in IEC 62271-100;
c) the term "thermal current" is no longer used; the rated continuous current is linked to the installed fuse-links, and values shall be provided by the manufacturer together with the list of the acceptable fuse-links; for tests purpose, the highest rated continuous current listed is referred, where previously the wording was "rated maximum thermal current", for consistency with IEC 62271-105;
d) making and breaking test duties are independent type tests (as some may be omitted if the switching device has been validated as a load-break switch). However, TD_{lt0} and TD_{llow} are kept as a sequence as they are linked to the same rated value (I_{t0});
e) differentiation has been introduced between requirements expressed for fulfilling the function expected from a fused circuit-switcher, 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 on the following documents:

FDIS	Report on voting
17A/1216/FDIS	17A/1227/RVD

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

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

This International Standard 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. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses, are numbered from 101.

Particular conditions existing in certain countries are listed in Annex B.

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 "http://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.

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

INTRODUCTION

Earthing switches forming an integral part of a circuit-switcher are covered by IEC 62271-102 [1][1].

Installation in enclosure, if any, is covered either by IEC 62271-200 [2] or by IEC 62271-201 [3].

1 Numbers in square brackets refer to the Bibliography.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 107: Alternating current fused circuit-switchers 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 operated units for distribution systems that are functional assemblies of a circuit-switcher and current-limiting fuses designed so as to be capable of:~~

- ~~breaking, at the rated recovery voltage, any load or fault 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.~~

This part of IEC 62271 applies to three-pole-operated fused circuit-switchers 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.

They can be designed either as stand-alone devices, or be embedded in a switchgear and controlgear assembly.

They are intended to be used for circuits or applications requiring only a normal mechanical and electrical endurance capability. Such applications cover protection of HV/LV transformers for instance, but exclude distribution lines or cables, as well as motor circuits and capacitor bank circuits.

Short-circuit conditions with low currents, up to the fused circuit-switcher rated take-over current, are dealt with by supplementary devices (strikers, relays, etc.), properly arranged, tripping the circuit-switcher. Current-limiting fuses are incorporated in order to ensure that the short-circuit breaking capacity of the device is above that of the circuit-switcher alone.

NOTE 1 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 fused circuit-switchers 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. Comparison with other existing switching devices is provided in Clause 8.~~

NOTE 2 Other circuit-switchers exist; see reference [4].

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

~~Fuses are covered by IEC 60282-1.~~

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

~~Installation in enclosure, if any, is covered either by IEC 62271-200 or by IEC 62271-201.~~

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.

IEC 60282-1:2009, *High-voltage fuses – Part 1: Current-limiting fuses*
IEC 60282-1:2009/AMD1:2014

IEC 62271-1:~~2007~~2017, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*
IEC 62271-100:2008/AMD1:2012
IEC 62271-100:2008/AMD2:2017

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

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

IEC 62271-105:2012, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

~~IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*~~

~~IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*~~

3 Terms and definitions

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

For the purposes of this document, the following terms and definitions 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 IEC Electropedia lists the terms defined in the IEC 60050 [5].

3.1 General terms and definitions

Subclause 3.1 of IEC 62271-1:~~2007~~2017 applies.

3.2 Assemblies of switchgear and controlgear

Subclause 3.2 of IEC 62271-1:~~2007~~2017 applies.

3.3 Parts of assemblies

Subclause 3.3 of IEC 62271-1:~~2007~~2017 applies.

3.4 Switching devices

Subclause 3.4 of IEC 62271-1:~~2007~~2017 applies, with the following additions.

3.4.101
circuit-switcher
mechanical switching device suitable for making, carrying and interrupting currents under normal circuit conditions and for interrupting specified fault currents that ~~may be less~~ are usually smaller than its short-time withstand current

Note 1 to entry: Other circuit-switchers exist; see reference [4].

3.4.102
fused circuit-switcher
~~device comprising a three-pole circuit-switcher and three current limiting fuses, capable of making and breaking any load or fault current up to its short-circuit breaking current, under TRV and power factor conditions defined in this standard~~
combination, in a single device or function, of a circuit-switcher and fuses, one fuse being placed in series with each pole of the circuit-switcher intended to be connected to a phase conductor

Note 1 to entry: the term "one fuse" does not preclude the use of several fuse-links in parallel.

3.4.103
fused circuit-switcher base
~~**device base**~~
fused circuit-switcher without fuse-links mounted

3.5 Parts of switchgear and controlgear

Subclause 3.5 of IEC 62271-1:~~2007~~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~~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~~

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

3.5.102
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~~2000, 441-16-41]

3.6 Operational characteristics of switchgear and controlgear

Subclause 3.6 of IEC 62271-1:~~2007~~2017 applies, with the following additions.

3.6.101
independent manual operation ~~(of the fused circuit-switcher)~~
<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~~2000, 441-16-16]

3.6.102
stored energy operation ~~(of the fused circuit-switcher)~~
<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 1 to entry: This kind of operation may be subdivided according to:

1) The manner of storing the energy (spring, weight, etc.);
2) The origin of the energy (manual, electric, etc.);
3) The manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:~~2007~~2000, 441-16-15]

3.7 Characteristic quantities

Subclause 3.7 of IEC 62271-1:~~2007~~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:~~2007~~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:~~2007~~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:~~2007~~2000, 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~~2000, 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~~2000, 441-17-07]

3.7.106
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:~~2007~~2000, 441-18-29]

3.7.107
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:~~2007~~2000, 441-17-10]

3.7.108
take-over current
current co-ordinate of the intersection between the time-current characteristics of two over-current protective devices

[SOURCE: IEC 60050-441:~~2007~~2000, 441-17-16]

~~**3.7.109**~~
~~**thermal current**~~
~~I_{th}~~
~~maximum current carried continuously without the temperature rise of the various parts exceeding the limits specified~~

3.7.109
fused short-circuit current
conditional short-circuit current when the current-limiting device is a fuse

[SOURCE: IEC 60050-441:~~2007~~2000, 441-17-21]

3.7.110
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]

3.7.111
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]

3.7.112
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]

3.7.113
power frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:~~2007~~2000, 441-17-27]

3.7.114
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:~~2007~~2000, 441-17-29]

3.7.115
opening time
<of a mechanical switching device> interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry: For release operation, instant of initiation is taken as the instant of application of power supply on the release

[SOURCE: IEC 60050-441:2000, 441-17-36, modified – The initial note has been deleted and the current note added.]

~~**3.7.116**~~
~~**minimum opening time** (of the fused circuit-switcher)~~
~~minimum interval of time between the initiation of the opening, from an external source, and the first instant of the separation of the arcing contacts in any one pole~~

3.7.116
fuse-initiated opening time
<of a fused circuit-switcher> time taken from the instant at which arcing in the fuse commences to the instant when the arcing contacts have separated in all poles

Note 1 to entry: This definition applies only for fused circuit-switchers fitted with fuse-striker release.

3.101 Fuses

3.101.1
fuse-base
fuse mount
fixed part of a fuse provided with contacts and terminals

[SOURCE: IEC 60050-441:~~2007~~2000, 441-18-02]

3.101.2
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:~~2007~~2000, 441-18-18]

3.101.3
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:~~2007~~2000, 441-17-12]

3.101.4
I*²*t
joule integral
integral of the square of the current over a given time interval:

$$I^2t = \int_{t_2}^{t_1} i^2 \mathrm{d}t$$

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 A^2s.

[SOURCE: IEC 60050-441:~~2007~~2000, 441-18-23]

4 Normal and special service conditions

Clause 4 of IEC 62271-1:~~2007~~2017 applies.

5 Ratings

5.1 General

Subclause 5.1 of IEC 62271-1:~~2007~~2017 applies with the following additions and exceptions.

In addition to the ratings listed in IEC 62271-1:~~2007~~2017 the following ratings apply:

a) rated short-circuit breaking current;

~~b) rated transient recovery voltage;~~

~~c~~b) rated short-circuit making current;

~~d~~c) rated take-over current;

~~e) rated maximal thermal current.~~

~~**4.4 Rated normal current and temperature rise**~~

~~**4.4.1 Rated normal current (I_r)**~~

~~Subclause 4.4.1 of IEC 62271-1:2007 is not applicable.~~

~~A rated normal current is normally not assigned to the fused circuit-switcher. When fused circuit-switchers are combined into larger enclosed assemblies, the rated normal current of the connecting busbars shall be in accordance with IEC 62271-200 or IEC 62271-201.~~

~~See also 4.4.101.~~

~~**4.4.2 Temperature rise**~~

~~Subclause 4.4.2 of IEC 62271-1:2007 is applicable with the following addition.~~

~~As far as fuses are concerned, Clause 6 of IEC 60282-1: 2009 applies.~~

~~**4.4.101 Rated maximum thermal current (I_{th})**~~

~~The rated maximum thermal current is the maximum value of the thermal current for the fused circuit-switcher.~~

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

~~NOTE The actual thermal current depends on the fuses installed.~~

~~**4.8 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.~~

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

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

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

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

~~**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 fused circuit-switcher shall be capable of breaking in the event of a short circuit.~~

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:~~2007~~2017 applies with the following addition.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated voltage is the one of the assembly.

5.3 Rated insulation level (U_d, U_p, U_s)

Subclause 5.3 of IEC 62271-1:~~2007~~2017 applies with the following additions.

NOTE The rated switching impulse withstand voltage U_s is not specified for the voltage range of this document.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated insulation level is the one of the assembly.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:~~2007~~2017 ~~is applicable with the following addition~~ does not apply.

Values of rated frequency for fused circuit-switchers are 50 Hz and 60 Hz.

NOTE 1 The proposed values for rated frequency are consistent with values for fuses

NOTE 2 In some cases, the rated characteristics of a fused circuit-switcher when used on a 60 Hz system ~~may be~~ are different from its rated characteristics when used on a 50 Hz system.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated frequency is the one of the assembly.

5.5 Rated continuous current (I_r)

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

The rated continuous current characterises the complete fused circuit-switcher, including the fuse-links. See 6.104.

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:~~2007~~2017 does not apply.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:~~2007~~2017 does not apply.

5.8 Rated duration of short-circuit (t_k)

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

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated supply voltage of auxiliary and control circuits is the one of the assembly.

5.10 Rated supply frequency of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 applies.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated supply frequency of auxiliary and control circuits is the one of the assembly.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:~~2007~~2017 applies.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated pressure of compressed gas supply for controlled pressure systems is the one of the assembly.

5.101 Rated short-circuit breaking current (I_{sc})

The rated short-circuit breaking current is the highest prospective short-circuit current which the fused circuit-switcher shall be capable of breaking, under the conditions of use and behaviour prescribed in this document, in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the fused circuit-switcher and having a prospective transient recovery voltage ~~equal to the rated value~~ as specified in ~~4.102~~ the type test subclause (see 7.101.2.9).

As the short-circuit breaking performance relies on the characteristics of the fuses installed, the instruction manual of the fused circuit-switcher shall list only fuses with rated maximum breaking current equal to or higher than I_{sc}. 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 as follows:

8 – 10 – 12,5 – 16 – 20 – 25 – 31,5 – 40 – 50 – 63 – 80 – 100 kA

NOTE ~~1~~ It is recognized that the series impedance of the fused circuit-switcher or rapid operation of the fuse or fused circuit-switcher sometimes causes 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.

~~NOTE 2 The short-circuit breaking performance relies on the characteristics of the fuses installed; only fuses with rated maximum breaking current equal or higher than I_{sc} can be listed in the instruction manual of the fused circuit-switcher.~~

5.102 Rated short-circuit making current (I_{ma})

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

NOTE 1 See also note~~s~~ in 5.101.

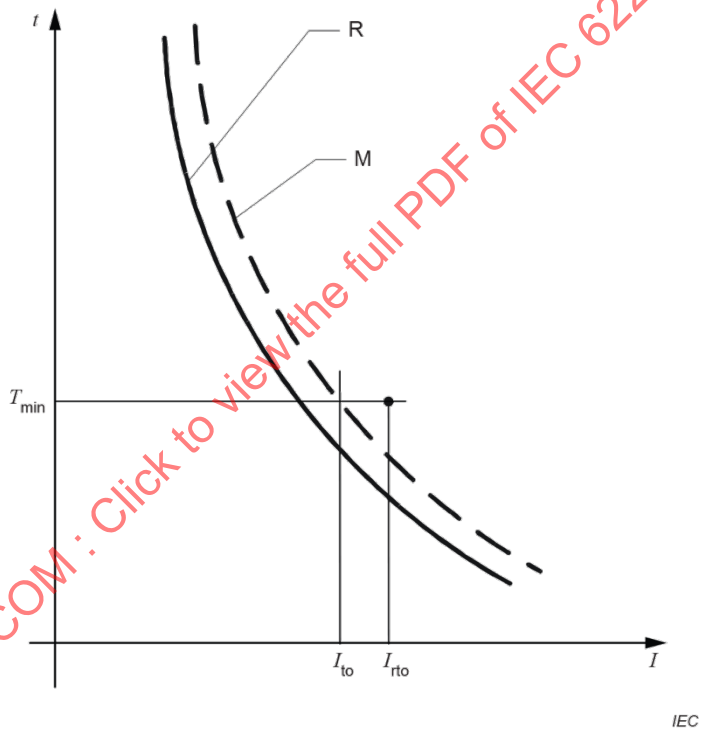
NOTE 2 Higher peak factor, linked with possible long time constant of the network, does not influence the performance of the fused circuit-switcher under short-circuit conditions, thanks to the current-limiting behaviour of the fuses. That is stated in IEC 60282-1:2009/AMD1:2014, 5.1.2.

5.103 Rated take-over current (I_{to})

The rated take-over current is the maximum RMS value of the take-over current which the circuit-switcher in the fused circuit-switcher is able to interrupt, under the conditions of use and behaviour prescribed in this document, in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the fused circuit-switcher and having a prospective transient recovery voltage equal to the value specified.

The rated value declared by the manufacturer shall be higher than the value of the take-over current, determined according to Figure 1, given by ~~the fuses used to demonstrate the rated maximum thermal current~~ the fuse type within the list having the highest melting curve in the time region around the minimum opening time under action of the opening release T_{min} (see 3.7.116).

NOTE The value of the minimum opening time under action of the opening release T_{min} is determined during the mechanical tests (see 7.102.2).



Key

R	fuse mean melting time-current characteristic
M	fuse slow melting time-current characteristic
T_{min}	minimum opening time under action of the opening release
I_{rto}	rated take-over current of the fused circuit-switcher
I_{to}	take-over current for the given fuse

Figure 1 – Characteristics for determining the take-over current

6 Design and construction

6.1 Requirements for liquids in fused circuit-switchers

Subclause 6.1 of IEC 62271-1:~~2007~~2017 applies.

6.2 Requirements for gases in fused circuit-switchers

Subclause 6.2 of IEC 62271-1:~~2007~~2017 applies.

6.3 Earthing of fused circuit-switchers

Subclause 6.3 of IEC 62271-1:~~2007~~2017 applies to stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:~~2007~~2017 applies to stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:~~2007~~2017 applies.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:~~2007~~2017 applies.

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

Subclause 6.7 of IEC 62271-1:~~2007~~2017 applies.

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:~~2007~~2017 applies, with the following addition.

Fused circuit-switchers shall be fitted with at least one shunt opening release.

6.10 ~~Low- and high- pressure interlocking and monitoring devices~~ Pressure/level indication

Subclause 6.10 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:~~2007~~2017 applies with the following modifications.

Table 9 in IEC 62271-1:~~2007~~2017 is replaced by the Table 1 below.

Table 1 – Nameplate ~~markings~~ information

(1)	~~Abbreviation~~ (2)	~~Unit~~ (3)	~~Fused circuit-switcher~~ (4)	~~Operating device~~ (5)	~~Condition for marking required~~ (6)
~~Manufacturer~~			~~X~~	~~Y~~	~~Only if not integral with the fused circuit-switcher and/or manufacturers are different~~
~~Type designation~~			~~X~~	~~Y~~	~~Only if not integral with the fused circuit-switcher and/or manufacturers are different~~
~~Instruction manual reference~~			~~X~~		
~~Serial number~~			~~X~~	~~(Y)~~	~~Required for operating device if different from those of the circuit-switcher~~
~~Year of manufacture~~			~~X~~		
~~Number of this standard~~			~~X~~		
~~Rated voltage~~	~~U_r~~	~~kV~~	~~X~~		
~~Rated lightning impulse withstand voltage~~	~~U_p~~	~~kV~~	~~X~~		
~~Rated frequency~~	~~f_r~~	~~Hz~~	~~X~~		
~~Rated maximum thermal current~~	~~I_{th}~~	~~A~~	~~X~~		
~~Acceptable fuse-links and thermal current with fuses~~			~~X~~		~~Mandatory marking: "Fuse-links: see instruction manual"~~
~~Rated gas pressure for operation~~	~~p_{op}~~	~~MPa~~		~~Y~~	~~When applicable~~
~~Rated supply voltage of auxiliary circuits~~	~~U_a~~	~~V~~		~~Y~~	~~When applicable~~
~~Temperature class~~			~~Y~~		~~Different from –5 °C indoor –25 °C outdoor~~
~~Insulating fluid and mass~~		~~kg~~	~~Y~~		~~When applicable~~

~~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 The abbreviations in column (2) are allowed instead of the terms in column (1). When the terms in column (1) are used, the word "rated" is optional.~~

(1)	Symbol (2)	Unit (3)	Fused circuit-switcher (4)	Operating device (5)	Condition for marking required (6)
Manufacturer			X	Y	Only if not integral with the fused circuit-switcher and/or manufacturers are different
Type designation			X	Y	Only if not integral with the fused circuit-switcher and/or manufacturers are different
Instruction manual reference			X	X	
Serial number			X	Y	Only if different from that of the fused circuit-switcher
Year of manufacture			X		
Number of this standard			X		
Rated voltage	U_r	kV	X		
Rated short duration power frequency withstand voltage	U_d	kV	X		
Rated lightning impulse withstand voltage	U_p	kV	X		
Rated frequency	f_r	Hz	X		
Acceptable fuse-links and rated continuous current with fuses	Mandatory marking: "I_r with fuse-links: see instruction manual"		X		
Filling pressure for operation	P_{rm}	MPa		Y	Where applicable
Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_a	V		Y	Where applicable
Minimum and maximum ambient air temperature		°C	Y		If different from −5 °C and/or 40 °C
Type and mass of fluid (liquid or gas) for insulation	M_f	kg	Y		if any
Mass (including any fluid)	M	kg	Y		- if more than 300 kg - no marking when part of an assembly

X: The marking of these values is mandatory.

Y: The marking of these values is mandatory, subject to the conditions in column (6).

NOTE The symbols in column (2) are allowed instead of the terms in column (1). When the terms in column (1) are used, the word "rated" is optional.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, only the characteristics which are not common within the assembly need to be on the nameplate for the fused circuit-switcher. They are:

– the number of this document;
– the acceptable fuse-links and rated continuous current with fuses;
– the filling pressure for operation.

6.12 ~~Interlocking~~ Locking devices

Subclause 6.12 of IEC 62271-1:~~2007~~2017 applies.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:~~2007~~2017 applies.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:~~2007~~2017 applies.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.17 ~~Liquid~~ Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:~~2007~~2017 applies.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:~~2007~~2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 applies for fused circuit-switchers having their own fluid containment.

For fused circuit-switchers sharing fluid within switchgear and controlgear assemblies, the assembly standard applies.

6.101 Basic requirements for fuses

Fuses shall comply with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

6.102 Linkages between the fuse striker(s) and the circuit-switcher release

The linkages between the fuse striker(s), if any, and the circuit-switcher release shall be such that the circuit-switcher operates satisfactorily under both three-phase and single-phase fault conditions at the minimum and maximum ~~requirements~~ characteristics of a given type of striker (medium or heavy) irrespective of the method of striker operation (thermal, spring or explosive). The ~~requirements~~ characteristics for strikers are given in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, Table 11.

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

Fused circuit-switcher equipped with fuse striker release shall be designed so that they will perform satisfactorily under any striker operation occurrence.

This is achieved by compliance with the following conditions a) and b):

a) Time coordination between circuit-switcher and fuse is provided by ~~either~~ 1), 2), or 3) below:

   1) The fuse-initiated opening time of the circuit-switcher shall be shorter than the maximum arcing time that the fuse can withstand. This arcing time value is at least 0,1 s according to IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

      NOTE Tests are specified in 7.6.3 of IEC 60282-1:2009 in order to assess that the maximum arcing duration withstand of the fuses 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 its rated short-circuit current down to the value equivalent to the minimum melting current of the fuse in the fused circuit-switcher (i.e. full range fuses), then the fuse-initiated opening time of the fused circuit-switcher is deemed not relevant.~~

      The fuses fitted in the fused circuit-switcher have been satisfactorily proven at all values of breaking current, from their rated short-circuit current down to the value equivalent to the minimum melting current of the fuse (i.e. full range fuses).

   3) ~~Where it can be shown that~~ The thermal ~~release~~ tripping of the fuse strikers makes the circuit-switcher 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 60282-1:2009 and IEC 60282-1:2009/AMD1:2014).

b) Temperature rise under these conditions does not impair the performances of the fused circuit-switcher as proven by the test described in 6.104 of IEC 62271-105:2012.

6.104 Rated continuous current values

The manufacturer shall provide in the instruction manual a list of the fuse-links to be used in the fused circuit-switcher. This list shall include at least, for each fuse-link, information about the manufacturer, the fuse-link designation, the fuse-link rated current, the associated rated continuous current of the fused circuit-switcher and the dissipated power of the fuse-link installed in the fused circuit-switcher under this value of current.

7 Type tests

~~**6.1 General**~~

~~Subclause 6.1 of IEC 62271-1:2007 is not applicable and is replaced as follows:~~

~~The purpose of type tests is to prove the characteristics of fused circuit-switchers, their operating devices and their operating equipment.~~

~~Type tests include:~~

- ~~dielectric tests;~~
- ~~temperature rise tests;~~
- ~~measurement of the resistance of the main circuit;~~
- ~~tests to prove the ability of the fused circuit-switcher 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.~~

~~The fused circuit-switcher submitted for test shall be in new condition with clean contact parts and fitted with the appropriate fuses.~~

~~Fuses shall be in accordance with IEC 60282-1. Relevant tests are out of the scope of this standard.~~

~~**6.1.1 Grouping of tests**~~

~~Subclause 6.1.1 of IEC 62271-1:2007 is applicable.~~

~~**6.1.2 Information for identification of specimens**~~

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

~~**6.1.3 Information to be included in type-test reports**~~

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

7.1 General

Subclause 7.1 of IEC 62271-1:2017 applies with the additions below.

Fuses used during type tests shall comply with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

7.2 Dielectric tests

Subclause 7.2 of IEC 62271-1:~~2007~~2017 applies with the addition below.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies for all phase-to-ground tests. Tests between open contacts shall be performed in accordance with 7.2 of IEC 62271-1:2017.

If the instruction manual lists fuse-links of different dimensions, the worst-case dimension shall be used for the tests. In case of doubt, tests shall be repeated for the smaller and the larger dimensions proposed.

NOTE Choice of the fuse-link is important, as the dimensions of the fuse-link affect the dielectric properties. See also 7.103.2.

~~Partial discharge tests as specified in IEC 62271-1:2007, 6.2.9 are not required.~~

7.3 Radio interference voltage (RIV) test

~~Subclause 6.3 of IEC 62271-1:2007 is not applicable.~~

This test does not apply. See 7.3 of IEC 62271-1:2017.

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

Subclause 7.4 of IEC 62271-1:~~2007~~2017 applies, with the clarification expressed below.

For the application of 7.4.4 of IEC 62271-1:2017, where this subclause is cited in this document, solid links of negligible resistance shall be used instead of fuses and the resistance of the links shall be recorded. ~~The current during the measurement shall have any convenient value between 50 A and the rated maximum thermal current.~~

~~**6.5 Temperature-rise tests**~~

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

~~The test shall be performed at the rated maximum thermal current, as determined by the manufacturer.~~

~~Fuses for the test shall be determined by the manufacturer and recorded in the test report.~~

7.5 Continuous current tests

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

The test shall be performed at the highest rated continuous current as stated in the list required by 6.104.

The test shall be repeated with the fuse-links generating the highest power dissipation, if these fuse-links are not the same as those providing the highest rated continuous current.

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

7.6 Short-time withstand current and peak withstand current tests

Subclause 7.6 of IEC 62271-1:~~2007~~2017 does not apply.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:~~2007~~2017 applies.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:~~2007~~2017 applies with the addition below.

Tightness of fuse-links, where applicable, is covered by IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:~~2007~~2017 applies.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:~~2007~~2017 applies for the auxiliary and control circuits involved in the operation of the circuit-switcher, as specified in this document. ~~Optional circuits are not in the scope of these tests.~~

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

Subclause 7.11 of IEC 62271-1:~~2007~~2017 applies with the following addition.

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

7.101 Making and breaking tests

7.101.1 General

~~This test contains four duties:~~

~~– TD_{lth}: making and breaking tests at the rated maximum thermal current;~~

~~– TD_{lsc}: making and breaking tests at the rated short-circuit current;~~

~~– TD_{lto}: breaking test at the rated take-over current;~~

~~– TD_{llow}: breaking test at one third of the rated take-over current.~~

Three type tests are defined: two independent test duties and a test sequence composed of two test duties:

– TD_{lr}: making and breaking tests at the highest rated continuous current (from the reference list);

– TD_{lsc}: making and breaking tests at the rated short-circuit current;

– Sequence of breaking tests at limited fault current:

  - TD_{lto}: breaking test at the rated take-over current;
  - TD_{llow}: breaking test at one third of the rated take-over current.

7.101.2 Conditions for performing the tests

7.101.2.1 Condition of the fused circuit-switcher before tests

The fused circuit-switcher 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 supply voltage or gas pressure for operation respectively as specified in 6.4.1 and 6.6.2 of IEC 62271-1:~~2007~~2017~~, unless current chopping influences the test results. In the latter case, the fused circuit-switcher shall be operated at a voltage or gas pressure within the tolerances specified in 4.8 and 4.10 of IEC 62271-1:2007, chosen to obtain the highest contact speed at contact separation and maximum arc extinguishing properties~~.

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

Fused circuit-switchers with only manual operation may be operated by an arrangement provided for the purposes of making remote control possible.

~~Due consideration shall be given to the choice of the live side connections.~~ When the fused circuit-switcher is intended for power supply from either side and the physical arrangement of one side of the break – or breaks – of the fused circuit-switcher differs from that of the other side, the ~~live~~ supply side of the test circuit shall be connected to that side of the fused circuit-switcher which gives the more ~~onerous~~ unfavourable condition. In case of doubt, the test duty shall be repeated with the supply ~~connections reversed~~ connected to the other side of the fused circuit-switcher, 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 tests shall be carried out at the ambient temperature.~~

The ambient air temperature during tests shall be within the range of 10 °C to 40 °C.

7.101.2.2 Test frequency

For limited fault current tests (test sequence composed of test duties TD_{lto} and TD_{llow}), the test circuit frequency shall be in accordance with the requirements expressed in IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017 for test duties T30 and T10.

NOTE 1 In the referenced edition of IEC 62271-100, the requirement is expressed as "Circuit-breakers shall be tested at rated frequency with a tolerance of ±8 %. However, for convenience of testing, some deviations from the above tolerance are allowable; for example, when circuit-breakers rated at 50 Hz are tested at 60 Hz and vice versa, care should be exercised in the interpretation of the results, taking into account all significant facts such as the type of the circuit-breaker and the type of test performed."

For tests involving operation of the fuses alone (test duties TD_{lsc}), the test circuit frequency shall be in accordance with the requirements expressed in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 for equivalent test duty.

NOTE 2 In the referenced edition of ~~IEC 60281-1~~ IEC 60282-1, the requirement is expressed as "The test-circuit frequency shall be between 48 Hz and 62 Hz."

For load current tests (test duty ~~TD_{lth}~~ TD_{lr}), the test circuit frequency shall be according to requirements expressed in the IEC 62271-103:2011 for the equivalent test duty.

NOTE 3 In the referenced edition of IEC 62271-103, the requirement is expressed as "Switches shall be tested at rated frequency, with a tolerance of ± 8 %".

7.101.2.3 Power factor

For test duty TD_{lr}, the power factor of the load shall be 0,7 ± 0,05 lagging and the power factor of the source shall be lower than 0,2.

For fault current test duties, the power factor of the test circuit shall be between 0,07 and 0,15 lagging.

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.

7.101.2.4 Arrangement of test circuits

For ~~TD_{lth}~~TD_{lr}, reference is made to three-phase test duty "TD_{load} mainly active load current" of IEC 62271-103:2011; then, the test circuit illustrated in Figure 2a shall be used.

For other test duties, the test circuit illustrated in Figure 2b shall be used.

For stand-alone fused circuit-switchers producing an emission of flame or metallic particles, the tests shall be made with metallic screens placed in the vicinity of the live parts, and separated from them by a clearance distance that the manufacturer shall specify in the instruction manual.

For stand-alone fused circuit-switchers, the screens, frame and other normally earthed parts shall be insulated from earth but connected to earth through a copper wire of 0,1 mm diameter and 50 mm in length. For fused circuit-switchers embedded within assemblies, this requirement applies to the frame of the assembly. This copper 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.

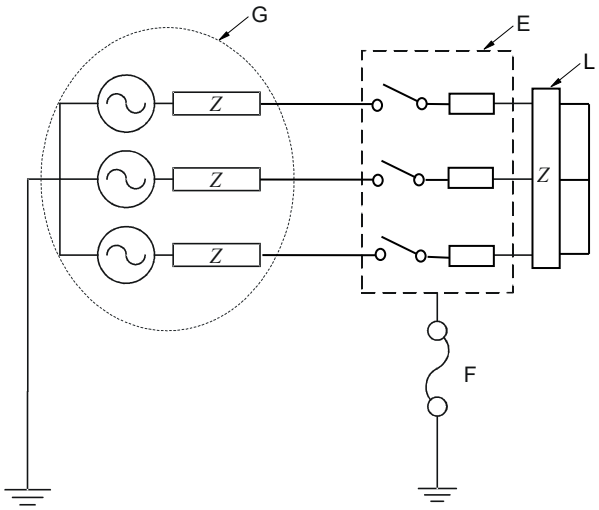


Figure 2a – Test circuit with load

Key

G Test power supply

E Frame or enclosure of the fused circuit-switcher

F Fuse to check the frame to earth leakage current

L Load circuit

NOTE The load impedance neutral may be earthed as an alternate to the supply neutral

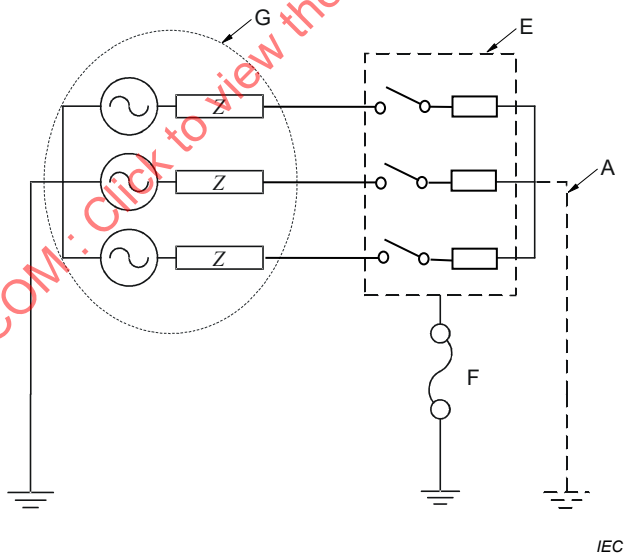


Figure 2b – Test circuit with short-circuit point

Key

A Alternate earth point if supply is not earthed

G Test power supply

E Frame or enclosure of the fused circuit-switcher

F Fuse to check the frame to earth leakage current

Figure 2 – Arrangement of test circuits for test duties ~~TD$_{lth}$~~ TD$_{lr}$, TD$_{lsc}$, TD$_{lto}$ and TD$_{llow}$

7.101.2.5 Test voltage for breaking tests

The test voltage is the average of the phase-to-phase voltages measured at the fused circuit-switcher location ~~immediately~~ between 0,5 period and 1,5 period after the breaking operation.

The voltage shall be measured as close as practicable to the terminals of the fused circuit-switcher, 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~~ between 95 % and 105 % of the rated voltage of the fused circuit-switcher.

~~The tolerance on the average value is ±5 % of the specified value, and~~ The tolerance on any phase to the average value is ±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.

7.101.2.7 Applied voltage before fault making tests

The applied voltage before the fault making tests of test duty TD_{lsc} is the RMS value of the voltage at the pole terminals immediately before the test.

~~In the case of three-phase tests~~ The average value of the applied voltages shall be not less than the rated voltage of the fused circuit-switcher 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 duty ~~TD_{lth}~~ TD_{lr}, the test quantities refer to the "TD_{load} mainly active load current" making and breaking tests of IEC 62271-103:2011.

For test duties TD_{lsc}, 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 sequence composed of test duties TD_{lto} and TD_{llow} the breaking current shall be the RMS value of the AC component measured at the initiation of arcing.

For test duties TD_{lsc}, TD_{lto} and TD_{llow} the RMS value of the AC component of the breaking current in any pole shall not vary from the average by more than 10 % of the average.

7.101.2.9 Transient recovery voltage (TRV)

For "mainly active load current", conditions of IEC 62271-103:2011 apply. For high fault levels, TRVs defined in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 apply. For reduced fault levels, TRVs defined in relevant test duties of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017 apply (see type tests duties TD_{lto} and TD_{llow} of this document). The parameters used for specifying the TRVs are illustrated in Figure 3.

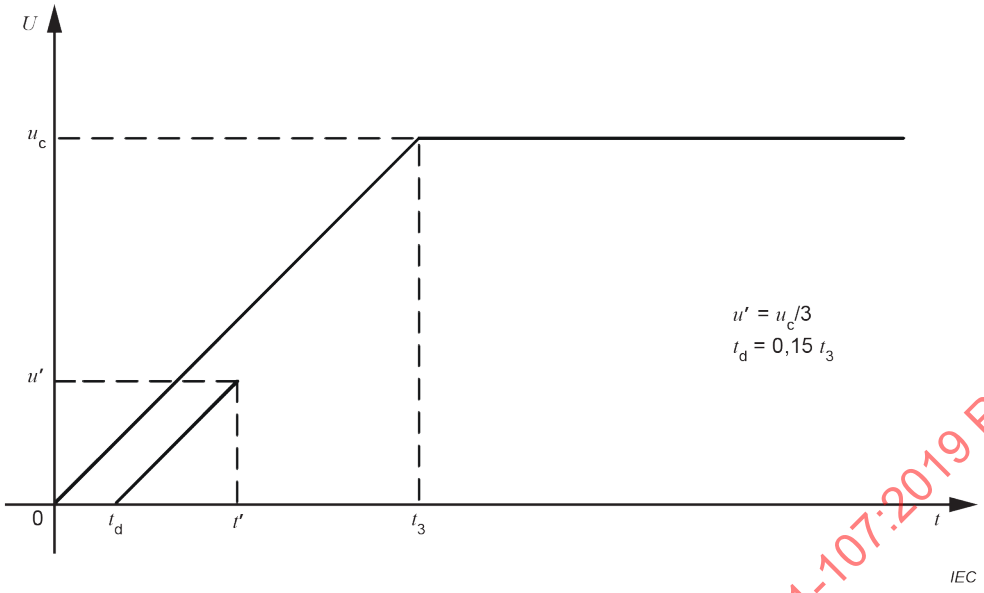


Figure 3 – Representation of a specified TRV by a two-parameter reference line and a delay line

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 device will be connected with all necessary test-measuring devices, such as voltage dividers, included. Suitable methods are described in Annex E and Annex F of IEC 62271-100:2008 and IEC 62271-100:2008/AMD2:2017.

~~For three-phase circuits,~~ The transient recovery voltage 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 transient recovery voltage curve of a test circuit is represented by its envelope drawn as shown in Figure 4 and by its initial portion.

The prospective transient recovery voltage wave of the test circuit shall comply with the following requirements:

a) its envelope shall at no time be below the specified reference line;

NOTE The extent by which the envelope exceeds the specified reference line requires the consent of the manufacturer.

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

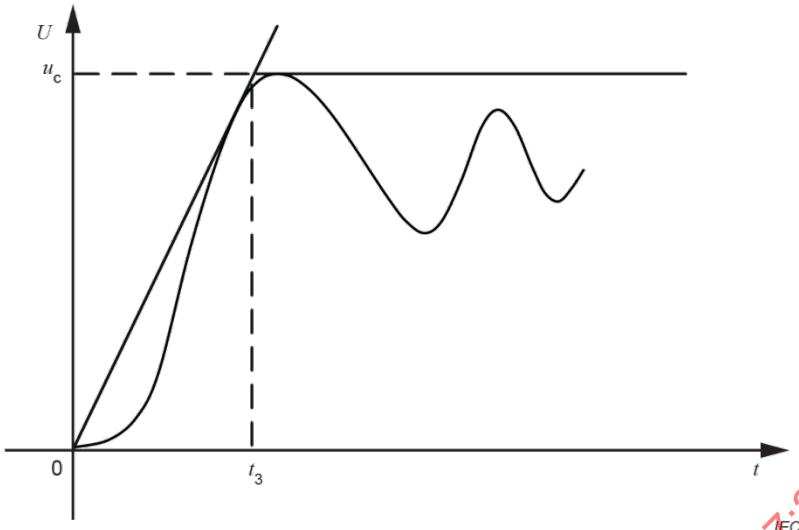


Figure 4 – Example of a two parameters envelope for a TRV

7.101.3 Test duty procedures

7.101.3.1 Test duty ~~TD_{Ith}~~ TD_{Ir} – Making and breaking tests at the highest rated ~~maximum thermal~~ continuous current

The test is performed in accordance with the test duty "TD_{load} mainly active load current" ~~of the IEC 62271-103~~ for Class E2 as specified in the IEC 62271-103:2011. ~~The class, as defined in IEC 62271-103, shall be E2.~~ Fuses may be replaced by solid links of negligible impedance.

If the switching device used within the fused circuit-switcher has already been tested in accordance with IEC 62271-103:2011, Class E2 or E3, with a rated mainly active load current higher than or equal to the highest rated ~~maximum thermal~~ continuous current of the fused circuit-switcher, then the test duty ~~TD_{Ith}~~ TD_{Ir} may be omitted.

7.101.3.2 Test duty TD_{Isc} – Making and breaking tests at the rated short-circuit current

This test duty is performed to demonstrate that the fused circuit-switcher is capable of making and withstanding the cut-off current of the fuse without damage ~~at this current~~. The two tests shall be carried out with fuses fitted in all three poles of the fused circuit-switcher.

If the circuit-switcher is fitted with a striker ~~operation is possible~~ release, fuses shall be fitted with strikers and the test shall demonstrate that the strikers open the fused circuit-switcher.

One break test 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 fused circuit-switcher with a tolerance of $^{+5}_{0}$ %. All three fuse-links shall be replaced after the first break test.

The making instant on the voltage wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

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

The applied voltage shall be in accordance with 7.101.2.7.

If striker ~~operation~~ tripping is ~~intended~~ demonstrated, the power frequency recovery voltage shall be determined as follows:

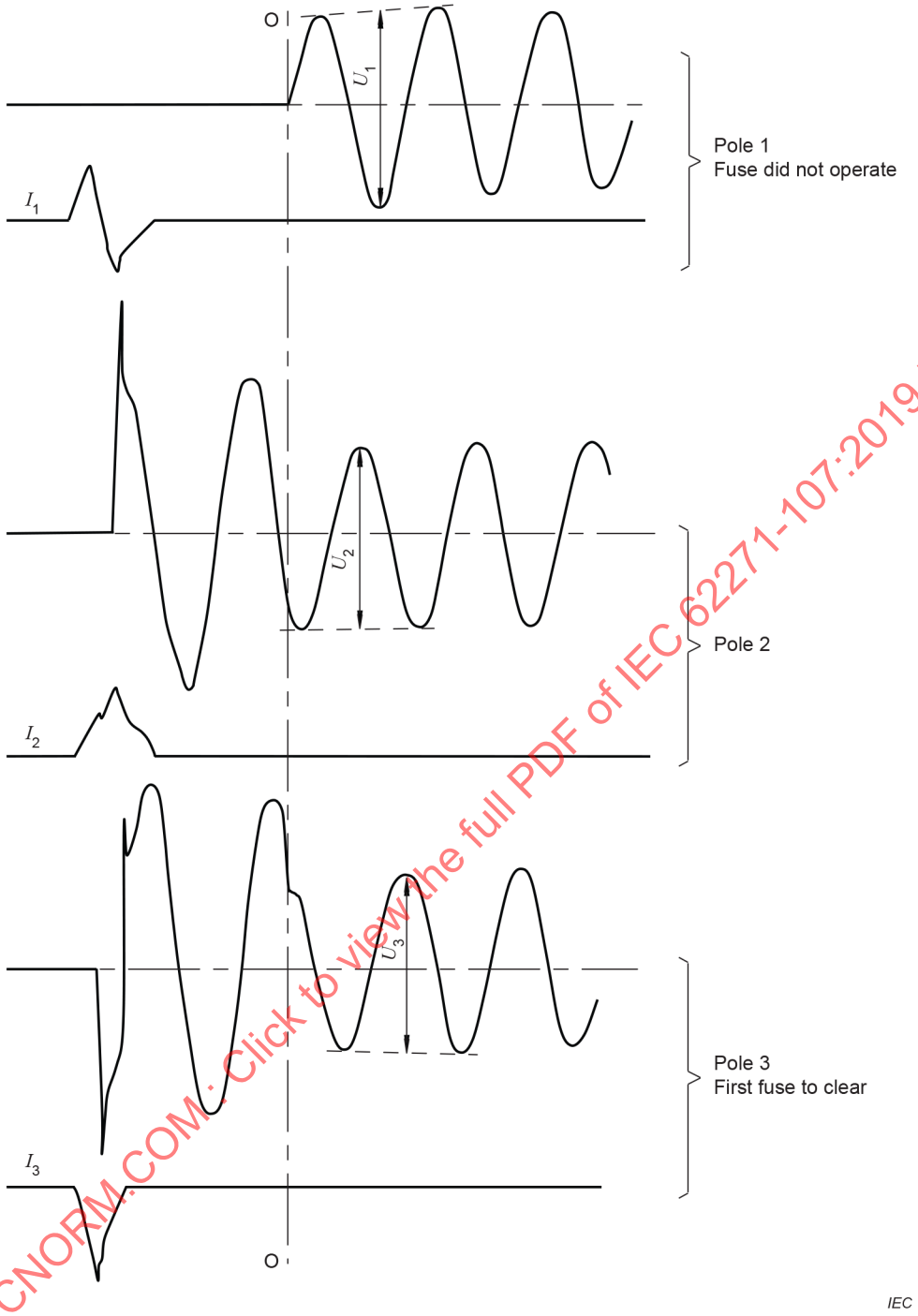
– the power frequency recovery voltage shall comply with 7.101.2.5;

– the power frequency recovery voltage shall be checked in accordance with Figure 5.

If no striker ~~operation~~ release is ~~possible~~ fitted, it is expected that only two fuses are going to operate and no acceptance criterion is provided for the power frequency recovery voltage.

The prospective transient recovery voltage shall be in accordance with ~~4.102 and 6.101.1.9~~ 7.101.2.9, meaning with reference to values provided in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

The first operation of the 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 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, i.e. within the range 65 electrical degrees to 90 electrical degrees after voltage zero in that pole.



$U_1/2\sqrt{2}$ = 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

Average voltage of poles 1, 2 and 3 =**Error! Bookmark not defined.**

$$\frac{\frac{U_1}{2\sqrt{2}} + \frac{U_2}{2\sqrt{2}} + \frac{U_3}{2\sqrt{2}}}{3}$$

Figure 5 – Measurement of the power frequency recovery voltage with striker operation

7.101.3.3 Breaking tests at limited fault currents

7.101.3.3.1 Test duty TD_{lto} – Breaking tests at the rated take-over current

This test duty is performed to prove the correct co-ordination between the release-operated circuit-switcher and fuses in the current region where the breaking duty is taken over from the fuses by the release-operated circuit-switcher.

Three break tests shall be made in a three-phase circuit, with the fuses in all three poles replaced by solid links of negligible impedance.

The opening instant of the poles on the current wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

The test current value is corresponding to the rated take-over current of the fused circuit-switcher, with a tolerance of $^{+5}_{0}$ %.

The prospective TRV shall be in accordance with ~~4.102 and 6.101.1.9~~ 7.101.2.9, with reference to the most severe values (highest peak value and shortest rise time) specified for test duty T30 of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017.

NOTE 1 In the referenced edition of the IEC 62271-100, this requirement refers to Table 25 specifying TRVs for Class S2 circuit-breakers, for k_{pp} = 1,5.

~~The power frequency recovery voltage shall be checked according to IEC 62271-100 relevant conditions.~~

NOTE 2 This test does not necessarily considers transformer limited faults with low capacitance connections as described in Annex M of IEC 62271-100:2008.

If current chopping happens and could influence the test results, the test duty shall be repeated with the fused circuit-switcher operated at a supply voltage or gas pressure within the tolerances specified, chosen to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

7.101.3.3.2 Test Duty TD_{llow} – Test at one third of the rated take-over current

This test duty is performed to prove the correct operation of the circuit-switcher when tripped under fault conditions, in the current region below the melting curve of the fuses.

This test duty shall be performed on the fused circuit-switcher previously subjected to the test duty TD_{lto}.

Three breaking tests shall be made in a three-phase circuit, with the fuses in all three poles replaced by solid links of negligible impedance.

The opening instant of the poles on the current wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

The test current shall be one third of the rated take-over current of the fused circuit-switcher with a tolerance of ± 10 %.

The prospective TRV shall be in accordance with ~~4.102 and 6.101.1.9~~ 7.101.2.9, with reference to the most severe values specified for test duty T10 of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012, and IEC 62271-100:2008/AMD2:2017.

NOTE In the referenced edition of the IEC 62271-100, this requirement refers to Table 25 specifying TRVs for Class S2 circuit-breakers, for k_{pp} = 1,5.

~~The power frequency recovery voltage shall be checked according to IEC 62271-100 relevant conditions.~~

If current chopping happens and could influence the test results, the test duty shall be repeated with the fused circuit-switcher operated at a supply voltage or gas pressure within the tolerances specified, chosen to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

7.101.3.4 Summary of test parameters

A summary of the parameters to be used when performing test duties is given in Table 2.

Table 2 – Summary of test parameters for test duties

Test duty Subclause No	Circuit	Test Voltage	Tolerances	Test current	Tolerances	Test series	Power factor	TRV
TD_{lth} (6.101.2.1)	3-phase with load Figure 2a	U_r	±5 %	Rated maximum thermal current I_{th} and 0,05 × I_{th}	$^{+10}_{0}$ %	30 CO 20 CO	Load: 0,7 ± 0,05 lagging source: <0,2 lagging	See IEC 62271-103, TD_{load}
TD_{lsc} (6.101.2.2)	3-phase Figure 2b	U_r	±5 %	Rated short-circuit breaking current	$^{+5}_{0}$ %	O CO	0,07 to 0,15 lagging	See IEC 60282-1
TD_{lto} (6.101.2.3)	3-phase Figure 2b	U_r	±5 %	Rated take-over current	$^{+5}_{0}$ %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T30 in IEC 62271-100
TD_{llow} (6.101.2.4)	3-phase Figure 2b	U_r	±5 %	One third of the rated take-over current	±10 %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T10 in IEC 62271-100
NOTE 1—Tolerance on the frequency is ±10 % for all test duties. NOTE 2—Most severe test conditions for TRVs mean highest amplitude factor and shortest rise time.								

Test sequence	Test duty Subclause No	Circuit	Test Frequency	Tolerances	Test current	Tolerances	Test series	Power factor	TRV
	TD_{lr} 7.101.3.1	3-phase with load Figure 2a	F_r	±8 %	Highest rated continuous current and 0,05 times this value	+10 0 %	30 CO 20 CO	Load: 0,7 ± 0,05 lagging source: <0,2 lagging	See IEC 62271-103:2011, TD_{load}
	TD_{lsc} 7.101.3.2	3-phase Figure 2b	F_r	between 48 and 62 Hz	Rated short-circuit breaking current	+5 0 %	O CO	0,07 to 0,15 lagging	See IEC 60282-1:2009 and IEC 60282-1:2009/ AMD1:2014
Breaking tests at limited fault current	TD_{lto} 7.101.3.3.1	3-phase Figure 2b	F_r	±8 % see also Note 1 in 7.101.2.2	Rated take-over current	+5 0 %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T30 in IEC 62271-100:2008, IEC 62271-100:2008/ AMD1:2012, and IEC 62271-100:2008/ AMD2:2017
	TD_{llow} 7.101.3.3.2	3-phase Figure 2b	F_r	±8 % see also Note 1 in 7.101.2.2	One third of the rated take-over current	±10 %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T10 in IEC 62271-100:2008, IEC 62271-100:2008/ AMD1:2012, and IEC 62271-100:2008/ AMD2:2017

NOTE 1 Tolerance on the voltage is ± 5 % for all test duties.

NOTE 2 Most severe test conditions for TRVs mean highest amplitude factor and shortest rise time.

7.101.4 Behaviour of the fused circuit-switcher during tests

~~The fused circuit-switcher may be inspected but not reconditioned (apart from the replacement of fuses) between any of the test duties, which shall all be performed on one sample.~~

During operation, the fused circuit-switcher shall show neither signs of excessive distress nor phenomena that might endanger an operator. These requirements are verified as follows.

From liquid-filled fused circuit-switchers there shall be no outward emission of flame, and the gases produced together with the liquid carried with the gases shall not be allowed to escape in such a way as to cause electrical breakdown. This later requirement is considered to be fulfiled if there is no significant leakage current.

For other types of fused circuit-switchers, flame or metallic particles such as might impair the insulation level of the fused circuit-switcher 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 duty TD_{lsc}, a fused circuit-switcher fitted with strikers shall open following the action of the fuse strikers.

Non-sustained disruptive discharges (NSDD) ~~may~~ can 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 to interpreting 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.

~~After each test, all three fuses should be replaced regardless of whether, they have operated or not during the test.~~

In three-phase operations, one fuse and/or its striker may not have operated during tests. This is a normal and not unusual condition; that will not invalidate acceptance of the test provided that the fuse did not ~~receive~~ suffer external damage in any way.

7.101.5 Condition of the apparatus after tests

After tests, fuses shall comply with the requirements of 5.1.3 of IEC 60282-1:2009.

After performing ~~each~~ any test duty:

a) the mechanical function and the insulators of the fused circuit-switcher 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 fused circuit-switcher shall, without reconditioning, be capable of maintaining its insulating properties;

c) for those fused circuit-switchers which incorporate a ~~disconnector~~ disconnecting function, the isolating properties of the ~~disconnector~~ function in the open position shall not be reduced below those specified by deterioration of insulating parts in the vicinity of, or parallel to, the isolating distance. The requirements for ~~disconnectors~~ isolating distance in ~~6.2.11 of IEC 62271-102: 2001~~ 7.2.12 of IEC 62271-1:2017 shall be fulfilled;

d) the fused circuit-switcher shall be capable of carrying its ~~thermal~~ highest rated continuous current continuously, from the reference list, after renewal of fuses.

If one test object is used to perform several test duties, the condition after tests may be checked only after the last test duty performed, provided no maintenance is done on the test object between the test duties.

Visual inspection and no-load operation of the fused circuit-switcher after tests are usually sufficient for checking the above requirements.

In case of doubt on the ability of the fused circuit-switcher to meet the conditions of 7.101.5 b), it shall be subjected to the relevant power-frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:~~2007~~2017. For fused circuit-switchers with sealed-for-life interrupters, the condition checking test is mandatory unless the sealed interrupter may be disassembled or opened for ~~the purposes of~~ inspection.

In case of doubt about the capability of the fused circuit-switcher, where applicable, to meet the conditions of 7.101.5 c), it shall be subjected to the relevant power-frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:~~2007~~2017. For fused circuit-switchers 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 on the capability of the fused circuit-switcher, 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:

a) visual inspection of the main contacts shows evidence of their ~~good~~ acceptable condition; or, if impracticable or unsatisfying,

b) ~~the resistance measured, as close as possible to the main contacts, and according to the procedure of 6.4.1 of IEC 62271-1:2007 does not exhibit an increase of more than 20 % compared with resistance measured before the test.~~
the resistance measurement, in accordance with the procedure and the relevant acceptance criteria of 7.4.4. of IEC 62271-1:2017, 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:

c) a test under the highest rated ~~maximum thermal~~ continuous current demonstrates that no thermal runaway occurs~~, by monitoring~~. The temperature at the ~~points~~ positions where the resistance measurements were made is monitored until ~~stabilization (~~ stable temperatures are achieved i.e. a variation of less than 1K per hour~~)~~. During this test, no other temperature measurements ~~is made~~ are required inside the switching device. If stabilization cannot be ~~obtained~~ achieved, then the condition check has failed and the fused circuit-switcher is considered to have failed the test duty as well.

7.102 Mechanical operation tests

7.102.1 General

The fused circuit-switcher should be mounted on its own support and its operating mechanism shall be operated in the specified manner. ~~Unless otherwise specified, the tests may be made at any convenient ambient air temperature.~~

During the test, three fuses of the minimum rating proposed in the instruction manual shall be fitted in the poles of the fused circuit-switcher. Cold resistance shall be measured before and after the tests.

The supply voltage of the operating device shall be measured at the terminals during operation of the switch. Auxiliary equipment forming part of the operating device shall be included. Impedance shall not be added between the supply and the terminals of the device for regulation of the applied voltage.

For manually operated fused circuit-switchers, the handle may, for convenience of testing, be replaced by an external power device where the operating force is equivalent to that for operation with a manual handle.

The determined minimum value of the opening time shall be stated in the test report.

7.102.2 Test procedure

The mechanical operation tests shall consist of 1 000 operating cycles without current or voltage ~~on, or current in,~~ applied to the main circuit. At least 50 opening operations shall be performed using the opening release supplied at its maximum supply voltage. During these operations, the opening time (see 3.7.115) shall be measured and its minimum value determined.

For a fused circuit-switcher having a power-operating device ~~shall be subjected to the following~~, the tests shall be organised as follows:

– 900 ~~closing and opening operations at~~ operating cycles with rated supply voltage and/or rated pressure of compressed gas supply for the power-operating device;

– 50 ~~closing and opening operations at~~ operating cycles with the specified minimum supply voltage and/or minimum pressure of compressed gas supply for the power-operating device;

– 50 ~~closing and~~ operating cycles, using the opening release for opening operations ~~at~~, with the specified maximum supply voltage and/or maximum pressure of compressed gas supply for the power-operating device and the maximum supply voltage of the opening release.

For a fused circuit-switcher fitted with striker tripping linkages, additional tests of the trip linkages shall be performed as follows:

1) To test the mechanical reliability of the linkages between the fuse striker(s) and the switchgear release, a total of 100 opening 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. During the tests, measurement of the opening time of the fused circuit-switcher is performed to check the requirement of 6.102 a) 1). After performing this test duty, the mechanical functioning of the trip linkages shall be practically the same as before the tests.
2) Using a dummy fuse-link with extended striker, set to the minimum actual travel within the tolerance specified in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, for each pole in turn it shall be shown that the fused circuit-switcher 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.

7.102.3 Condition of fused circuit-switcher during and after mechanical operation tests

The fully closed and fully opened positions shall be attained during each operating cycle. ~~The fused circuit-switcher shall be in such a condition that it is capable of operating normally, making, carrying and breaking its rated maximum thermal current.~~ Satisfactory operation of operating devices, of control and auxiliary contacts, and of position-indicating devices (if any), shall be verified during the test.

A tightness test shall be performed, where applicable, before and after the mechanical operation test in accordance with 7.8 of IEC 62271-1:~~2007~~2017. Lubrication in accordance with the manufacturer's instructions is permissible during the test, but mechanical adjustments are not permitted.

~~After the tests, all parts shall be in good condition and shall not show excessive wear.~~

After the tests, the fused circuit-switcher shall be in such a condition that it is capable of making, carrying and breaking its highest rated continuous current. This is considered to be satisfied if the resistance measurement, according to the procedure and the relevant acceptance criteria of 7.4.4. of IEC 62271-1:2017, is satisfying.

7.102.4 Condition of the fuses during and after mechanical operation tests

~~During the test given in 6.102, three fuses shall be fitted in the poles of the fused circuit-switcher. Cold resistance shall be measured before and after the tests.~~

After performing this (these) test duty (duties), the fuses shall show neither signs of mechanical damage nor ~~significant~~ change in resistance larger than the accuracy of the measuring procedure. They shall not have become displaced in their contacts.

~~NOTE A change of resistance larger than the accuracy of the measuring procedure should be considered as significant.~~

7.103 Extension of validity of type tests

7.103.1 General

Annex J of the IEC 62271-1:2017 describes general information about extension of validity of type tests and should be read in conjunction with 7.103.2, 7.103.3 and 7.103.4.

7.103.2 Dielectric properties

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

7.103.3 ~~Temperature rise~~ Continuous current tests

The compliance with ~~temperature rise~~ continuous current tests of the fused circuit-switcher made of the fused circuit-switcher base and the proposed fuse type (referred to as X) demonstrates the compliance of any fused circuit-switcher made of the same fused circuit-switcher base fitted with other fuse type, at the associated ~~thermal~~ rated continuous current of this new fused circuit-switcher ($~~I_{th}~~ I_{r\ fused\ circuit\text{-}switcher}$), provided that the four criteria below are fulfilled:

– the fuses have the same length as the fuse X;
– the fuses have rated current lower than, or equal to, those of the fuses X;
– the fuses have a value of the dissipated power (in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014) lower than, or equal to those of the fuses X;
– the derating of the fuses within the fused circuit-switcher ($~~I_{th}~~ I_{r\ fused\ circuit\text{-}switcher} / I_{r\ fuse}$) is lower than, or equal to those of the fuses X.

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

On request of the manufacturer, other ~~temperature rise~~ continuous current tests may be performed, with different fuse types providing other ~~thermal~~ rated continuous current values lower than the ~~rated maximum thermal current~~ highest one in order to provide further possibilities in the fuse selection criteria.

7.103.4 Making and breaking

Compliance with this document ~~is~~ can also be achieved by alternative untested or partially tested fused circuit-switchers made of the fused circuit-switcher base and fuses, provided that the following conditions are met:

a) any fuse considered shall comply with its standard (IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);

b) the same type of striker (if used) ~~must~~ shall be fitted i.e. medium or heavy in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014;

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 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, are not greater than those of the tested type similarly established.

8 Routine tests

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

8.1 General

Subclause 8.1 of IEC 62271-1:2017 applies.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.101 Mechanical operating tests

Operating tests shall be carried out to ensure that fused circuit-switchers comply with the prescribed 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 fused circuit-switchers open and close correctly when their operating devices are energized or under pressure. It shall also be verified that operation will not cause any damage to the fused circuit-switchers. Tests may be made without fuses.

For all fused circuit-switchers the following test shall be carried out, where applicable:

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

b) at the specified maximum supply voltage and/or the maximum pressure of the compressed gas supply: five closing and opening operations;

c) at the specified minimum supply voltage and/or the minimum pressure of the compressed gas supply: five closing and opening operations;

d) if a fused circuit-switcher can be operated by hand as well as by its normal electric or pneumatic operating device: five manual closing and opening operations;

e) for manually operated fused circuit-switchers only: ten closing and opening operations;

f) at rated supply voltage and/or rated pressure of the compressed gas supply: five closing and opening operations with a tripping circuit energized by the closing of the main contacts.

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

NOTE During test according to f), the current of the tripping circuit, flowing through the main contacts, is considered to be negligible.

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

After the tests, the fused circuit-switcher shall be examined to determine that no parts have suffered damage.

9 Guide to the selection of fused circuit-switchers (informative)

9.1 General

Subclause 9.1 of IEC 62271-1:2017 applies.

9.2 Selection of rated values

Subclause 9.2 of IEC 62271-1:~~2007~~2017 applies.

9.3 Cable-interface consideration

Subclause 9.3 of IEC 62271-1:2017 applies.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC 62271-1:~~2007~~2017 does not apply.

9.5 Environmental aspects

Subclause 9.5 of IEC 62271-1:2017 applies.

9.101 Additional criteria

The objective of this subclause and Subclauses 9.102 to 9.106 is to specify criteria for the selection of a fused circuit-switcher that will ensure correct performance, using the parameter values ~~established~~ validated by tests in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 and this document.

All applications of fused circuit-switchers may be covered using the highest fuse current rating proposed, with or without strikers, and an appropriate means of over-current tripping. However, the user may decide to use fuses with lower ratings, for example to benefit from current limitation on lower fault current values. Subclauses 9.102 to 9.106 provide information that may be used to make the proper choice.

Additional information for the co-ordination 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~~ 62655 [6].

Usage similar to that of switch-fuse combinations can be achieved by employing fused circuit-switchers fitted with a striker release and without any other tripping device. Fused circuit-switchers generally provide a higher rated take-over current than those of a switch-fuse combination, and ~~are~~ their application is not limited by the transfer current, as explained in Annex A. However, the user should be aware of the possibility of overheating and unpredictable behaviour if sustained conditions occur with current above the ~~thermal~~ rated continuous current and below the minimum breaking current of the installed fuses. In such applications, it is preferable to use a fuse with means of thermal limitation or an over-current protection relay.

It is anticipated the manufacturer will perform the type tests with back-up fuses. In the case where the type tests have been carried out on the circuit-switcher using full range fuses, any use of back-up fuses may require additional verification. Such verification should be subject to agreement between the manufacturer and the user.

9.102 Rated short-circuit breaking current

The rated short-circuit breaking current of a fused circuit-switcher should not be less than the maximum expected RMS symmetrical fault current level of the point in the distribution system at which the fused circuit-switcher is to be located.

~~The short-circuit breaking capacity is largely determined by that of the fuses. According to fuses installed, the actual short-circuit breaking capacity of the fused circuit-switcher could be lower than the rated value.~~

9.103 Rated ~~maximum thermal~~ continuous current

The rated ~~maximum thermal~~ continuous current of a fused circuit-switcher is assigned by the manufacturer and verified by the ~~temperature-rise~~ continuous current test. The ~~actual thermal~~ rated continuous current depends on the fuses installed and ~~should be determined by application of the rules stated in 8.107~~ is listed in the instruction manual. It may have to be reduced where the ambient temperature in service exceeds that specified under normal conditions in Clause 4.

NOTE Reference is made to IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 where a 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.

9.104 Currents between ~~thermal~~ rated continuous current and I_3 of the fuses

The current I_3 is defined for fuses in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 as the minimum breaking current.

For any current between ~~thermal~~ rated continuous current and I_3 of the fuses, protection can ~~only~~ be provided by external tripping means, such as an over-current relay or an over-temperature relay. However, striker action, either actuated by over-current conditions or over-temperature conditions, may provide a tripping order. If so, the circuit-switcher will be able to clear the current.

9.105 Transfer current

The transfer current, defined when the tripping action is provided by means of strikers, does not provide any additional requirement for a fused circuit-switcher above those already covered by this document. A complete explanation is provided in Annex A.

9.106 Take-over current

The value of the take-over current of a fused circuit-switcher is dependent upon both the minimum opening time of the circuit-switcher and the time-current characteristic of the fuse. As its name implies, it is the value of over-current above which the fuses take over the function of current interruption from the tripping device and circuit-switcher.

Proper fuse selection ensures that the take-over current is smaller than the rated take-over current of the fused circuit-switcher (see 3.7.108, 5.103 and the test conditions given in 7.101.3.3.1). From a practical point of view, it has to be checked that the maximum melting curve of the selected fuses is placed on the left-hand side of the point defined by the rated take-over current and the minimum opening time of the circuit-switcher (see Figure 1). This condition ensures that, in case of external relaying, faults currents higher than the rated take-over current will be cleared by the fuses alone. As the values of fault currents lower than the rated take-over current can be cleared by the circuit-switcher, the full range of fault current values is therefore covered. Detailed analysis is provided in Annex A.

It could occur that the TRV specified for the take-over current type test ~~may~~ does not cover the situation of a bolted short-circuit on the secondary side of a MV-LV transformer, if the type of transformer and the MV connections provide a very low capacitance. In such a situation with low capacitance, the performance should be specified according to the special test duty T30 documented in Annex M of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017, and relevant TRVs as listed in Table M.1 or Table M.3 of the same standard.

9.107 Extension of the validity of type tests

It ~~may be~~ is impractical to test a fused circuit-switcher with fuses of various current ratings and/or manufacturers. However, the principles on which the validity of the making, breaking and ~~temperature rise~~ continuous current tests ~~may~~ can be extended are expressed in this document.

Rules for extension are provided in 7.103 for the relevant type tests.

The satisfactory performance of the mechanical tests, including a high number of operations with the same ~~fuse samples~~ fuse-links installed, provides sufficient evidence for justifying the use of fuses other than those tested without further mechanical testing.

9.108 Operation

The three fuses fitted in a given fused circuit-switcher should be of the same type and current rating, otherwise the breaking performance of the fused circuit-switcher could be adversely affected. The instruction manual provides the list of fuses, or fuse-links, acceptable in the fused circuit-switcher.

It is vital, for the correct operation of the fused circuit-switcher, that the fuses are inserted with the strikers, if any, in the correct orientation.

When a fused circuit-switcher has operated as a result of a three-phase fault, it is possible for:

a) only two out of the three fuses to have operated;

b) 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.

All three fuses should be discarded and replaced if the fuse(s) in one or two poles of a fused circuit-switcher has have operated, unless it is definitely known that no over-current has passed through the un-melted fuse(s).

Before removing or replacing fuses, the operator should satisfy himself that the fuse-mount is electrically disconnected from all parts of the fused circuit-switcher that could still be electrically energized. This is especially important when the fuse-mount is not visibly isolated.

Where a fused circuit-switcher has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses, if any, as well as indications which could be provided by tripping devices, may give an indication on the type of fault current and its approximate value.

In the case of a tripping operation initiated apparently without melting any fuse, a proper cold resistance measurement of the fuses is the minimal precaution before putting them back in service. If a relay is able to provide information on the fault level and the fault duration, the resulting point should be at least 20 % below the minimum melting curve of the fuses to consider that they can still be maintained in service.

9.109 Comparison of performances of fused circuit-switchers with performances of switch-fuse combinations and circuit-breakers

Fused circuit-switchers provide intermediate performances between switch-fuse combinations (according to the relevant IEC ~~62271-105~~ standard) and circuit-breakers (according to the relevant IEC ~~62271-100~~ standard). Tables 3 and 4 give comparisons of the main features.

Table 3 – Comparison between switch-fuse combination and fused circuit-switcher

	Switch-fuse combination	Fused circuit-switcher
~~Correct operation range~~	~~Between melting current and I_{transf} according to TRV, and above I_{transf} in any case (see note)~~	~~Full~~
Protection settings	Choice of fuse and optional external device	Choice of fuse and external device
Strikers	Basic	Optional
Transfer current	Relevant, and limiting applications	Not relevant
Take-over current	Relevant, if tripping unit	Basic
NOTE On transformer protection applications, the expected TRVs below $I_{transfer}$ are usually compatible with switch specifications.		

Table 4 – Comparison between fused circuit-switcher and circuit breaker

	Fused circuit-switcher	Circuit-breaker
~~Correct operation range~~	~~Full~~	~~Full~~
Protection settings	Choice of fuse and external device	External device
Strikers	Optional	Not relevant
Take-over current	Basic	Not relevant
Fault current limitation	YES	NO
Reclosing capability	NO, if fuse operates	YES, at any current

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 ~~to be given~~ with enquiries and orders

Subclause 10.2 of IEC 62271-1:~~2007~~2017 applies with the following additions.

~~In addition to the information listed for the relevant component standard,~~ The enquirer should ~~identify the limit of supply~~ determine, for example, if the fused circuit-switcher described is to include the fuse-links.

10.3 Information ~~to be given~~ with tenders

Subclause 10.3 of IEC 62271-1:~~2007~~2017 applies with the following additions.

~~In addition to that defined for the relevant component standard, the manufacturer should give, apart from the rated values, the instruction manual including at least the following information:~~

The manufacturer's instruction manual should at least provide the rated values and the following information:

a) ~~the type of fuses used in the device when demonstrating the performances~~ the list of the fuse-links to be used in the fused circuit-switcher (required in 6.104), from which the type of fuses used in the device when tested is selected;

b) filling fluid (type and amount), where applicable;

c) the relevant information, concerning the fuses mentioned above, for the extension of the type test validity, i.e.:

– length and diameter ~~(6.5)~~;

– ~~maximum rating current (6.5);~~

– ~~rated dissipated power (6.5);~~

– rated current (4.6 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);

– power dissipation (6.5.3 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);

– derating (6.5.3 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);

– operating Joule integral (~~6.101.2.2~~ 4.13 of IEC 60282-1:2009);

– cut-off current (~~6.101.2.2~~ 4.12 of IEC 60282-1:2009).

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

Clause 11 of IEC 62271-1:~~2007~~2017 applies with the following addition.

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 fused circuit-switcher, they should be temporarily removed while the unit is installed.

12 Safety

Clause 12 of IEC 62271-1:~~2007~~2017 applies.

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:~~2007~~2017 applies with the following addition.

Any known chemical and environmental impact hazards should be identified in the fused circuit-switcher ~~handbook/~~instruction manual.

Annex A
(informative)

Applicability of the rated take-over current test duty

A.1 Problem formulation

This document for fused circuit-switchers does not consider a type test to verify the "transfer current breaking capacity", as in the fuse-switch combination standard.

The fault breaking capacity of the circuit-switcher alone is demonstrated as a take-over current by a three-phase test at rated voltage in the test conditions of T30 (IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017). The test current is the rated take-over current I_{rto}. It is required in 5.103 that the rated take-over current ensures the proper breaking capability with any fuse providing melting characteristics lower than those of the fuses used to demonstrate the ~~rated maximum thermal~~ highest rated continuous current.

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. Under such an assumption, it could be feared that the two remaining phases should be cleared by the circuit-switcher with conditions not clearly addressed by this document.

The purpose of this annex is to review the extent of applications that this take-over current test covers, considering the characteristics of the fuses and protection relays used in the fused circuit-switcher.

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 circuit-switcher can be opened by any tripping device. There is no reason for concern.

A.2 Background

In this document, the take-over current performance is demonstrated on a three-phase fault current, with a three-phase breaking capacity test. It is required that the maximum fuse melting time-current characteristic is kept below the point (rated take-over current I_{rto} / minimum opening time T_m).

Take-over current is defined by the IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 without considering differences between melting characteristics of the three fuses. The demonstrated rated value I_{rto} is based on the slowest acceptable fuse characteristic. The second phases clear $0{,}866 \times I_{rto}$.

In IEC 62271-105:2012, the 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.

If introducing the possibility of fuses with different characteristics, then one can consider a fault current, higher than the rated take-over current, which would lead to a first fuse to melt

(on a fast curve) and then second fuses melting with an additional delay such that a relay could have tripped the circuit-switcher before. This situation is not covered by the type test. Second phases could be cleared by the circuit-switcher with a current higher than 0,866 × I_{rto}.

Technical developments in this annex investigate the limits of such situation.

A.3 Terms, definitions and symbols

For the purposes of this annex, the following terms, definitions and symbols apply.

I_{rto} rated three-phase take-over current; it is also the fault-breaking capacity of the circuit-switcher as demonstrated by the type test

I_p prospective three-phase short-circuit current corresponding to a particular application

I_1 short-circuit current in the three phases, before interruption in the first pole

I_2 short-circuit current in the second and third pole after interruption in the first pole

NOTE $I_1 = I_p$ and $I_2 = I_p \times \sqrt{3}/2$.

I_{sup} the current above which there is no required delay time for the protection relays

Am application margin factor: ratio between the rated three phase take-over current of the circuit-switcher and the maximum fuse melting current of the fuses for a time equal to the minimum opening time of the circuit-switcher (see Figure A.1)

T_m minimum opening time of the circuit-switcher

t_r minimum protection operating time – it may depend on the value of the prospective current (protection curve) – if several protections are installed (maximum current relay, differential relay, Buchholz relay, arc detection device), the operating time of the fastest protection is considered

t_1 pre-arcing time of the first fuse to melt (first pole) when the current is not interrupted by the circuit-switcher

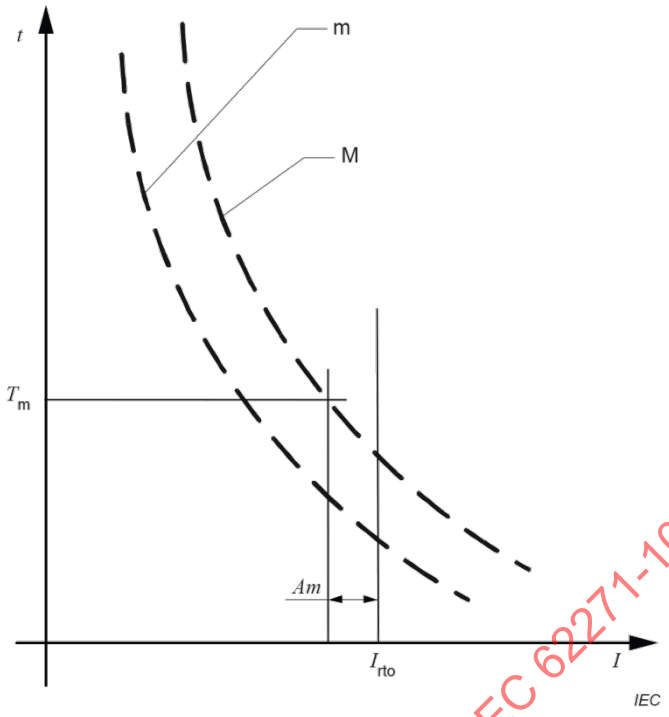
t_2 pre-arcing time of the second fuse to melt (second pole) when the current is not interrupted by the circuit-switcher

α slope coefficient of the pre-arcing time/current characteristic of the fuses

C parameter of the pre-arcing time/current characteristic of the fuses

x current margin between the slowest and fastest fuse characteristics

NOTE Parameters α, C and x are those used in IEC 62271-105.



Key

M slow melting time-current characteristic of the fuse

m fast melting time-current characteristic of the fuse

Figure A.1 – Visualization of the application margin for a given fuse

A.4 Assumptions about the fuse melting process

A.4.1 General

Assumptions are the same as those used in IEC 62271-105:2012.

A.4.2 First phase

In the zone of interest, a straight line in a log-log diagram approximates the pre-arcing time/current characteristic of the fuse, then for the fast fuse:

$$I_1^{\alpha} \times t_1 = C \tag{A.1}$$

where

I_1 is the RMS value of the prospective current;

t_1 is the pre-arcing time on the "fast" fuse characteristic.

A.4.3 Second phase

The two other fuses have a slower characteristic; the melting current is augmented by a factor (1 + x); so the pre-arcing characteristic is

$$[I/(1+x)]^{\alpha} \times t = C$$

but the current is equal to I_1 in the period [0, t_1] and to I_2 in the period [t_1, t_2]; t_2 being the final melting time of the fuse 2.

NOTE This is conservative since the fact the current does not fall immediately from I_1 to I_2 when arcing initiated in the first fuse is disregarded; this leads to an over-estimation of t_2.

It is assumed that the melting process of the second fuse is governed by the equation:

$$[I_1/(1+x)]^{\alpha} \times t_1 + [I_2/(1+x)]^{\alpha} \times (t_2 - t_1) = C \quad \text{(A.2)}$$

A.4.4 Modelling of the "application margin"

By definition, $$[(I_{rto}/Am)/(1+x)]^{\alpha} \times T_m = C \quad \text{(A.3)}$$

This makes a link between the rated take-over current of the circuit-switcher (I_{rto}) and the fuse characteristics.

A.5 Mathematical expression of the application requirements

A.5.1 General

Given a particular prospective current, here it is determined in which conditions the duties of the first and second poles to clear are covered by the type test. The practical analysis and synthesis of these mathematical conditions is made in Clause A.6.

A.5.2 First pole-to-clear

Any current larger than I_{rto} shall be interrupted by the fuse and not by the circuit-switcher: the sum of minimum opening time and the minimum protection operating time shall be higher than the pre-arcing time of a slow fuse (maximum pre-arcing time characteristic of the fuses).

$$T_m + t_r(I_p) \geq C \times [I_p/(1+x)]^{\alpha} \quad \text{for } I_p > I_{rto} \quad \text{(A.4)}$$

Since $t_r(I_p)$ is necessarily ≥ 0, a sufficient condition is that the relation is already satisfied with $t_r = 0$. Then, using Formula (A.3) to make the link with the "application margin" (Am), the condition becomes:

$$T_m \geq T_m / Am^{\alpha} \quad \text{(A.5)}$$

that is true for $Am \geq 1$ (which is mandatory).

A.5.3 Second pole-to-clear

A.5.3.1 General

The current cleared by the second pole should not be larger than $I_{rto} \times \sqrt{3}/2$ since this is the current cleared in the second pole-to-clear during the type test. The limiting case is when the prospective current is such that arcing in the second fuse begins at the moment of contact separation in the circuit-switcher.

Two cases are to be considered.

A.5.3.2 Opening of the circuit-switcher triggered by the fuse striker

The limiting case corresponds to:

$$T_m = t_2 - t_1 \tag{A.6}$$

This is when the maximum extra time needed by the second fuse for melting is equal to the opening time of the circuit-switcher: arcing begins simultaneously in the second fuse and in the circuit-switcher. If the prospective current is smaller than the one corresponding to this situation, the circuit-switcher might have to interrupt the current on the second pole. This is no problem if this situation is covered by the type test, that is, if the prospective current corresponding to the limiting case is smaller than the demonstrated interrupting capability of the circuit-switcher (I_{rto}).

Using and combining Formulas (A.1), (A.2), (A.3), (A.5) and (A.6), one obtains in the limiting case,

$$\frac{I_p}{I_{rto}} = \frac{1}{Am} \times \frac{\left[(1+x)^{\alpha} - 1\right]^{1/\alpha}}{0{,}866 \times (1+x)} \text{ should be} \leq 1 \tag{A.7}$$

NOTE 0,866 = √3/2.

A.5.3.3 Opening of the circuit-switcher triggered by a protection relay

The limiting case is when:

$$T_m + t_r = t_2 \tag{A.8}$$

This is when the maximum total time needed by the second fuse for melting is equal to the opening time of the circuit-switcher, augmented by the protection operating time since the opening is triggered by the protection; then, arcing begins simultaneously in the second fuse and in the circuit-switcher.

If the relay has a time dependent curve, both members of Formula (A.8) depend on the prospective current I_p. Therefore, one has to verify that it is on the safe side for any prospective current of concern.

$$T_m + t_r(I_p) \geq t_2(I_p) \tag{A.9}$$

The condition (A.9) shall be checked within a narrow range of prospective currents:

– Lower limit: for prospective currents smaller then I_{rto}, there is no problem because the case is covered by the type test.

– Upper limit: since $t_r(I_p)$ is necessarily non-negative and also because $t_2(I_p)$ is a decreasing function of I_p, the condition (A.9) is automatically verified for prospective currents higher than the prospective current corresponding to:

  $T_m = t_2(I_p)$.

  This current is called I_{sup}.

Since $t_r(I_p)$ and $t_2(I_p)$ are both decreasing functions of I_p, a sufficient condition is that

$$t_r(I_{sup}) \geq t_2(I_{to}) - T_m \tag{A.10}$$

Note that if $I_{sup} < I_{rto}$, the condition (A.10) is always verified.

Formula (A.10) is the key formula for the application: it determines the minimum protection operating time in order to cover the application.

One needs to express the relationship $t_2(I_p)$:

Using Formulas (A.1) and (A.2), one obtains:

$$t_2 = \frac{C}{I_p^{\alpha}} \times \left\{ \left[\frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} \right] + 1 \right\} \quad \text{(A.11)}$$

This equation can be particularized for finding I_{sup}, expressing that for this value of the prospective current, $t_2 = T_m$ and using Formula (A.3) to make the link with the application margin Am:

$$\frac{I_{sup}}{I_{rto}} = \frac{1}{Am \times (1+x)} \times \left[\frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} + 1 \right]^{1/\alpha} \quad \text{(A.12)}$$

Finally, using Formula (A.3) relating I_{rto} with C and T_m, one derives the formula that will be of practical use to calculate the minimum protection operating time in the range [I_{rto}, I_{sup}]:

$$t_r \geq T_m \times \left\{ \frac{1}{Am^{\alpha} \times (1+x)^{\alpha}} \times \left[1 + \frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} \right] - 1 \right\} \quad \text{(A.13)}$$

It can be seen in this equation that increasing the application margin factor (Am) may relieve the need for having a time delay on the protection.

A.6 Analysis

A.6.1 Applications with fuse strikers

If the fused circuit-switcher is equipped with fuse striker-tripping mechanisms, the condition (A.7) should be verified.

~~Provided the minimum opening time T_{min} stated in 4.104 considers the striker operation mode, the application margin is ≥ 1 for any fused circuit-switcher (mandatory from 4.104).~~

Assuming that the opening operation under action of the striker is not significantly slower than under action of opening release, and that the initiation comes from the melting of the fuse-link, the actual duration between the beginning of the fault and the separation of contacts is always longer than the minimum opening time T_{min} given in 5.103. This results in an application margin larger than 1 for any fused circuit-switcher tripped by a striker.

Table A.1 – Minimum application margin Am according to fuse characteristic

Am	α			
x	**5**	**4**	**3**	**2**
0,30	1,084	1,037	0,943	0,738
0,20	1,042	0,980	0,866	0,638
0,15	1,006	0,934	0,808	0,570
0,10	0,951	0,866	0,726	0,481
0,05	0,850	0,749	0,594	0,352

From Formula (A.7), one can derive a minimum application margin as a function of the fuse characteristics x and α. See Table A.1.

It can be seen that an application margin factor of 1 is sufficient.

As a reminder, conditions used for the transfer current in IEC 62271-105:2012 (switch-fuse combinations) are x equal to 0,13 and α equal to 4. Such conditions are therefore covered in this document without a dedicated type test.

A.6.2 Applications with protection relays

Conditions (A.4) and (A.13) apply.

Condition (A.13) allows for the definition of the minimum protection time delay as a function of the application margin, for specific values of the fuse characteristics; see Table A.2.

Table A.2 – Minimum protection time delay

Row	Min t_r/T_m	Am	x	α
1	3,111	0,75	0,13	4
2	0,301	1,00	0,13	4
3	-0,008	1,07	0,13	4
4	0,403	1,00	0,2	4
5	-0,006	1,09	0,2	4

The first row illustrates that application margin factors < 1 would need a dedicated time delay to ensure correct performance.

The requirement of this standard for $Am \geq 1$ clears this point. By this, condition (A.4) is also verified.

For usual applications:

– with Am = 1, one can see (rows 2 and 4) that a protection time delay, up to 0,5 T_m, should be required to ensure complete coverage of the cases studied here;

– with $Am \geq 1{,}1$, there is no more need for a specific protection time delay.

Current range for which the protection operating time is necessary: relation (A.12) provides I_{sup}/I_{rto} for the case Am = 1, for typical fuse characteristics. See Table A.3.

Table A.3 – Examples of possible need for time delay

Row	I_{sup}/I_{rto}	Am	x	α
1	1,068	1,00	0,13	4
2	1,082	1,00	0,13	5
3	1,088	1,00	0,2	4
4	1,139	1,00	0,5	5

One observes that, if the minimum protection operating time applies in the current range from 100 % up to 120 % of the rated take-over current of the circuit-switcher, there is no need for an application margin > 1.

A.7 Conclusions

The transfer current, as defined for combinations, is covered in this document by the rated take-over current and the associated type test.

When using high rating fuses, with curves very close to the maximum allowed in the fused circuit-switcher, a minimum operating time, up to half the minimum opening time of the circuit-switcher, may be needed on the protection chain to prevent exceptional situations from occurring.

Annex B
(informative)

Particular conditions existing in certain countries

According to Czech regulation (Act No. 458/2000 Coll., on the conditions for entrepreneurial activities and the performance of stateadministration in energy industries and on an amendment to certain acts ("Energy Act"), as amended by later legislative acts and regulations) the nominal voltages given in Table B.1 are used in AC three-phase systems in the Czech Republic.

Table B.1 – Voltages used in the Czech Republic

Highest voltage for equipment (kV)	Nominal system voltage (kV)
25	22
38,5	35

For these systems, the insulation levels given in Table B.2 apply.

Table B.2 – Rated insulation levels for voltage ratings of Table B.1

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across isolating distance	Common value	Across isolating distance
25	50	60	95	110
			125	145
38,5	80	90	155	175
			180	210

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IEC 62271-107

Edition 3.0 2019-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

High-voltage switchgear and controlgear – Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV

Appareillage à haute tension – Partie 107: Circuits-switchers à fusibles pour courant alternatif de tension assignée supérieure à 1 kV et jusqu'à 52 kV inclus

IEC 62271-107:2019-05(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV

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International Standard IEC 62271-107 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear

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) technical changes introduced by the second edition of IEC 62271-1 are applied, where relevant;
b) rated TRV is removed and TRV is now treated as a test parameter, as in IEC 62271-100;
c) the term "thermal current" is no longer used; the rated continuous current is linked to the installed fuse-links, and values shall be provided by the manufacturer together with the list of the acceptable fuse-links; for tests purpose, the highest rated continuous current listed

is referred, where previously the wording was "rated maximum thermal current", for consistency with IEC 62271-105;

d) making and breaking test duties are independent type tests (as some may be omitted if the switching device has been validated as a load-break switch). However, TD_{lt0} and TD_{llow} are kept as a sequence as they are linked to the same rated value (I_{t0});

e) differentiation has been introduced between requirements expressed for fulfilling the function expected from a fused circuit-switcher, 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 on the following documents:

FDIS	Report on voting
17A/1216/FDIS	17A/1227/RVD

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

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

This International Standard 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. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses, are numbered from 101.

Particular conditions existing in certain countries are listed in Annex B.

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 "http://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.

INTRODUCTION

Earthing switches forming an integral part of a circuit-switcher are covered by IEC 62271-102 [1][1].

Installation in enclosure, if any, is covered either by IEC 62271-200 [2] or by IEC 62271-201 [3].

1 Numbers in square brackets refer to the Bibliography.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV

1 Scope

This part of IEC 62271 applies to three-pole-operated fused circuit-switchers 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.

They can be designed either as stand-alone devices, or be embedded in a switchgear and controlgear assembly.

They are intended to be used for circuits or applications requiring only a normal mechanical and electrical endurance capability. Such applications cover protection of HV/LV transformers for instance, but exclude distribution lines or cables, as well as motor circuits and capacitor bank circuits.

Short-circuit conditions with low currents, up to the fused circuit-switcher rated take-over current, are dealt with by supplementary devices (strikers, relays, etc.), properly arranged, tripping the circuit-switcher. Current-limiting fuses are incorporated in order to ensure that the short-circuit breaking capacity of the device is above that of the circuit-switcher alone.

NOTE 1 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.

NOTE 2 Other circuit-switchers exist; see reference [4].

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

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.

IEC 60282-1:2009, *High-voltage fuses – Part 1: Current-limiting fuses*
IEC 60282-1:2009/AMD1:2014

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

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*
IEC 62271-100:2008/AMD1:2012
IEC 62271-100:2008/AMD2:2017

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

IEC 62271-105:2012, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 IEC Electropedia lists the terms defined in the IEC 60050 [5].

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
circuit-switcher
mechanical switching device suitable for making, carrying and interrupting currents under normal circuit conditions and for interrupting specified fault currents that are usually smaller than its short-time withstand current

Note 1 to entry: Other circuit-switchers exist; see reference [4].

3.4.102
fused circuit-switcher
combination, in a single device or function, of a circuit-switcher and fuses, one fuse being placed in series with each pole of the circuit-switcher intended to be connected to a phase conductor

Note 1 to entry: the term "one fuse" does not preclude the use of several fuse-links in parallel.

3.4.103
fused circuit-switcher base
fused circuit-switcher without fuse-links mounted

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
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, 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 60050-441:2000, 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 1 to entry: This kind of operation may be subdivided according to:

1) The manner of storing the energy (spring, weight, etc.);
2) The origin of the energy (manual, electric, etc.);
3) The manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441: 2000, 441-16-15]

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

3.7.106
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]

3.7.107
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]

3.7.108
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]

3.7.109
fused short-circuit current
conditional short-circuit current when the current-limiting device is a fuse

[SOURCE: IEC 60050-441:2000, 441-17-21]

3.7.110
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]

3.7.111
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]

3.7.112
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]

3.7.113
power frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

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

3.7.114
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]

3.7.115
opening time
<of a mechanical switching device> interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles

Note 1 to entry: For release operation, instant of initiation is taken as the instant of application of power supply on the release

[SOURCE: IEC 60050-441:2000, 441-17-36, modified – The initial note has been deleted and the current note added.]

3.7.116
fuse-initiated opening time
<of a fused circuit-switcher> time taken from the instant at which arcing in the fuse commences to the instant when the arcing contacts have separated in all poles

Note 1 to entry: This definition applies only for fused circuit-switchers fitted with fuse-striker release.

3.101 Fuses

3.101.1
fuse-base
fuse mount
fixed part of a fuse provided with contacts and terminals

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

3.101.2
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]

3.101.3
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]

3.101.4
I*²*t
joule integral
integral of the square of the current over a given time interval:

$$I^2t = \int_{t_2}^{t_1} i^2 \mathrm{d}t$$

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 A^2s.

[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 and exceptions.

In addition to the ratings listed in IEC 62271-1:2017 the following ratings apply:

a) rated short-circuit breaking current;
b) rated short-circuit making current;
c) rated take-over current;

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 applies with the following addition.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated voltage is the one of the assembly.

5.3 Rated insulation level (U_d, U_p, U_s)

Subclause 5.3 of IEC 62271-1:2017 applies with the following additions.

NOTE The rated switching impulse withstand voltage U_s is not specified for the voltage range of this document.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated insulation level is the one of the assembly.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 does not apply.

Values of rated frequency for fused circuit-switchers are 50 Hz and 60 Hz.

NOTE 1 The proposed values for rated frequency are consistent with values for fuses

NOTE 2 In some cases, the rated characteristics of a fused circuit-switcher when used on a 60 Hz system are different from its rated characteristics when used on a 50 Hz system.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated frequency is the one of the assembly.

5.5 Rated continuous current (I_r)

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

The rated continuous current characterises the complete fused circuit-switcher, including the fuse-links. See 6.104.

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.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated supply voltage of auxiliary and control circuits is the one of the assembly.

5.10 Rated supply frequency of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 applies.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated supply frequency of auxiliary and control circuits is the one of the assembly.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 applies.

When the fused circuit-switcher is part of a switchgear and controlgear assembly, its rated pressure of compressed gas supply for controlled pressure systems is the one of the assembly.

5.101 Rated short-circuit breaking current (I_{sc})

The rated short-circuit breaking current is the highest prospective short-circuit current which the fused circuit-switcher shall be capable of breaking, under the conditions of use and behaviour prescribed in this document, in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the fused circuit-switcher and having a prospective transient recovery voltage as specified in the type test subclause (see 7.101.2.9).

As the short-circuit breaking performance relies on the characteristics of the fuses installed, the instruction manual of the fused circuit-switcher shall list only fuses with rated maximum breaking current equal to or higher than I_{sc}. 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 as follows:

8 – 10 – 12,5 – 16 – 20 – 25 – 31,5 – 40 – 50 – 63 – 80 – 100 kA

NOTE It is recognized that the series impedance of the fused circuit-switcher or rapid operation of the fuse or fused circuit-switcher sometimes causes 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 (I_{ma})

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

NOTE 1 See also note in 5.101.

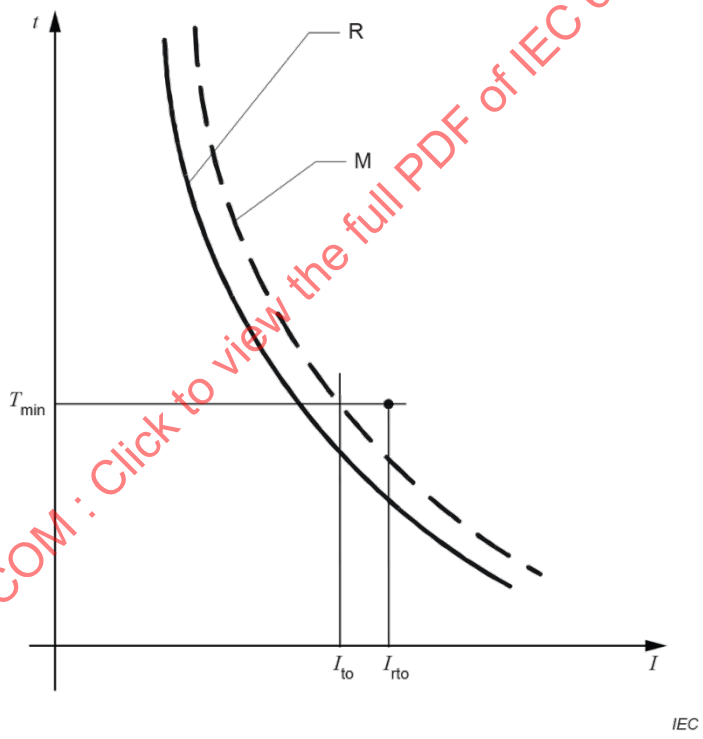
NOTE 2 Higher peak factor, linked with possible long time constant of the network, does not influence the performance of the fused circuit-switcher under short-circuit conditions, thanks to the current-limiting behaviour of the fuses. That is stated in IEC 60282-1:2009/AMD1:2014, 5.1.2.

5.103 Rated take-over current (I_{to})

The rated take-over current is the maximum RMS value of the take-over current which the circuit-switcher in the fused circuit-switcher is able to interrupt, under the conditions of use and behaviour prescribed in this document, in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the fused circuit-switcher and having a prospective transient recovery voltage equal to the value specified.

The rated value declared by the manufacturer shall be higher than the value of the take-over current, determined according to Figure 1, given by the fuse type within the list having the highest melting curve in the time region around the minimum opening time under action of the opening release T_{min} (see 3.7.116).

NOTE The value of the minimum opening time under action of the opening release T_{min} is determined during the mechanical tests (see 7.102.2).



Key

R	fuse mean melting time-current characteristic
M	fuse slow melting time-current characteristic
T_{min}	minimum opening time under action of the opening release
I_{rto}	rated take-over current of the fused circuit-switcher
I_{to}	take-over current for the given fuse

Figure 1 – Characteristics for determining the take-over current

6 Design and construction

6.1 Requirements for liquids in fused circuit-switchers

Subclause 6.1 of IEC 62271-1:2017 applies.

6.2 Requirements for gases in fused circuit-switchers

Subclause 6.2 of IEC 62271-1:2017 applies.

6.3 Earthing of fused circuit-switchers

Subclause 6.3 of IEC 62271-1:2017 applies to stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 applies to stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 applies.

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.

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, with the following addition.

Fused circuit-switchers shall be fitted with at least one shunt opening release.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.11 Nameplates

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

Table 9 in IEC 62271-1:2017 is replaced by the Table 1 below.

Table 1 – Nameplate information

(1)	Symbol (2)	Unit (3)	Fused circuit-switcher (4)	Operating device (5)	Condition for marking required (6)
Manufacturer			X	Y	Only if not integral with the fused circuit-switcher and/or manufacturers are different
Type designation			X	Y	Only if not integral with the fused circuit-switcher and/or manufacturers are different
Instruction manual reference			X	X	
Serial number			X	Y	Only if different from that of the fused circuit-switcher
Year of manufacture			X		
Number of this standard			X		
Rated voltage	U_r	kV	X		
Rated short duration power frequency withstand voltage	U_d	kV	X		
Rated lightning impulse withstand voltage	U_p	kV	X		
Rated frequency	f_r	Hz	X		
Acceptable fuse-links and rated continuous current with fuses	Mandatory marking: "I_r with fuse-links: see instruction manual"		X		
Filling pressure for operation	p_{rm}	MPa		Y	Where applicable
Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_a	V		Y	Where applicable
Minimum and maximum ambient air temperature		°C	Y		If different from −5 °C and/or 40 °C
Type and mass of fluid (liquid or gas) for insulation	M_f	kg	Y		if any
Mass (including any fluid)	M	kg	Y		- if more than 300 kg - no marking when part of an assembly

X: The marking of these values is mandatory.

Y: The marking of these values is mandatory, subject to the conditions in column (6).

NOTE The symbols in column (2) are allowed instead of the terms in column (1). When the terms in column (1) are used, the word "rated" is optional.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, only the characteristics which are not common within the assembly need to be on the nameplate for the fused circuit-switcher. They are:

– the number of this document;
– the acceptable fuse-links and rated continuous current with fuses;
– the filling pressure for operation.

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 for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard 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 for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard 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 for stand-alone devices.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 applies for fused circuit-switchers having their own fluid containment.

For fused circuit-switchers sharing fluid within switchgear and controlgear assemblies, the assembly standard applies.

6.101 Basic requirements for fuses

Fuses shall comply with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

6.102 Linkages between the fuse striker(s) and the circuit-switcher release

The linkages between the fuse striker(s), if any, and the circuit-switcher release shall be such that the circuit-switcher operates satisfactorily under both three-phase and single-phase fault conditions at the minimum and maximum characteristics of a given type of striker (medium or heavy) irrespective of the method of striker operation (thermal, spring or explosive). The characteristics for strikers are given in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, Table 11.

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

Fused circuit-switcher equipped with fuse striker release shall be designed so that they will perform satisfactorily under any striker operation occurrence.

This is achieved by compliance with the following conditions a) and b):

a) Time coordination between circuit-switcher and fuse is provided by 1), 2), or 3) below:
   1) The fuse-initiated opening time of the circuit-switcher shall be shorter than the maximum arcing time that the fuse can withstand. This arcing time value is at least 0,1 s according to IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

      NOTE Tests are specified in 7.6.3 of IEC 60282-1:2009 in order to assess that the maximum arcing duration withstand of the fuses is at least 100 ms.
   2) The fuses fitted in the fused circuit-switcher have been satisfactorily proven at all values of breaking current, from their rated short-circuit current down to the value equivalent to the minimum melting current of the fuse (i.e. full range fuses).
   3) The thermal tripping of the fuse strikers makes the circuit-switcher 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 60282-1:2009 and IEC 60282-1:2009/AMD1:2014).
b) Temperature rise under these conditions does not impair the performances of the fused circuit-switcher as proven by the test described in 6.104 of IEC 62271-105:2012.

6.104 Rated continuous current values

The manufacturer shall provide in the instruction manual a list of the fuse-links to be used in the fused circuit-switcher. This list shall include at least, for each fuse-link, information about the manufacturer, the fuse-link designation, the fuse-link rated current, the associated rated continuous current of the fused circuit-switcher and the dissipated power of the fuse-link installed in the fused circuit-switcher under this value of current.

7 Type tests

7.1 General

Subclause 7.1 of IEC 62271-1:2017 applies with the additions below.

Fuses used during type tests shall comply with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies.

7.2 Dielectric tests

Subclause 7.2 of IEC 62271-1:2017 applies with the addition below.

For fused circuit-switchers embedded within switchgear and controlgear assemblies, the assembly standard applies for all phase-to-ground tests. Tests between open contacts shall be performed in accordance with 7.2 of IEC 62271-1:2017.

If the instruction manual lists fuse-links of different dimensions, the worst-case dimension shall be used for the tests. In case of doubt, tests shall be repeated for the smaller and the larger dimensions proposed.

NOTE Choice of the fuse-link is important, as the dimensions of the fuse-link affect the dielectric properties. See also 7.103.2.

7.3 Radio interference voltage (RIV) test

This test does not apply. See 7.3 of IEC 62271-1:2017.

7.4 Resistance measurement

Subclause 7.4 of IEC 62271-1:2017 applies, with the clarification expressed below.

For the application of 7.4.4 of IEC 62271-1:2017, where this subclause is cited in this document, 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 addition:

The test shall be performed at the highest rated continuous current as stated in the list required by 6.104.

The test shall be repeated with the fuse-links generating the highest power dissipation, if these fuse-links are not the same as those providing the highest rated continuous current.

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

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 with the addition below.

Tightness of fuse-links, where applicable, is covered by IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

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 62271-1:2017 applies for the auxiliary and control circuits involved in the operation of the circuit-switcher, as specified in this document.

7.11 X-radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 applies with the following addition.

As this test is independent of the switching device, but only applied to the vacuum interrupters alone as components, the test results can be valid for several types of switching devices provided the type of vacuum interrupter is properly identified and the tested open gap spacing is equal or lower than used in the fused circuit-switcher.

7.101 Making and breaking tests

7.101.1 General

Three type tests are defined: two independent test duties and a test sequence composed of two test duties:

– TD_{lr}: making and breaking tests at the highest rated continuous current (from the reference list);
– TD_{lsc}: making and breaking tests at the rated short-circuit current;
– Sequence of breaking tests at limited fault current:
  - TD_{lto}: breaking test at the rated take-over current;
  - TD_{llow}: breaking test at one third of the rated take-over current.

7.101.2 Conditions for performing the tests

7.101.2.1 Condition of the fused circuit-switcher before tests

The fused circuit-switcher 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 supply voltage or gas pressure for operation respectively as specified in 6.4.1 and 6.6.2 of IEC 62271-1:2017.

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

Fused circuit-switchers with only manual operation may be operated by an arrangement provided for the purposes of making remote control possible.

When the fused circuit-switcher is intended for power supply from either side and the physical arrangement of one side of the break – or breaks – of the fused circuit-switcher differs from

that of the other side, the supply side of the test circuit shall be connected to that side of the fused circuit-switcher which gives the more unfavourable condition. In case of doubt, the test duty shall be repeated with the supply connected to the other side of the fused circuit-switcher, 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 ambient air temperature during tests shall be within the range of 10 °C to 40 °C.

7.101.2.2 Test frequency

For limited fault current tests (test sequence composed of test duties TD_{lto} and TD_{llow}), the test circuit frequency shall be in accordance with the requirements expressed in IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017 for test duties T30 and T10.

NOTE 1 In the referenced edition of IEC 62271-100, the requirement is expressed as "Circuit-breakers shall be tested at rated frequency with a tolerance of ±8 %. However, for convenience of testing, some deviations from the above tolerance are allowable; for example, when circuit-breakers rated at 50 Hz are tested at 60 Hz and vice versa, care should be exercised in the interpretation of the results, taking into account all significant facts such as the type of the circuit-breaker and the type of test performed."

For tests involving operation of the fuses alone (test duties TD_{lsc}), the test circuit frequency shall be in accordance with the requirements expressed in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 for equivalent test duty.

NOTE 2 In the referenced edition of IEC 60282-1, the requirement is expressed as "The test-circuit frequency shall be between 48 Hz and 62 Hz."

For load current tests (test duty TD_{lr}), the test circuit frequency shall be according to requirements expressed in the IEC 62271-103:2011 for the equivalent test duty.

NOTE 3 In the referenced edition of IEC 62271-103, the requirement is expressed as "Switches shall be tested at rated frequency, with a tolerance of ± 8 %".

7.101.2.3 Power factor

For test duty TD_{lr}, the power factor of the load shall be 0,7 ± 0,05 lagging and the power factor of the source shall be lower than 0,2.

For fault current test duties, the power factor of the test circuit shall be between 0,07 and 0,15 lagging.

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.

7.101.2.4 Arrangement of test circuits

For TD_{lr}, reference is made to three-phase test duty "TD_{load} mainly active load current" of IEC 62271-103:2011; then, the test circuit illustrated in Figure 2a shall be used.

For other test duties, the test circuit illustrated in Figure 2b shall be used.

For stand-alone fused circuit-switchers producing an emission of flame or metallic particles, the tests shall be made with metallic screens placed in the vicinity of the live parts, and separated from them by a clearance distance that the manufacturer shall specify in the instruction manual.

For stand-alone fused circuit-switchers, the screens, frame and other normally earthed parts shall be insulated from earth but connected to earth through a copper wire of 0,1 mm diameter and 50 mm in length. For fused circuit-switchers embedded within assemblies, this requirement applies to the frame of the assembly. This copper 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.

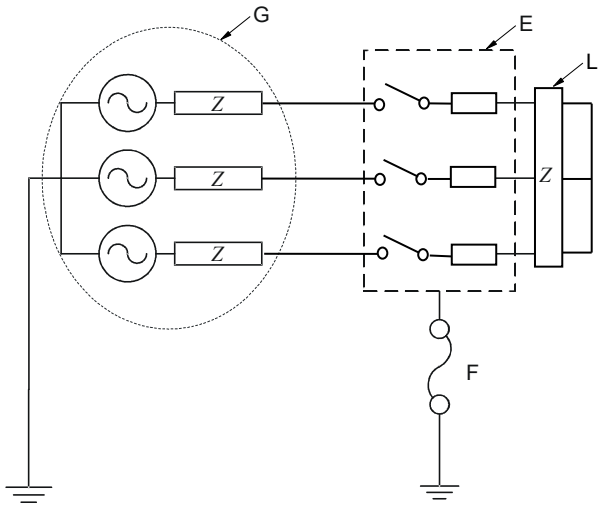


Figure 2a – Test circuit with load

Key

G Test power supply

E Frame or enclosure of the fused circuit-switcher

F Fuse to check the frame to earth leakage current

L Load circuit

NOTE The load impedance neutral may be earthed as an alternate to the supply neutral

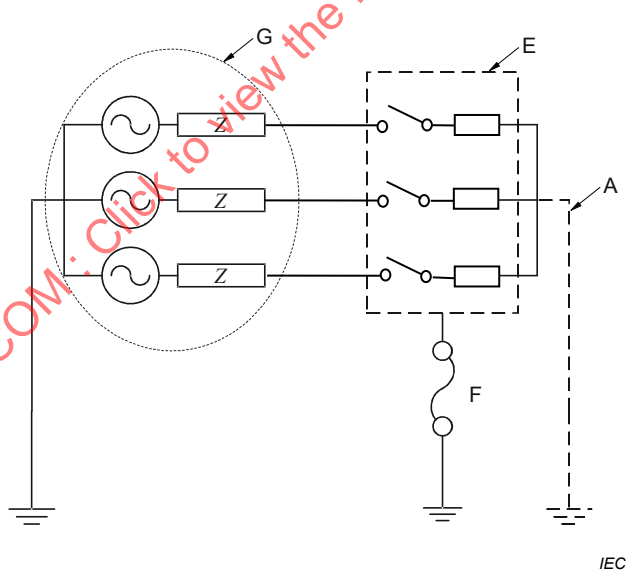


Figure 2b – Test circuit with short-circuit point

Key

A Alternate earth point if supply is not earthed

G Test power supply

E Frame or enclosure of the fused circuit-switcher

F Fuse to check the frame to earth leakage current

Figure 2 – Arrangement of test circuits for test duties TD_{lr}, TD_{lsc}, TD_{lto} and TD_{llow}

7.101.2.5 Test voltage for breaking tests

The test voltage is the average of the phase-to-phase voltages measured at the fused circuit-switcher location between 0,5 period and 1,5 period after the breaking operation.

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

The test voltage shall be between 95 % and 105 % of the rated voltage of the fused circuit-switcher. The tolerance on any phase to the average value is ±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.

7.101.2.7 Applied voltage before fault making tests

The applied voltage before the fault making tests of test duty TD_{lsc} is the RMS value of the voltage at the pole terminals immediately before the test.

The average value of the applied voltages shall be not less than the rated voltage of the fused circuit-switcher 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 duty TD_{lr}, the test quantities refer to the "TD_{load} mainly active load current" making and breaking tests of IEC 62271-103:2011.

For test duties TD_{lsc}, 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 sequence composed of test duties TD_{lto} and TD_{llow} the breaking current shall be the RMS value of the AC component measured at the initiation of arcing.

For test duties TD_{lsc}, TD_{lto} and TD_{llow} the RMS value of the AC component of the breaking current in any pole shall not vary from the average by more than 10 % of the average.

7.101.2.9 Transient recovery voltage (TRV)

For "mainly active load current", conditions of IEC 62271-103:2011 apply. For high fault levels, TRVs defined in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 apply. For reduced fault levels, TRVs defined in relevant test duties of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017 apply (see type tests duties TD_{lto} and TD_{llow} of this document). The parameters used for specifying the TRVs are illustrated in Figure 3.

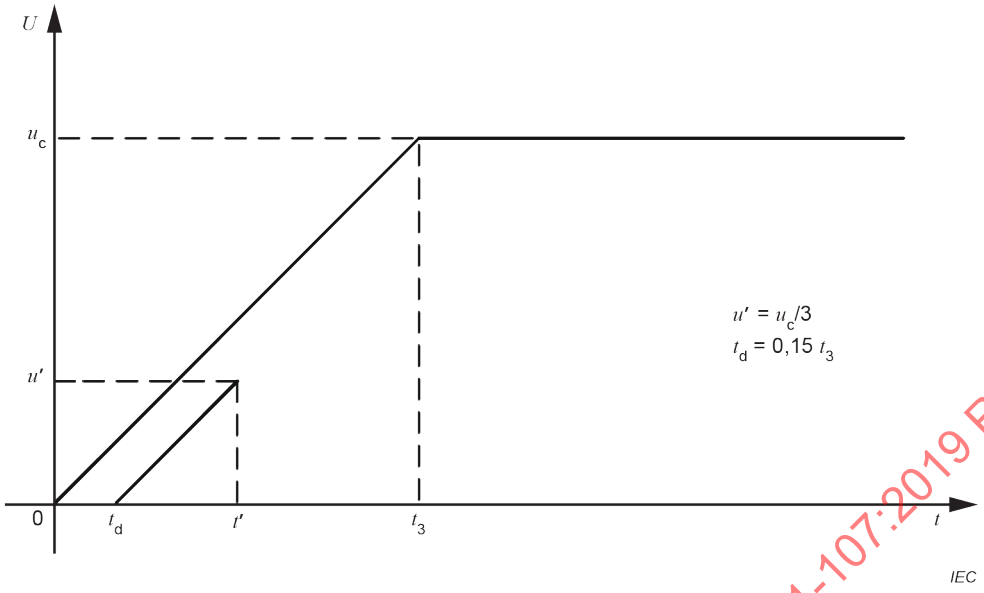


Figure 3 – Representation of a specified TRV by a two-parameter reference line and a delay line

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 device will be connected with all necessary test-measuring devices, such as voltage dividers, included. Suitable methods are described in Annex E and Annex F of IEC 62271-100:2008 and IEC 62271-100:2008/AMD2:2017.

The transient recovery voltage 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 transient recovery voltage curve of a test circuit is represented by its envelope drawn as shown in Figure 4 and by its initial portion.

The prospective transient recovery voltage wave of the test circuit shall comply with the following requirements:

a) its envelope shall at no time be below the specified reference line;

NOTE The extent by which the envelope exceeds the specified reference line requires the consent of the manufacturer.

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

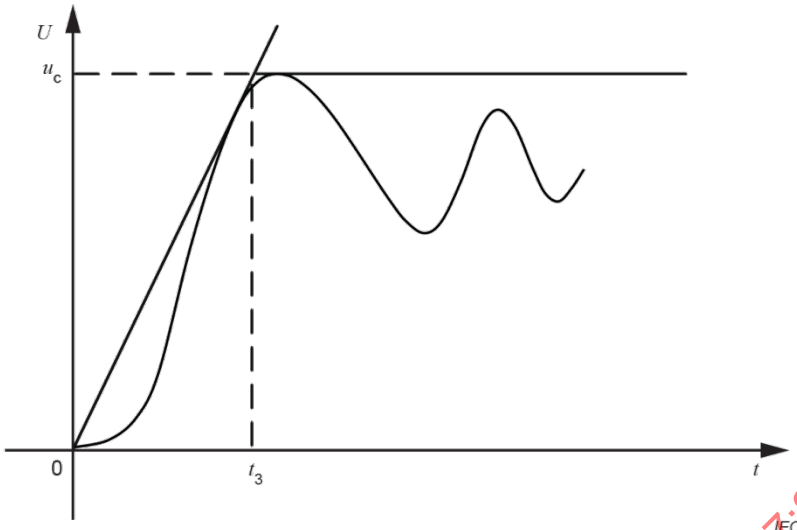


Figure 4 – Example of a two parameters envelope for a TRV

7.101.3 Test duty procedures

7.101.3.1 Test duty TD_{lr} – Making and breaking tests at the highest rated continuous current

The test is performed in accordance with the test duty "TD_{load} mainly active load current" for Class E2 as specified in the IEC 62271-103:2011. Fuses may be replaced by solid links of negligible impedance.

If the switching device used within the fused circuit-switcher has already been tested in accordance with IEC 62271-103:2011, Class E2 or E3, with a rated mainly active load current higher than or equal to the highest rated continuous current of the fused circuit-switcher, then the test duty TD_{lr} may be omitted.

7.101.3.2 Test duty TD_{lsc} – Making and breaking tests at the rated short-circuit current

This test duty is performed to demonstrate that the fused circuit-switcher is capable of making and withstanding the cut-off current of the fuse without damage. The two tests shall be carried out with fuses fitted in all three poles of the fused circuit-switcher.

If the circuit-switcher is fitted with a striker release, fuses shall be fitted with strikers and the test shall demonstrate that the strikers open the fused circuit-switcher.

One break test 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 fused circuit-switcher with a tolerance of $^{+5}_{0}$ %. All three fuse-links shall be replaced after the first break test.

The making instant on the voltage wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

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

The applied voltage shall be in accordance with 7.101.2.7.

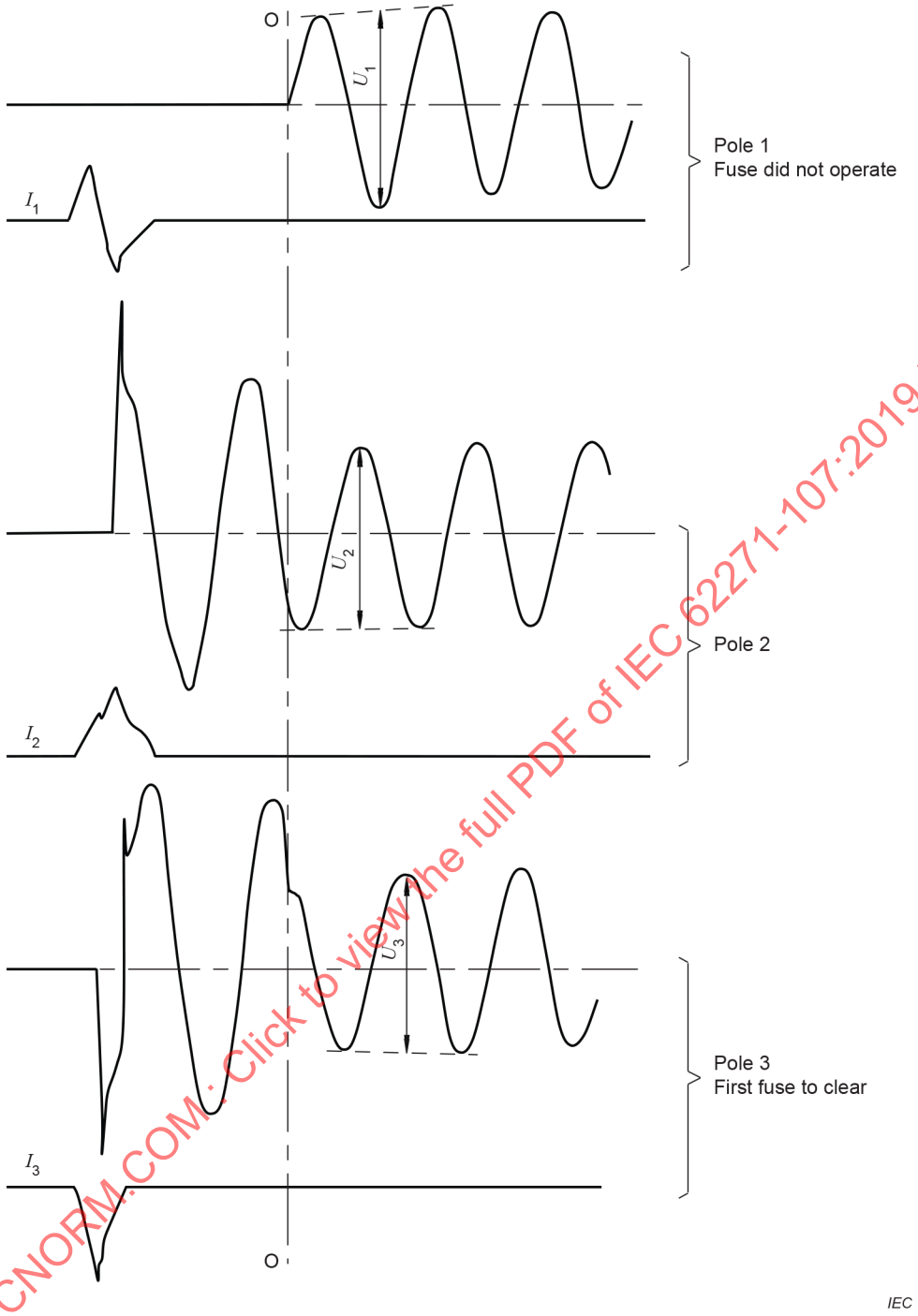
If striker tripping is demonstrated, the power frequency recovery voltage shall be determined as follows:

– the power frequency recovery voltage shall comply with 7.101.2.5;
– the power frequency recovery voltage shall be checked in accordance with Figure 5.

If no striker release is fitted, it is expected that only two fuses are going to operate and no acceptance criterion is provided for the power frequency recovery voltage.

The prospective transient recovery voltage shall be in accordance with 7.101.2.9, meaning with reference to values provided in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014.

The first operation of the 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 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, i.e. within the range 65 electrical degrees to 90 electrical degrees after voltage zero in that pole.



$U_1/2\sqrt{2}$ = 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

Average voltage of poles 1, 2 and 3 =**Error! Bookmark not defined.**

$$\frac{\frac{U_1}{2\sqrt{2}} + \frac{U_2}{2\sqrt{2}} + \frac{U_3}{2\sqrt{2}}}{3}$$

Figure 5 – Measurement of the power frequency recovery voltage with striker operation

7.101.3.3 Breaking tests at limited fault currents

7.101.3.3.1 Test duty TD_{lto} – Breaking tests at the rated take-over current

This test duty is performed to prove the correct co-ordination between the release-operated circuit-switcher and fuses in the current region where the breaking duty is taken over from the fuses by the release-operated circuit-switcher.

Three break tests shall be made in a three-phase circuit, with the fuses in all three poles replaced by solid links of negligible impedance.

The opening instant of the poles on the current wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

The test current value is corresponding to the rated take-over current of the fused circuit-switcher, with a tolerance of $^{+5}_{0}$ %.

The prospective TRV shall be in accordance with 7.101.2.9, with reference to the most severe values (highest peak value and shortest rise time) specified for test duty T30 of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017.

NOTE 1 In the referenced edition of the IEC 62271-100, this requirement refers to Table 25 specifying TRVs for Class S2 circuit-breakers, for k_{pp} = 1,5.

NOTE 2 This test does not necessarily considers transformer limited faults with low capacitance connections as described in Annex M of IEC 62271-100:2008.

If current chopping happens and could influence the test results, the test duty shall be repeated with the fused circuit-switcher operated at a supply voltage or gas pressure within the tolerances specified, chosen to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

7.101.3.3.2 Test Duty TD_{llow} – Test at one third of the rated take-over current

This test duty is performed to prove the correct operation of the circuit-switcher when tripped under fault conditions, in the current region below the melting curve of the fuses.

This test duty shall be performed on the fused circuit-switcher previously subjected to the test duty TD_{lt0}.

Three breaking tests shall be made in a three-phase circuit, with the fuses in all three poles replaced by solid links of negligible impedance.

The opening instant of the poles on the current wave is not specified (i.e. random).

The test circuit shall be in accordance with 7.101.2.4 (Figure 2b applies).

The test current shall be one third of the rated take-over current of the fused circuit-switcher with a tolerance of ± 10 %.

The prospective TRV shall be in accordance with 7.101.2.9, with reference to the most severe values specified for test duty T10 of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012, and IEC 62271-100:2008/AMD2:2017.

NOTE In the referenced edition of the IEC 62271-100, this requirement refers to Table 25 specifying TRVs for Class S2 circuit-breakers, for k_{pp} = 1,5.

If current chopping happens and could influence the test results, the test duty shall be repeated with the fused circuit-switcher operated at a supply voltage or gas pressure within the tolerances specified, chosen to obtain the highest contact speed at contact separation and maximum arc extinguishing properties.

7.101.3.4 Summary of test parameters

A summary of the parameters to be used when performing test duties is given in Table 2.

Table 2 – Summary of test parameters for test duties

Test sequence	Test duty Subclause No	Circuit	Test Frequency	Tolerances	Test current	Tolerances	Test series	Power factor	TRV
	TD_{lr} 7.101.3.1	3-phase with load Figure 2a	F_r	±8 %	Highest rated continuous current and 0,05 times this value	$^{+10}_{0}$ %	30 CO 20 CO	Load: 0,7 ± 0,05 lagging source: <0,2 lagging	See IEC 62271-103:2011, TD_{load}
	TD_{lsc} 7.101.3.2	3-phase Figure 2b	F_r	between 48 and 62 Hz	Rated short-circuit breaking current	$^{+5}_{0}$ %	O CO	0,07 to 0,15 lagging	See IEC 60282-1:2009 and IEC 60282-1:2009/ AMD1:2014
Breaking tests at limited fault current	TD_{lto} 7.101.3.3.1	3-phase Figure 2b	F_r	±8 % see also Note 1 in 7.101.2.2	Rated take-over current	$^{+5}_{0}$ %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T30 in IEC 62271-100:2008, IEC 62271-100:2008/ AMD1:2012, and IEC 62271-100:2008/ AMD2:2017
	TD_{llow} 7.101.3.3.2	3-phase Figure 2b	F_r	±8 % see also Note 1 in 7.101.2.2	One third of the rated take-over current	±10 %	O O O	0,07 to 0,15 lagging	Most severe test conditions defined for T10 in IEC 62271-100:2008, IEC 62271-100:2008/ AMD1:2012, and IEC 62271-100:2008/ AMD2:2017
NOTE 1 Tolerance on the voltage is ± 5 % for all test duties. NOTE 2 Most severe test conditions for TRVs mean highest amplitude factor and shortest rise time.									

7.101.4 Behaviour of the fused circuit-switcher during tests

During operation, the fused circuit-switcher shall show neither signs of excessive distress nor phenomena that might endanger an operator. These requirements are verified as follows.

From liquid-filled fused circuit-switchers there shall be no outward emission of flame, and the gases produced together with the liquid carried with the gases shall not be allowed to escape in such a way as to cause electrical breakdown. This later requirement is considered to be fulfiled if there is no significant leakage current.

For other types of fused circuit-switchers, flame or metallic particles such as might impair the insulation level of the fused circuit-switcher 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 duty TD_{lsc}, a fused circuit-switcher fitted with strikers shall open following the action of the fuse strikers.

Non-sustained disruptive discharges (NSDD) can 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 to interpreting 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.

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

7.101.5 Condition of the apparatus after tests

After tests, fuses shall comply with the requirements of 5.1.3 of IEC 60282-1:2009.

After performing any test duty:

a) the mechanical function and the insulators of the fused circuit-switcher 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 fused circuit-switcher shall, without reconditioning, be capable of maintaining its insulating properties;

c) for those fused circuit-switchers which incorporate a disconnecting function, the isolating properties of the function in the open position shall not be reduced below those specified by deterioration of insulating parts in the vicinity of, or parallel to, the isolating distance. The requirements for isolating distance in 7.2.12 of IEC 62271-1:2017 shall be fulfilled;

d) the fused circuit-switcher shall be capable of carrying its highest rated continuous current continuously, from the reference list, after renewal of fuses.

If one test object is used to perform several test duties, the condition after tests may be checked only after the last test duty performed, provided no maintenance is done on the test object between the test duties.

Visual inspection and no-load operation of the fused circuit-switcher after tests are usually sufficient for checking the above requirements.

In case of doubt on the ability of the fused circuit-switcher to meet the conditions of 7.101.5 b), it shall be subjected to the relevant power-frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:2017. For fused circuit-switchers with sealed-for-life interrupters, the condition checking test is mandatory unless the sealed interrupter may be disassembled or opened for inspection.

In case of doubt about the capability of the fused circuit-switcher, where applicable, to meet the conditions of 7.101.5 c), it shall be subjected to the relevant power-frequency voltage withstand tests in accordance with 7.2.12 of IEC 62271-1:2017. For fused circuit-switchers with sealed-for-life interrupters, the condition checking test is mandatory unless the sealed interrupter may be disassembled or opened for inspection.

In case of doubt on the capability of the fused circuit-switcher, 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:

a) visual inspection of the main contacts shows evidence of their acceptable condition; or, if impracticable or unsatisfying,

b) the resistance measurement, in accordance with the procedure and the relevant acceptance criteria of 7.4.4. of IEC 62271-1:2017, 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:

c) a test under the highest rated continuous current demonstrates that no thermal runaway occurs. The temperature at the positions where the resistance measurements were made is monitored until stable temperatures are achieved i.e. a variation of less than 1K per hour. During this test, no other temperature measurements are required inside the switching device. If stabilization cannot be achieved, then the condition check has failed and the fused circuit-switcher is considered to have failed the test duty as well.

7.102 Mechanical operation tests

7.102.1 General

The fused circuit-switcher should be mounted on its own support and its operating mechanism shall be operated in the specified manner.

During the test, three fuses of the minimum rating proposed in the instruction manual shall be fitted in the poles of the fused circuit-switcher. Cold resistance shall be measured before and after the tests.

The supply voltage of the operating device shall be measured at the terminals during operation of the switch. Auxiliary equipment forming part of the operating device shall be included. Impedance shall not be added between the supply and the terminals of the device for regulation of the applied voltage.

For manually operated fused circuit-switchers, the handle may, for convenience of testing, be replaced by an external power device where the operating force is equivalent to that for operation with a manual handle.

The determined minimum value of the opening time shall be stated in the test report.

7.102.2 Test procedure

The mechanical operation tests shall consist of 1 000 operating cycles without current or voltage applied to the main circuit. At least 50 opening operations shall be performed using the opening release supplied at its maximum supply voltage. During these operations, the opening time (see 3.7.115) shall be measured and its minimum value determined.

For a fused circuit-switcher having a power-operating device, the tests shall be organised as follows:

– 900 operating cycles with rated supply voltage and/or rated pressure of compressed gas supply for the power-operating device;
– 50 operating cycles with the specified minimum supply voltage and/or minimum pressure of compressed gas supply for the power-operating device;
– 50 operating cycles, using the opening release for opening operations, with the specified maximum supply voltage and/or maximum pressure of compressed gas supply for the power-operating device and the maximum supply voltage of the opening release.

For a fused circuit-switcher fitted with striker tripping linkages, additional tests of the trip linkages shall be performed as follows:

1) To test the mechanical reliability of the linkages between the fuse striker(s) and the switchgear release, a total of 100 opening 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. During the tests, measurement of the opening time of the fused circuit-switcher is performed to check the requirement of 6.102 a) 1). After performing this test duty, the mechanical functioning of the trip linkages shall be practically the same as before the tests.
2) Using a dummy fuse-link with extended striker, set to the minimum actual travel within the tolerance specified in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, for each pole in turn it shall be shown that the fused circuit-switcher 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.

7.102.3 Condition of fused circuit-switcher during and after mechanical operation tests

The fully closed and fully opened positions shall be attained during each operating cycle. Satisfactory operation of operating devices, of control and auxiliary contacts, and of position-indicating devices (if any), shall be verified during the test.

A tightness test shall be performed, where applicable, before and after the mechanical operation test in accordance with 7.8 of IEC 62271-1:2017. Lubrication in accordance with the manufacturer's instructions is permissible during the test, but mechanical adjustments are not permitted.

After the tests, the fused circuit-switcher shall be in such a condition that it is capable of making, carrying and breaking its highest rated continuous current. This is considered to be satisfied if the resistance measurement, according to the procedure and the relevant acceptance criteria of 7.4.4. of IEC 62271-1:2017, is satisfying.

7.102.4 Condition of the fuses during and after mechanical operation tests

After performing this (these) test duty (duties), the fuses shall show neither signs of mechanical damage nor change in resistance larger than the accuracy of the measuring procedure. They shall not have become displaced in their contacts.

7.103 Extension of validity of type tests

7.103.1 General

Annex J of the IEC 62271-1:2017 describes general information about extension of validity of type tests and should be read in conjunction with 7.103.2, 7.103.3 and 7.103.4.

7.103.2 Dielectric properties

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

7.103.3 Continuous current tests

The compliance with continuous current tests of the fused circuit-switcher made of the fused circuit-switcher base and the proposed fuse type (referred to as X) demonstrates the compliance of any fused circuit-switcher made of the same fused circuit-switcher base fitted with other fuse type, at the associated rated continuous current of this new fused circuit-switcher ($I_{\text{r fused circuit-switcher}}$), provided that the four criteria below are fulfilled:

– the fuses have the same length as the fuse X;

– the fuses have rated current lower than, or equal to, those of the fuses X;

– the fuses have a value of the dissipated power (in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014) lower than, or equal to those of the fuses X;

– the derating of the fuses within the fused circuit-switcher ($I_{\text{r fused circuit-switcher}}$ / $I_{\text{r fuse}}$) is lower than, or equal to those of the fuses X.

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

On request of the manufacturer, other continuous current tests may be performed, with different fuse types providing other rated continuous current values lower than the highest one in order to provide further possibilities in the fuse selection criteria.

7.103.4 Making and breaking

Compliance with this document can also be achieved by alternative untested or partially tested fused circuit-switchers made of the fused circuit-switcher base and fuses, provided that the following conditions are met:

a) any fuse considered shall comply with its standard (IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);

b) the same type of striker (if used) shall be fitted i.e. medium or heavy in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014;

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 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014, are not greater than those of the tested type similarly established.

8 Routine tests

8.1 General

Subclause 8.1 of IEC 62271-1:2017 applies.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 applies for stand-alone devices.

For fused circuit-switchers embedded within switchgear assemblies, the assembly standard applies.

8.101 Mechanical operating tests

Operating tests shall be carried out to ensure that fused circuit-switchers comply with the prescribed 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 fused circuit-switchers open and close correctly when their operating devices are energized or under pressure. It shall also be verified that operation will not cause any damage to the fused circuit-switchers. Tests may be made without fuses.

For all fused circuit-switchers the following test shall be carried out, where applicable:

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

b) at the specified maximum supply voltage and/or the maximum pressure of the compressed gas supply: five closing and opening operations;

c) at the specified minimum supply voltage and/or the minimum pressure of the compressed gas supply: five closing and opening operations;

d) if a fused circuit-switcher can be operated by hand as well as by its normal electric or pneumatic operating device: five manual closing and opening operations;

e) for manually operated fused circuit-switchers only: ten closing and opening operations;

f) at rated supply voltage and/or rated pressure of the compressed gas supply: five closing and opening operations with a tripping circuit energized by the closing of the main contacts.

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

NOTE During test according to f), the current of the tripping circuit, flowing through the main contacts, is considered to be negligible.

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

After the tests, the fused circuit-switcher shall be examined to determine that no parts have suffered damage.

9 Guide to the selection of fused circuit-switchers (informative)

9.1 General

Subclause 9.1 of IEC 62271-1:2017 applies

9.2 Selection of rated values

Subclause 9.2 of IEC 62271-1:2017 applies

9.3 Cable-interface consideration

Subclause 9.3 of IEC 62271-1:2017 applies.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC 62271-1:2017 does not apply.

9.5 Environmental aspects

Subclause 9.5 of IEC 62271-1:2017 applies.

9.101 Additional criteria

The objective of this subclause and Subclauses 9.102 to 9.106 is to specify criteria for the selection of a fused circuit-switcher that will ensure correct performance, using the parameter values validated by tests in accordance with IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 and this document.

All applications of fused circuit-switchers may be covered using the highest fuse current rating proposed, with or without strikers, and an appropriate means of over-current tripping. However, the user may decide to use fuses with lower ratings, for example to benefit from current limitation on lower fault current values. Subclauses 9.102 to 9.106 provide information that may be used to make the proper choice.

Additional information for the co-ordination 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 62655 [6].

Usage similar to that of switch-fuse combinations can be achieved by employing fused circuit-switchers fitted with a striker release and without any other tripping device. Fused circuit-switchers generally provide a higher rated take-over current than those of a switch-fuse combination, and their application is not limited by the transfer current, as explained in Annex A. However, the user should be aware of the possibility of overheating and unpredictable behaviour if sustained conditions occur with current above the rated continuous current and below the minimum breaking current of the installed fuses. In such applications, it is preferable to use a fuse with means of thermal limitation or an over-current protection relay.

It is anticipated the manufacturer will perform the type tests with back-up fuses. In the case where the type tests have been carried out on the circuit-switcher using full range fuses, any

use of back-up fuses may require additional verification. Such verification should be subject to agreement between the manufacturer and the user.

9.102 Rated short-circuit breaking current

The rated short-circuit breaking current of a fused circuit-switcher should not be less than the maximum expected RMS symmetrical fault current level of the point in the distribution system at which the fused circuit-switcher is to be located.

9.103 Rated continuous current

The rated continuous current of a fused circuit-switcher is assigned by the manufacturer and verified by the continuous current test. The rated continuous current depends on the fuses installed and is listed in the instruction manual. It may have to be reduced where the ambient temperature in service exceeds that specified under normal conditions in Clause 4.

NOTE Reference is made to IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 where a 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.

9.104 Currents between rated continuous current and I_3 of the fuses

The current I_3 is defined for fuses in IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 as the minimum breaking current.

For any current between rated continuous current and I_3 of the fuses, protection can be provided by external tripping means, such as an over-current relay or an over-temperature relay. However, striker action, either actuated by over-current conditions or over-temperature conditions, may provide a tripping order. If so, the circuit-switcher will be able to clear the current.

9.105 Transfer current

The transfer current, defined when the tripping action is provided by means of strikers, does not provide any additional requirement for a fused circuit-switcher above those already covered by this document. A complete explanation is provided in Annex A.

9.106 Take-over current

The value of the take-over current of a fused circuit-switcher is dependent upon both the minimum opening time of the circuit-switcher and the time-current characteristic of the fuse. As its name implies, it is the value of over-current above which the fuses take over the function of current interruption from the tripping device and circuit-switcher.

Proper fuse selection ensures that the take-over current is smaller than the rated take-over current of the fused circuit-switcher (see 3.7.108, 5.103 and the test conditions given in 7.101.3.3.1). From a practical point of view, it has to be checked that the maximum melting curve of the selected fuses is placed on the left-hand side of the point defined by the rated take-over current and the minimum opening time of the circuit-switcher (see Figure 1). This condition ensures that, in case of external relaying, faults currents higher than the rated take-over current will be cleared by the fuses alone. As the values of fault currents lower than the rated take-over current can be cleared by the circuit-switcher, the full range of fault current values is therefore covered. Detailed analysis is provided in Annex A.

It could occur that the TRV specified for the take-over current type test does not cover the situation of a bolted short-circuit on the secondary side of a MV-LV transformer, if the type of transformer and the MV connections provide a very low capacitance. In such a situation with low capacitance, the performance should be specified according to the special test duty T30 documented in Annex M of IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and

IEC 62271-100:2008/AMD2:2017, and relevant TRVs as listed in Table M.1 or Table M.3 of the same standard.

9.107 Extension of the validity of type tests

It is impractical to test a fused circuit-switcher with fuses of various current ratings and/or manufacturers. However, the principles on which the validity of the making, breaking and continuous current tests can be extended are expressed in this document.

Rules for extension are provided in 7.103 for the relevant type tests.

The satisfactory performance of the mechanical tests, including a high number of operations with the same fuse-links installed, provides sufficient evidence for justifying the use of fuses other than those tested without further mechanical testing.

9.108 Operation

The three fuses fitted in a given fused circuit-switcher should be of the same type and current rating, otherwise the breaking performance of the fused circuit-switcher could be adversely affected. The instruction manual provides the list of fuses, or fuse-links, acceptable in the fused circuit-switcher.

It is vital, for the correct operation of the fused circuit-switcher, that the fuses are inserted with the strikers, if any, in the correct orientation.

When a fused circuit-switcher has operated as a result of a three-phase fault, it is possible for:

a) only two out of the three fuses to have operated;

b) 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.

All three fuses should be discarded and replaced if the fuse(s) in one or two poles of a fused circuit-switcher has have operated, unless it is definitely known that no over-current has passed through the un-melted fuse(s).

Before removing or replacing fuses, the operator should satisfy himself that the fuse-mount is electrically disconnected from all parts of the fused circuit-switcher that could still be electrically energized. This is especially important when the fuse-mount is not visibly isolated.

Where a fused circuit-switcher has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses, if any, as well as indications which could be provided by tripping devices, may give an indication on the type of fault current and its approximate value.

In the case of a tripping operation initiated apparently without melting any fuse, a proper cold resistance measurement of the fuses is the minimal precaution before putting them back in service. If a relay is able to provide information on the fault level and the fault duration, the resulting point should be at least 20 % below the minimum melting curve of the fuses to consider that they can still be maintained in service.

9.109 Comparison of performances of fused circuit-switchers with performances of switch-fuse combinations and circuit-breakers

Fused circuit-switchers provide intermediate performances between switch-fuse combinations (according to the relevant IEC standard) and circuit-breakers (according to the relevant IEC standard). Tables 3 and 4 give comparisons of the main features.

Table 3 – Comparison between switch-fuse combination and fused circuit-switcher

	Switch-fuse combination	Fused circuit-switcher
Protection settings	Choice of fuse and optional external device	Choice of fuse and external device
Strikers	Basic	Optional
Transfer current	Relevant, and limiting applications	Not relevant
Take-over current	Relevant, if tripping unit	Basic
NOTE On transformer protection applications, the expected TRVs below $I_{transfer}$ are usually compatible with switch specifications.		

Table 4 – Comparison between fused circuit-switcher and circuit breaker

	Fused circuit-switcher	Circuit-breaker
Protection settings	Choice of fuse and external device	External device
Strikers	Optional	Not relevant
Take-over current	Basic	Not relevant
Fault current limitation	YES	NO
Reclosing capability	NO, if fuse operates	YES, at any current

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.

The enquirer should determine, for example, if the fused circuit-switcher described is to include the fuse-links.

10.3 Information with tenders

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

The manufacturer's instruction manual should at least provide the rated values and the following information:

a) the list of the fuse-links to be used in the fused circuit-switcher (required in 6.104), from which the type of fuses used in the device when tested is selected;

b) filling fluid (type and amount), where applicable;

c) the relevant information, concerning the fuses mentioned above, for the extension of the type test validity, i.e.:

– length and diameter;

- rated current (4.6 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);
- power dissipation (6.5.3 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);
- derating (6.5.3 of IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014);
- operating Joule integral (4.13 of IEC 60282-1:2009);
- cut-off current (4.12 of IEC 60282-1:2009).

11 Transport, storage, installation, operating instructions and maintenance

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

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 fused circuit-switcher, they should be temporarily removed while the unit is installed.

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 with the following addition.

Any known chemical and environmental impact hazards should be identified in the fused circuit-switcher instruction manual.

Annex A
(informative)

Applicability of the rated take-over current test duty

A.1 Problem formulation

This document for fused circuit-switchers does not consider a type test to verify the "transfer current breaking capacity", as in the fuse-switch combination standard.

The fault breaking capacity of the circuit-switcher alone is demonstrated as a take-over current by a three-phase test at rated voltage in the test conditions of T30 (IEC 62271-100:2008, IEC 62271-100:2008/AMD1:2012 and IEC 62271-100:2008/AMD2:2017). The test current is the rated take-over current I_{rto}. It is required in 5.103 that the rated take-over current ensures the proper breaking capability with any fuse providing melting characteristics lower than those of the fuses used to demonstrate the highest rated continuous current.

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. Under such an assumption, it could be feared that the two remaining phases should be cleared by the circuit-switcher with conditions not clearly addressed by this document.

The purpose of this annex is to review the extent of applications that this take-over current test covers, considering the characteristics of the fuses and protection relays used in the fused circuit-switcher.

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 circuit-switcher can be opened by any tripping device. There is no reason for concern.

A.2 Background

In this document, the take-over current performance is demonstrated on a three-phase fault current, with a three-phase breaking capacity test. It is required that the maximum fuse melting time-current characteristic is kept below the point (rated take-over current I_{rto} / minimum opening time T_m).

Take-over current is defined by the IEC 60282-1:2009 and IEC 60282-1:2009/AMD1:2014 without considering differences between melting characteristics of the three fuses. The demonstrated rated value I_{rto} is based on the slowest acceptable fuse characteristic. The second phases clear $0{,}866 \times I_{rto}$.

In IEC 62271-105:2012, the 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.

If introducing the possibility of fuses with different characteristics, then one can consider a fault current, higher than the rated take-over current, which would lead to a first fuse to melt

(on a fast curve) and then second fuses melting with an additional delay such that a relay could have tripped the circuit-switcher before. This situation is not covered by the type test. Second phases could be cleared by the circuit-switcher with a current higher than 0,866 × I_{rto}.

Technical developments in this annex investigate the limits of such situation.

A.3 Terms, definitions and symbols

For the purposes of this annex, the following terms, definitions and symbols apply.

I_{rto} rated three-phase take-over current; it is also the fault-breaking capacity of the circuit-switcher as demonstrated by the type test

I_p prospective three-phase short-circuit current corresponding to a particular application

I_1 short-circuit current in the three phases, before interruption in the first pole

I_2 short-circuit current in the second and third pole after interruption in the first pole

NOTE $I_1 = I_p$ and $I_2 = I_p \times \sqrt{3}/2$.

I_{sup} the current above which there is no required delay time for the protection relays

Am application margin factor: ratio between the rated three phase take-over current of the circuit-switcher and the maximum fuse melting current of the fuses for a time equal to the minimum opening time of the circuit-switcher (see Figure A.1)

T_m minimum opening time of the circuit-switcher

t_r minimum protection operating time – it may depend on the value of the prospective current (protection curve) – if several protections are installed (maximum current relay, differential relay, Buchholz relay, arc detection device), the operating time of the fastest protection is considered

t_1 pre-arcing time of the first fuse to melt (first pole) when the current is not interrupted by the circuit-switcher

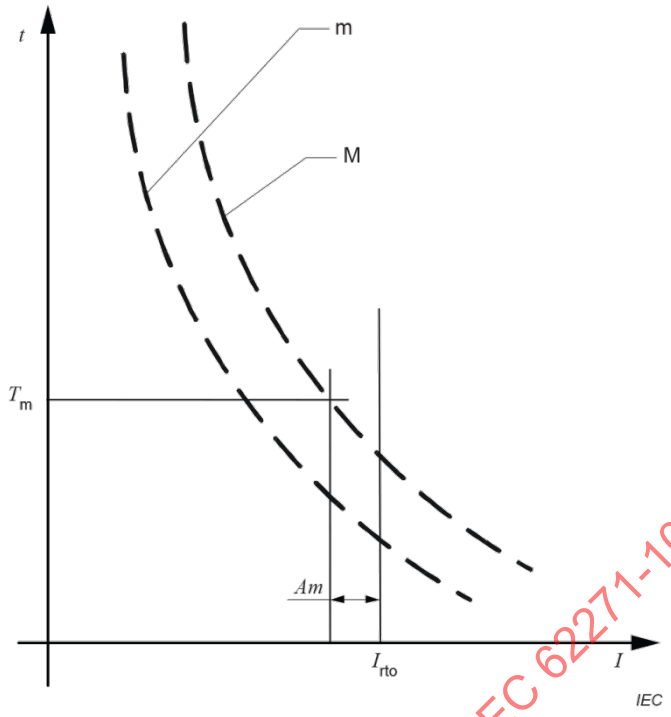
t_2 pre-arcing time of the second fuse to melt (second pole) when the current is not interrupted by the circuit-switcher

α slope coefficient of the pre-arcing time/current characteristic of the fuses

C parameter of the pre-arcing time/current characteristic of the fuses

x current margin between the slowest and fastest fuse characteristics

NOTE Parameters α, C and x are those used in IEC 62271-105.



Key

M slow melting time-current characteristic of the fuse

m fast melting time-current characteristic of the fuse

Figure A.1 – Visualization of the application margin for a given fuse

A.4 Assumptions about the fuse melting process

A.4.1 General

Assumptions are the same as those used in IEC 62271-105:2012.

A.4.2 First phase

In the zone of interest, a straight line in a log-log diagram approximates the pre-arcing time/current characteristic of the fuse, then for the fast fuse:

$$I_1^{\alpha} \times t_1 = C \tag{A.1}$$

where

I_1 is the RMS value of the prospective current;

t_1 is the pre-arcing time on the "fast" fuse characteristic.

A.4.3 Second phase

The two other fuses have a slower characteristic; the melting current is augmented by a factor (1 + x); so the pre-arcing characteristic is

$$[I/(1+x)]^{\alpha} \times t = C$$

but the current is equal to I_1 in the period [0, t_1] and to I_2 in the period [t_1, t_2]; t_2 being the final melting time of the fuse 2.

NOTE This is conservative since the fact the current does not fall immediately from I_1 to I_2 when arcing initiated in the first fuse is disregarded; this leads to an over-estimation of t_2.

It is assumed that the melting process of the second fuse is governed by the equation:

$$[I_1/(1+x)]^{\alpha} \times t_1 + [I_2/(1+x)]^{\alpha} \times (t_2 - t_1) = C \quad \text{(A.2)}$$

A.4.4 Modelling of the "application margin"

By definition,

$$[(I_{rto}/Am)/(1+x)]^{\alpha} \times T_m = C \quad \text{(A.3)}$$

This makes a link between the rated take-over current of the circuit-switcher (I_{rto}) and the fuse characteristics.

A.5 Mathematical expression of the application requirements

A.5.1 General

Given a particular prospective current, here it is determined in which conditions the duties of the first and second poles to clear are covered by the type test. The practical analysis and synthesis of these mathematical conditions is made in Clause A.6.

A.5.2 First pole-to-clear

Any current larger than I_{rto} shall be interrupted by the fuse and not by the circuit-switcher: the sum of minimum opening time and the minimum protection operating time shall be higher than the pre-arcing time of a slow fuse (maximum pre-arcing time characteristic of the fuses).

$$T_m + t_r(I_p) \geq C \times [I_p/(1+x)]^{\alpha} \text{ for } I_p > I_{rto} \quad \text{(A.4)}$$

Since $t_r(I_p)$ is necessarily ≥ 0, a sufficient condition is that the relation is already satisfied with t_r = 0. Then, using Formula (A.3) to make the link with the "application margin" (Am), the condition becomes:

$$T_m \geq T_m / Am^{\alpha} \quad \text{(A.5)}$$

that is true for $Am \geq 1$ (which is mandatory).

A.5.3 Second pole-to-clear

A.5.3.1 General

The current cleared by the second pole should not be larger than $I_{rto} \times \sqrt{3}/2$ since this is the current cleared in the second pole-to-clear during the type test. The limiting case is when the prospective current is such that arcing in the second fuse begins at the moment of contact separation in the circuit-switcher.

Two cases are to be considered.

A.5.3.2 Opening of the circuit-switcher triggered by the fuse striker

The limiting case corresponds to:

$$T_m = t_2 - t_1 \tag{A.6}$$

This is when the maximum extra time needed by the second fuse for melting is equal to the opening time of the circuit-switcher: arcing begins simultaneously in the second fuse and in the circuit-switcher. If the prospective current is smaller than the one corresponding to this situation, the circuit-switcher might have to interrupt the current on the second pole. This is no problem if this situation is covered by the type test, that is, if the prospective current corresponding to the limiting case is smaller than the demonstrated interrupting capability of the circuit-switcher (I_{rto}).

Using and combining Formulas (A.1), (A.2), (A.3), (A.5) and (A.6), one obtains in the limiting case,

$$\frac{I_p}{I_{rto}} = \frac{1}{Am} \times \frac{\left[(1+x)^{\alpha} - 1\right]^{1/\alpha}}{0{,}866 \times (1+x)} \text{ should be} \leq 1 \tag{A.7}$$

NOTE 0,866 = √3/2.

A.5.3.3 Opening of the circuit-switcher triggered by a protection relay

The limiting case is when:

$$T_m + t_r = t_2 \tag{A.8}$$

This is when the maximum total time needed by the second fuse for melting is equal to the opening time of the circuit-switcher, augmented by the protection operating time since the opening is triggered by the protection; then, arcing begins simultaneously in the second fuse and in the circuit-switcher.

If the relay has a time dependent curve, both members of Formula (A.8) depend on the prospective current I_p. Therefore, one has to verify that it is on the safe side for any prospective current of concern.

$$T_m + t_r(I_p) \geq t_2(I_p) \tag{A.9}$$

The condition (A.9) shall be checked within a narrow range of prospective currents:

– Lower limit: for prospective currents smaller then I_{rto}, there is no problem because the case is covered by the type test.

– Upper limit: since $t_r(I_p)$ is necessarily non-negative and also because $t_2(I_p)$ is a decreasing function of I_p, the condition (A.9) is automatically verified for prospective currents higher than the prospective current corresponding to:

  $T_m = t_2(I_p)$.

  This current is called I_{sup}.

Since $t_r(I_p)$ and $t_2(I_p)$ are both decreasing functions of I_p, a sufficient condition is that

$$t_r(I_{sup}) \geq t_2(I_{to}) - T_m \tag{A.10}$$

Note that if $I_{sup} < I_{rto}$, the condition (A.10) is always verified.

Formula (A.10) is the key formula for the application: it determines the minimum protection operating time in order to cover the application.

One needs to express the relationship $t_2(I_p)$:

Using Formulas (A.1) and (A.2), one obtains:

$$t_2 = \frac{C}{I_p^{\alpha}} \times \left\{ \left[\frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} \right] + 1 \right\} \quad \text{(A.11)}$$

This equation can be particularized for finding I_{sup}, expressing that for this value of the prospective current, $t_2 = T_m$ and using Formula (A.3) to make the link with the application margin Am:

$$\frac{I_{sup}}{I_{rto}} = \frac{1}{Am \times (1+x)} \times \left[\frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} + 1 \right]^{1/\alpha} \quad \text{(A.12)}$$

Finally, using Formula (A.3) relating I_{rto} with C and T_m, one derives the formula that will be of practical use to calculate the minimum protection operating time in the range [I_{rto}, I_{sup}]:

$$t_r \geq T_m \times \left\{ \frac{1}{Am^{\alpha} \times (1+x)^{\alpha}} \times \left[1 + \frac{(1+x)^{\alpha}-1}{0{,}866^{\alpha}} \right] - 1 \right\} \quad \text{(A.13)}$$

It can be seen in this equation that increasing the application margin factor (Am) may relieve the need for having a time delay on the protection.

A.6 Analysis

A.6.1 Applications with fuse strikers

If the fused circuit-switcher is equipped with fuse striker-tripping mechanisms, the condition (A.7) should be verified.

Assuming that the opening operation under action of the striker is not significantly slower than under action of opening release, and that the initiation comes from the melting of the fuse-link, the actual duration between the beginning of the fault and the separation of contacts is always longer than the minimum opening time T_{min} given in 5.103. This results in an application margin larger than 1 for any fused circuit-switcher tripped by a striker.

Table A.1 – Minimum application margin Am according to fuse characteristic

Am	α			
x	**5**	**4**	**3**	**2**
0,30	1,084	1,037	0,943	0,738
0,20	1,042	0,980	0,866	0,638
0,15	1,006	0,934	0,808	0,570
0,10	0,951	0,866	0,726	0,481
0,05	0,850	0,749	0,594	0,352

From Formula (A.7), one can derive a minimum application margin as a function of the fuse characteristics x and α. See Table A.1.

It can be seen that an application margin factor of 1 is sufficient.

As a reminder, conditions used for the transfer current in IEC 62271-105:2012 (switch-fuse combinations) are x equal to 0,13 and α equal to 4. Such conditions are therefore covered in this document without a dedicated type test.

A.6.2 Applications with protection relays

Conditions (A.4) and (A.13) apply.

Condition (A.13) allows for the definition of the minimum protection time delay as a function of the application margin, for specific values of the fuse characteristics; see Table A.2.

Table A.2 – Minimum protection time delay

Row	Min t_r/T_m	Am	x	α
1	3,111	0,75	0,13	4
2	0,301	1,00	0,13	4
3	-0,008	1,07	0,13	4
4	0,403	1,00	0,2	4
5	-0,006	1,09	0,2	4

The first row illustrates that application margin factors < 1 would need a dedicated time delay to ensure correct performance.

The requirement of this standard for $Am \geq 1$ clears this point. By this, condition (A.4) is also verified.

For usual applications:

– with Am = 1, one can see (rows 2 and 4) that a protection time delay, up to 0,5 $T_{m,}$ should be required to ensure complete coverage of the cases studied here;

– with $Am \geq$ 1,1, there is no more need for a specific protection time delay.

Current range for which the protection operating time is necessary: relation (A.12) provides I_{sup}/I_{rto} for the case Am = 1, for typical fuse characteristics. See Table A.3.

Table A.3 – Examples of possible need for time delay

Row	I_{sup}/I_{rto}	Am	x	α
1	1,068	1,00	0,13	4
2	1,082	1,00	0,13	5
3	1,088	1,00	0,2	4
4	1,139	1,00	0,5	5

One observes that, if the minimum protection operating time applies in the current range from 100 % up to 120 % of the rated take-over current of the circuit-switcher, there is no need for an application margin > 1.

A.7 Conclusions

The transfer current, as defined for combinations, is covered in this document by the rated take-over current and the associated type test.

When using high rating fuses, with curves very close to the maximum allowed in the fused circuit-switcher, a minimum operating time, up to half the minimum opening time of the circuit-switcher, may be needed on the protection chain to prevent exceptional situations from occurring.

Annex B
(informative)

Particular conditions existing in certain countries

According to Czech regulation (Act No. 458/2000 Coll., on the conditions for entrepreneurial activities and the performance of stateadministration in energy industries and on an amendment to certain acts ("Energy Act"), as amended by later legislative acts and regulations) the nominal voltages given in Table B.1 are used in AC three-phase systems in the Czech Republic.

Table B.1 – Voltages used in the Czech Republic

Highest voltage for equipment (kV)	Nominal system voltage (kV)
25	22
38,5	35

For these systems, the insulation levels given in Table B.2 apply.

Table B.2 – Rated insulation levels for voltage ratings of Table B.1

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across isolating distance	Common value	Across isolating distance
25	50	60	95	110
			125	145
38,5	80	90	155	175
			180	210

Bibliography

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

[2] IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

[3] IEC 62271-201, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

[4] IEEE C37.016, *IEEE Standard for AC High Voltage Circuit Switchers rated 15.5 kV through 245 kV*

[5] IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

[6] IEC/TR 62655, *Tutorial and application guide for high-voltage fuses*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À HAUTE TENSION –

Partie 107: Circuits-switchers à fusibles pour courant alternatif de tension assignée supérieure à 1 kV et jusqu'à 52 kV inclus

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La Norme internationale IEC 62271-107 a été établie par le sous-comité 17A: Appareils de connexion, du comité d'études 17 de l'IEC: Appareillage haute tension.

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) les modifications techniques introduites par la deuxième édition de l'IEC 62271-1 sont appliquées, lorsqu'elles sont pertinentes;
b) la TTR assignée est supprimée et la TTR est maintenant traitée comme un paramètre d'essai, comme dans l'IEC 62271-100;

c) le terme "courant thermique" n'est plus employé; le courant permanent assigné est lié aux éléments de remplacement installés, et les valeurs doivent être fournies par le constructeur ainsi que la liste des éléments de remplacement acceptables; pour les besoins des essais, le courant continu assigné le plus élevé est indiqué dans la liste, en lieu et place du terme "valeur de courant thermique maximal assignée" à des fins de cohérence avec l'IEC 62271-105;

d) les séries d'essais d'établissement et de coupure sont des essais de type indépendants (certains peuvent être omis si l'appareil de coupure a été validé en tant qu'interrupteur de charge). Cependant, TD_{lt0} et TD_{llow} sont conservés sous forme de séquence car ils sont liés à la même valeur assignée (I_{t0});

e) une distinction est désormais faite entre les exigences formulées pour remplir la fonction attendue d'un circuit-switcher à fusibles, et celles uniquement pertinentes lorsque la fonction est assurée par un appareil autonome. L'objectif est d'éviter la duplication ou les conflits d'exigences avec une norme traitant des 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/1216/FDIS	17A/1227/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Cette norme doit être lue conjointement avec l'IEC 62271-1:2017, à laquelle elle se réfère et qui est applicable sauf indication contraire. Afin de simplifier l'indication des exigences correspondantes, la numérotation des articles et paragraphes utilisée est la même que celle de l'IEC 62271-1. Les amendements à ces articles et paragraphes reprennent la même numérotation, et les paragraphes supplémentaires sont numérotés à partir de 101.

Une liste des conditions particulières existant dans certains pays est donnée à l'Annexe B.

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 "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

Les sectionneurs de terre faisant partie intégrale d'un circuit-switcher sont couverts par l'IEC 62271-102 [1][1].

L'installation sous enveloppe, le cas échéant, est couverte soit par l'IEC 62271-200 [2], soit par l'IEC 62271-201 [3].

1 Les nombres entre crochets se réfèrent à la Bibliographie.

APPAREILLAGE À HAUTE TENSION –

Partie 107: Circuits-switchers à fusibles pour courant alternatif de tension assignée supérieure à 1 kV et jusqu'à 52 kV inclus

1 Domaine d'application

La présente partie de l'IEC 62271 s'applique aux circuits-switchers à fusibles à manœuvre tripolaire conçus avec des tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV, pour utilisation sur des réseaux alternatifs triphasés de fréquence 50 Hz ou 60 Hz.

Ils peuvent être soit conçus sous forme d'appareils autonomes, soit intégrés dans un ensemble d'appareillage.

Ils sont destinés à être utilisés dans des circuits ou des applications qui ne nécessitent qu'une endurance mécanique et électrique normale. De telles applications couvrent, par exemple, la protection des transformateurs HT/BT, mais excluent les circuits de distribution en lignes ou en câbles ainsi que les circuits de moteurs et de bancs de condensateurs.

Les conditions de défaut de court-circuit avec de faibles courants, jusqu'au courant d'intersection assigné du circuit-switcher à fusibles, sont gérées par des dispositifs complémentaires (percuteurs, relais, etc.), correctement mis en œuvre, déclenchant le circuit-switcher. Les fusibles limiteurs de courant sont intégrés de manière à assurer que le pouvoir de coupure en court-circuit du dispositif est supérieur à celui du circuit-switcher seul.

NOTE 1 Dans le présent document, le mot "fusible" est utilisé pour désigner soit le fusible, soit l'élément de remplacement, quand le sens général du texte ne comporte aucune ambiguïté.

NOTE 2 Il existe d'autres circuits-switchers: voir référence [4].

Les dispositifs qui exigent une manœuvre manuelle dépendante ne sont pas couverts par le présent document.

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).

IEC 60282-1:2009, *Fusibles à haute tension – Partie 1: Fusibles limiteurs de courant*
IEC 60282-1:2009/AMD1:2014

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-100:2008, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif*
IEC 62271-100:2008/AMD1:2012
IEC 62271-100:2008/AMD2:2017

IEC 62271-103:2011, *Appareillage à haute tension – Partie 103: Interrupteurs pour tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

IEC 62271-105:2012, *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*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions 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 IEC Electropedia dresse la liste des termes définis dans l'IEC 60050 [5].

3.1 Termes généraux et définitions

Le paragraphe 3.1 de l'IEC 62271-1:2017 est applicable.

3.2 Ensembles d'appareillage

Le paragraphe 3.2 de l'IEC 62271-1:2017 est applicable.

3.3 Parties d'ensemble

Le paragraphe 3.3 de l'IEC 62271-1:2017 est applicable.

3.4 Appareils de connexion

Le paragraphe 3.4 de l'IEC 62271-1:2017 est applicable avec les compléments suivants.

3.4.101
circuit-switcher
dispositif de manœuvre mécanique adapté pour établir, supporter et interrompre des courants dans des conditions normales de réseaux et pour interrompre des courants de défaut spécifiés qui sont généralement inférieurs à son courant de courte durée admissible

Note 1 à l'article: Il existe d'autres circuits-switchers; voir référence [4].

3.4.102
circuit-switcher à fusibles
combinaison, dans un seul dispositif ou une seule fonction, d'un circuit-switcher et de fusibles, un fusible étant placé en série avec chaque pôle du circuit-switcher destiné à être raccordé à un conducteur de phase

Note 1 à l'article: le terme "un fusible" n'interdit pas l'utilisation de plusieurs éléments de remplacement en parallèle.

3.4.103
socle d'un circuit-switcher à fusibles
circuit-switcher à fusibles sans les éléments de remplacement installés

3.5 Parties d'appareillage

Le paragraphe 3.5 de l'IEC 62271-1:2017 est applicable avec les compléments 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 shunt
déclencheur alimenté par une source de tension

Note 1 to entry: 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 d'un appareillage

Le paragraphe 3.6 de l'IEC 62271-1:2017 est applicable avec les compléments suivants.

3.6.101
manœuvre indépendante manuelle
<d'un appareil mécanique de connexion> manœuvre à accumulation d'énergie dans laquelle l'énergie provient de l'énergie manuelle accumulée et libérée en une seule manœuvre continue, de telle sorte que la vitesse et la force de la manœuvre sont indépendantes de l'action de l'opérateur

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

3.6.102
manœuvre à accumulation d'énergie
<d'un appareil mécanique de connexion> manœuvre effectuée au moyen d'énergie emmagasinée dans le mécanisme lui-même avant l'achèvement de la manœuvre et suffisante pour achever la manœuvre dans des conditions prédéterminées

Note 1 à l'article: Ce type de manœuvre peut être subdivisé suivant:

1) Le mode d'accumulation de l'énergie (ressort, poids, etc.);
2) La provenance de l'énergie (manuelle, électrique, etc.);
3) Le mode de libération de l'énergie (manuel, électrique, etc.).

[SOURCE: IEC 60050-441: 2000, 441-16-15]

3.7 Grandeurs caractéristiques

Le paragraphe 3.7 de l'IEC 62271-1:2017 est applicable avec les compléments 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 dont le courant peut emprunter 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 présumé
<pour un pôle d'un appareil de connexion ou un fusible> courant présumé évalué à l'instant correspondant au début du phénomène de coupure

Note 1 à l'article: Des spécifications concernant l'instant du début du phénomène de coupure sont données dans les publications particulières. Pour les appareils mécaniques de connexion ou les fusibles, cet instant est habituellement choisi comme l'instant du début d'un arc au cours d'une coupure.

[SOURCE: IEC 60050-441:2000, 441-17-06]

3.7.105
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]

3.7.106
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]

3.7.107
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]

3.7.108
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]

3.7.109
courant de court-circuit avec fusible
courant de court-circuit conditionnel lorsque l'appareil limiteur de courant est un fusible

[SOURCE: IEC 60050-441:2000, 441-17-21]

3.7.110
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]

3.7.111
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]

3.7.112
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]

3.7.113
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]

3.7.114
tension transitoire de rétablissement présumée
<d'un circuit> tension transitoire de rétablissement 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 dont le courant peut emprunter 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]

3.7.115
durée d'ouverture
<d'un appareil mécanique de connexion> intervalle de temps entre l'instant spécifié de début de la manœuvre d'ouverture et l'instant de la séparation des contacts d'arc sur tous les pôles

Note 1 à l'article: Pour la manœuvre d'un déclencheur, on considère que l'instant de début est l'instant où l'alimentation est appliquée au déclencheur

[SOURCE: IEC 60050-441:2000, 441-17-36 modifiée – la note initiale a été supprimée et la note actuelle ajoutée.]

3.7.116
durée minimale d'ouverture initiée par un fusible
<d'un circuit-switcher à fusibles> durée prise entre l'instant où l'arc commence dans le fusible et l'instant où les contacts d'arc se sont séparés dans tous les pôles

Note 1 à l'article: Cette définition s'applique uniquement pour les circuits-switchers à fusibles équipés d'un déclenchement par percuteur.

3.101 Fusibles

3.101.1
socle
partie fixe d'un fusible munie de contacts et de bornes

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

3.101.2
percuteur
dispositif mécanique faisant partie d'un élément de remplacement qui, lors du fonctionnement du fusible, libère l'énergie exigée pour faire fonctionner d'autres appareils, des dispositifs indicateurs ou pour effectuer un verrouillage

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

3.101.3
courant coupé limité
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]

3.101.4
I^2t
intégrale de Joule
intégrale du carré du courant pour un intervalle de temps donné:

$$I^2t = \int_{t_2}^{t_1} i^2 \mathrm{d}t$$

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 A^2s.

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

4 Conditions normales et spéciales de service

L'Article 4 de l'IEC 62271-1:2017 est applicable.

5 Caractéristiques assignées

5.1 Généralités

Le paragraphe 5.1 de l'IEC 62271-1:2017 est applicable avec les compléments suivants et les exceptions suivantes.

En complément des caractéristiques assignées énumérées dans l'IEC 62271-1:2017, les caractéristiques assignées ci-dessous s'appliquent:

a) courant coupé assigné en court-circuit;

b) courant établi assigné en court-circuit;

c) courant d'intersection assigné.

5.2 Tension assignée (U_r)

Le paragraphe 5.2 de l'IEC 62271-1:2017 est applicable avec le complément suivant.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, sa tension assignée est celle de l'ensemble.

5.3 Niveau d'isolement assigné (U_d, U_p, U_s)

Le paragraphe 5.3 de l'IEC 62271-1:2017 est applicable avec les compléments suivants.

NOTE La tension de tenue aux chocs de manœuvre assignée U_s n'est pas spécifiée pour la plage de tension du présent document.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, son niveau d'isolement assigné est celui de l'ensemble.

5.4 Fréquence assignée (f_r)

Le paragraphe 5.4 de l'IEC 62271-1:2017 n'est pas applicable.

Les valeurs de fréquence assignée pour les circuits-switchers à fusibles sont 50 Hz et 60 Hz.

NOTE 1 Les valeurs proposées pour la fréquence assignée sont en accord avec celles des fusibles.

NOTE 2 Dans quelques cas, les caractéristiques assignées d'un circuit-switcher à fusibles utilisé à 60 Hz sont différentes de ses caractéristiques assignées à 50 Hz.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, sa fréquence assignée est celle de l'ensemble.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 est applicable avec le complément suivant.

Le courant permanent assigné caractérise le circuit-switcher à fusibles complet, y compris les éléments de remplacement. Voir 6.104.

5.6 Courant de courte durée admissible assigné (I_k)

Le paragraphe 5.6 de l'IEC 62271-1:2017 n'est pas applicable.

5.7 Valeur de crête du courant admissible assignée (I_p)

Le paragraphe 5.7 de l'IEC 62271-1:2017 n'est pas applicable.

5.8 Durée de court-circuit assignée (t_k)

Le paragraphe 5.8 de l'IEC 62271-1:2017 n'est pas applicable.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le paragraphe 5.9 de l'IEC 62271-1:2017 est applicable.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, sa tension d'alimentation assignée des circuits auxiliaires et de commande est celle de l'ensemble.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le paragraphe 5.10 de l'IEC 62271-1:2017 est applicable.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, sa fréquence d'alimentation assignée des circuits auxiliaires et de commande est celle de l'ensemble.

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 est applicable.

Lorsque le circuit-switcher à fusibles fait partie d'un ensemble d'appareillage, sa pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue est celle de l'ensemble.

5.101 Courant coupé assigné en court-circuit (I_{sc})

Le courant coupé assigné en court-circuit est le courant de court-circuit présumé le plus élevé que le circuit-switcher à fusibles doit être capable de couper, dans les conditions d'utilisation et de comportement prescrites dans le présent document, dans un circuit ayant une tension de rétablissement à fréquence industrielle correspondant à la tension assignée du circuit-switcher à fusibles et ayant une tension transitoire de rétablissement présumée égale à celle spécifiée dans le paragraphe des essais de type (voir 7.101.2.9).

Comme la performance de coupure en court-circuit dépend des caractéristiques des fusibles installés, le manuel d'utilisation du circuit-switcher à fusibles ne doit énumérer que les fusibles ayant un courant coupé maximal assigné supérieur ou égal à I_{sc}. Le courant coupé assigné en court-circuit est exprimé par la valeur efficace de sa composante alternative.

Les courants coupés assignés doivent être sélectionnés dans la série R10 comme suit:

8 – 10 – 12,5 – 16 – 20 – 25 – 31,5 – 40 – 50 – 63 – 80 – 100 kA

NOTE Il est reconnu que l'impédance série du circuit-switcher à fusibles ou l'intervention rapide des fusibles ou du circuit-switcher à fusibles produit parfois l'un et/ou l'autre des effets ci-dessous:

a) une réduction du courant de court-circuit à une valeur sensiblement au-dessous de la valeur attendue;

b) une intervention tellement rapide que l'onde de courant de court-circuit est déformée.
C'est pourquoi le terme "courant présumé" est utilisé pour définir les performances d'établissement et de coupure.

5.102 Courant établi assigné en court-circuit (I_{ma})

Le courant établi assigné en court-circuit est la crête de courant présumée la plus élevée que le circuit-switcher à fusibles doit être capable d'établir, dans les conditions d'utilisation et de comportement définies dans la présente norme, dans un circuit ayant une tension à fréquence industrielle correspondant à la tension assignée du circuit-switcher à fusibles. Il doit être au moins égal à 2,5 fois (50 Hz) ou 2,6 fois (60 Hz) la valeur du courant coupé assigné en court-circuit.

NOTE 1 Voir aussi la note du 5.101.

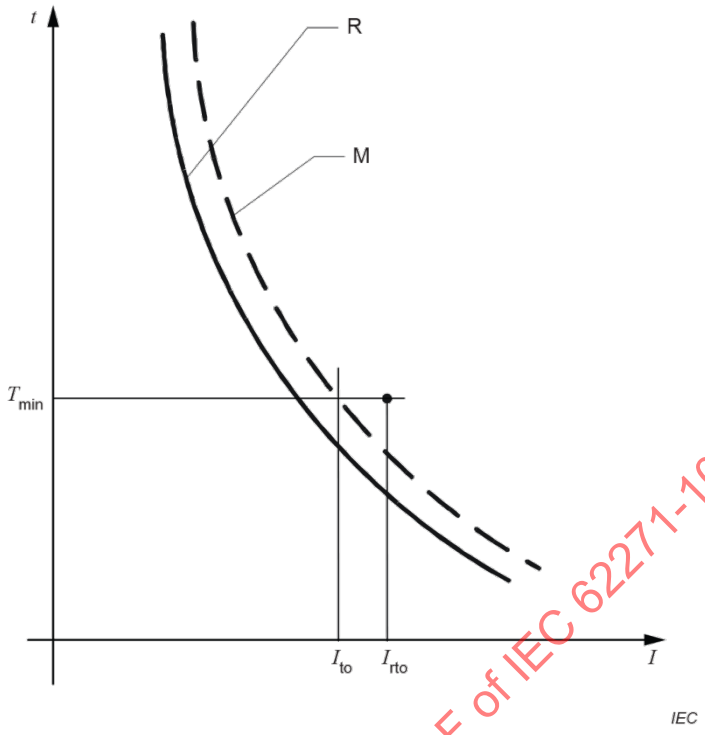
NOTE 2 Un facteur de crête élevé, éventuellement associé à une longue constante de temps du réseau, n'influe pas sur les performances du circuit-switcher à fusibles en conditions de court-circuit, grâce au comportement de limitation du courant des fusibles. Ceci est indiqué dans l'IEC 60282-1:2009/AMD1:2014, 5.1.2.

5.103 Courant d'intersection assigné (I_{to})

Le courant d'intersection assigné est la valeur efficace maximale du courant d'intersection que le circuit-switcher dans le circuit-switcher à fusibles est capable d'interrompre, dans les conditions d'utilisation et de comportement spécifiées dans le présent document, dans un circuit ayant une tension de rétablissement à fréquence industrielle correspondant à la tension assignée du circuit-switcher à fusibles et ayant une tension transitoire de rétablissement présumée égale à la valeur spécifiée.

La valeur assignée déclarée par le constructeur doit être supérieure à la valeur du courant d'intersection, déterminée selon la Figure 1, donnée par le type de fusible dans la liste ayant la courbe de fusion la plus élevée dans la zone de temps autour de la durée d'ouverture minimale sous l'action du déclencheur d'ouverture T_{min} (voir 3.7.116).

NOTE La valeur de la durée d'ouverture minimale sous l'action du déclencheur d'ouverture T_{min} est déterminée pendant les essais mécaniques (voir 7.102.2).



Légende

R	caractéristique de temps-courant de fusion moyenne du fusible
M	caractéristique temps-courant de fusion lente du fusible
T_{min}	durée d'ouverture minimale sous l'action du déclencheur d'ouverture
I_{rto}	courant d'intersection assigné du circuit-switcher à fusibles
I_{to}	courant d'intersection pour le fusible considéré

Figure 1 – Caractéristiques pour déterminer le courant d'intersection

6 Conception et construction

6.1 Exigences pour les liquides utilisés dans les circuits-switchers à fusibles

Le paragraphe 6.1 de l'IEC 62271-1:2017 est applicable.

6.2 Exigences pour les gaz utilisés dans les circuits-switchers à fusibles

Le paragraphe 6.2 de l'IEC 62271-1:2017 est applicable.

6.3 Raccordement à la terre des circuits-switchers à fusibles

Le paragraphe 6.3 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.4 Equipements et circuits auxiliaires et de commande

Le paragraphe 6.4 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 est applicable.

6.6 Manœuvre à accumulation d'énergie

Le paragraphe 6.6 de l'IEC 62271-1:2017 est applicable.

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 est applicable.

6.8 Organes de commande à manœuvre manuelle

Le paragraphe 6.8 de l'IEC 62271-1:2017 est applicable.

6.9 Fonctionnement des déclencheurs

Le paragraphe 6.9 de l'IEC 62271-1:2017 est applicable avec le complément suivant.

Les circuits-switchers à fusibles doivent être équipés d'au moins un déclencheur shunt d'ouverture.

6.10 Indication de la pression/du niveau

Le paragraphe 6.10 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.11 Plaques signalétiques

Le paragraphe 6.11 de l'IEC 62271-1:2017 est applicable avec les modifications suivantes.

Le Tableau 9 dans l'IEC 62271-1:2017 est remplacé par le Tableau 1 ci-après.

Tableau 1 – Informations de la plaque signalétique

(1)	Symbole (2)	Unité (3)	Circuit-switcher à fusibles (4)	Dispositif de manœuvre (5)	Condition particulière pour le marquage (6)
Constructeur			X	Y	Seulement si le dispositif est indépendant du circuit-switcher à fusibles et/ou de constructeur différent
Désignation du type			X	Y	Seulement si le dispositif est indépendant du circuit-switcher à fusibles et/ou de constructeur différent
Référence du manuel d'utilisation			X	X	
Numéro de série			X	Y	Seulement si le dispositif est différent de celui du circuit-switcher à fusibles
Année de fabrication			X		
Numéro de la présente norme			X		
Tension assignée	U_r	kV	X		
Tension de tenue de courte durée à fréquence industrielle assignée	U_d	kV	X		
Tension de tenue aux chocs de foudre assignée	U_p	kV	X		
Fréquence assignée	f_r	Hz	X		
Eléments de remplacement utilisables et courant permanent assigné avec fusibles	Marquage obligatoire: "I_r avec éléments de remplacement: voir manuel d'utilisation"		X		
Pression de remplissage pour la manœuvre	P_{rm}	MPa		Y	Le cas échéant
Tension(s) d'alimentation assignée(s) des circuits auxiliaires et de commande Spécifier courant continu/courant alternatif (avec fréquence assignée)	U_a	V		Y	Le cas échéant
Température minimale et maximale de l'air ambiant		°C	Y		Si différente de −5 °C et/ou 40 °C
Type et masse du fluide (liquide ou gaz) pour l'isolement	M_f	kg	Y		S'il existe
Masse (y compris tout fluide)	M	kg	Y		- Si supérieure à 300 kg - Aucun marquage s'il s'agit d'une partie d'un ensemble

X: le marquage de ces valeurs est obligatoire.

Y: le marquage de ces valeurs est obligatoire, soumis aux conditions de la colonne (6).

NOTE Les symboles de la colonne (2) sont autorisés à la place des termes de la colonne (1). Quand les termes de la colonne (1) sont utilisés, le mot "assigné" est facultatif.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, il est nécessaire de faire figurer uniquement les caractéristiques non communes au sein de l'ensemble sur la plaque signalétique du circuit-switcher à fusibles. Ces caractéristiques sont:

– le numéro du présent document;
– les éléments de remplacement utilisables et le courant permanent assigné avec fusibles;
– la pression de remplissage pour la manœuvre.

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 est applicable.

6.13 Indication de position

Le paragraphe 6.13 de l'IEC 62271-1:2017 est applicable.

6.14 Degrés de protection procurés par les enveloppes

Le paragraphe 6.14 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le paragraphe 6.15 de l'IEC 62271-1:2017 est applicable.

6.16 Étanchéité au gaz et au vide

Le paragraphe 6.16 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.17 Étanchéité des systèmes de liquide

Le paragraphe 6.17 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.18 Risque de feu (inflammabilité)

Le paragraphe 6.18 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.19 Compatibilité électromagnétique (CEM)

Le paragraphe 6.19 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.20 Émission de rayons X

Le paragraphe 6.20 de l'IEC 62271-1:2017 est applicable.

6.21 Corrosion

Le paragraphe 6.21 de l'IEC 62271-1:2017 est applicable aux appareils autonomes.

Pour les circuits-switchers à fusibles intégrés dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.22 Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre

Le paragraphe 6.22 de l'IEC 62271-1:2017 est applicable aux circuits-switchers à fusibles ayant leur propre confinement de fluide.

Pour les circuits-switchers à fusibles partageant du fluide dans des ensembles d'appareillage, la norme de l'appareillage est applicable.

6.101 Exigences de base pour les fusibles

Les fusibles doivent se conformer à l'IEC 60282-1:2009 et à l'IEC 60282-1:2009/AMD1:2014.

6.102 Tringlages entre le(s) percuteur(s) des fusibles et le déclencheur du circuit-switcher

Les tringlages entre le(s) percuteur(s) des fusibles, s'il y en a, et le déclencheur du circuit-switcher doivent être conçus de telle sorte que le circuit-switcher fonctionne convenablement, en conditions de défaut aussi bien triphasé que monophasé, aux caractéristiques minimales et maximales d'un type de percuteur donné (moyen ou fort), indépendamment du mode de fonctionnement de ce percuteur (thermique, à ressort ou à charge explosive). Les caractéristiques des percuteurs sont données dans le Tableau 11 de l'IEC 60282-1:2009 et de l'IEC 60282-1:2009/AMD1:2014.

6.103 Conditions de faible courant de défaut (conditions de longue durée de préarc des fusibles)

Le circuit-switcher à fusibles équipé d'un déclenchement par percuteur doit être conçu de manière à fonctionner de façon satisfaisante dans des conditions de fonctionnement du percuteur.

Cela est réalisé si les conditions a) et b) suivantes sont satisfaites:

a) La coordination entre le circuit-switcher et les fusibles est assurée par l'une des conditions 1), 2) ou 3) ci-dessous:

   1) La durée d'ouverture du circuit-switcher provoquée par le percuteur des fusibles doit être plus courte que la durée d'arc maximale que les fusibles peuvent supporter. Cette durée d'arc est au moins de 0,1 s selon l'IEC 60282-1:2009 et l'IEC 60282-1:2009/AMD1:2014.

      NOTE Des essais sont spécifiés au 7.6.3 de l'IEC 60282-1:2009 pour vérifier que le temps d'arc admissible des fusibles est au minimum de 100 ms.

   2) Les fusibles installés dans le circuit-switcher à fusibles ont subi avec succès tous les essais de coupure, depuis leur courant assigné en court-circuit jusqu'à la valeur équivalant au courant minimal de fusion des fusibles (c'est-à-dire des fusibles à coupure intégrale).

   3) Le déclenchement thermique des percuteurs des fusibles entraîne la coupure du courant du circuit-switcher avant apparition de l'arc dans ceux-ci, pour tous les courants inférieurs à I_3 (courant minimal de coupure du fusible conformément à l'IEC 60282-1:2009 et à l'IEC 60282-1:2009/AMD1:2014).

b) Dans ces circonstances, la montée en température du circuit-switcher à fusibles ne diminue pas ses performances comme il est démontré dans l'essai décrit au 6.104 de l'IEC 62271-105:2012.