AS IEC 62271.105:2015

IEC 62271-105, Ed.2.0 (2012)

AS IEC 62271.105:2015

Australian STANDARD

High-voltage switchgear and control gear

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

STANDARDS Australia

This Australian Standard® was prepared by Committee EL-007, Industrial Switchgear and Controlgear. It was approved on behalf of the Council of Standards Australia on 12 December 2014.
This Standard was published on 28 January 2015.

The following are represented on Committee EL-007:

- Australian Industry Group
- Ausgrid
- Energy Networks Association
- Engineers Australia
- University of New South Wales

This Standard was issued in draft form for comment as DR AS IEC 62271.105:2014.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard®

High-voltage switchgear and control gear

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

First published as AS IEC 62271.105:2015.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 978 1 74342 957 0

PREFACE

This Standard was prepared by the Standards Australia Committee EL-007, Industrial Switchgear and Controlgear.

The objective of this Standard is to specify requirements for three-pole units for public and industrial distribution systems, which are functional assemblies of switches including switch-disconnectors and current limiting fuses.

This Standard is identical with, and has been reproduced from IEC 62271-105 Ed.2.0 (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*.

This Standard is to be read in conjunction with IEC 62271-1 (which has been adopted as AS 62271.1) and to which it refers and which is applicable, unless otherwise specified in this Standard. In order to simplify the indication of corresponding requirements, the same numbering of clauses is used as in IEC 62271-1. Variations to these clauses are given under the same numbering, while additional subclauses are numbered from 101.

As this Standard is reproduced from an International Standard, the following applies:

(a) In the source text 'this part of IEC 62271' should read 'this Australian Standard'.

(b) A full point substitutes for a comma when referring to a decimal marker.

References to International Standards should be replaced by references to Australian Standards, as follows:

Reference to International Standard		*Australian Standard*	
IEC		AS	
62271	High-voltage switchgear and controlgear	62271	High-voltage switchgear and controlgear
62271-1*	Part 1: Common specifications	62271.1*	Part 1: Common specifications
62271-100	Part 100: Alternating-current circuit-breakers	62271.100	Part 100: High-voltage alternating-current circuit-breakers (IEC 62271-100, Ed.1.2 (2006) MOD)
62271-102	Part 102: Alternating current disconnectors and earthing switches	62271.102	Part 102: Alternating current disconnectors and earthing switches (IEC 62271-102, Ed.1.0 (2003) MOD)

Only normative references that have been adopted as Australian or Australian/New Zealand Standard have been listed.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the annex to which they apply. A 'normative' annex is an integral part of a Standard, whereas an 'informative' annex is only for information and guidance.

* The source text specifically references the 2007 edition of IEC 62271-1. IEC released an Amendment to that edition in 2011 and incorporated it into IEC 62271-1 Ed.1.1 (2011). The IEC incorporated edition was adopted as AS 62271.1—2012. For the application of this Standard, the Australian adoption of IEC 62271-1 is recommended.

CONTENTS

Page

Page

NOTES

AUSTRALIAN STANDARD

High-voltage switchgear and control gear

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

1 General

1.1 Scope

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

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

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

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

In this standard, the word “combination” is used for a combination in which the components constitute a functional assembly. Each association of a given type of switch and a given type of fuse defines one type of combination.

In practice, different types of fuses may be combined with one type of switch, which give several combinations with different characteristics, in particular concerning the rated currents. Moreover, for maintenance purposes, the user should know the types of fuses that can be combined to a given switch without impairing compliance to the standard, and the corresponding characteristics of the so-made combination.

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

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

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

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

Fuses are covered by IEC 60282-1.

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

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

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

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

IEC 62271-1:2007, *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 62271-102:2001, *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*

2 Normal and special service conditions

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

3 Terms and definitions

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

3.1 General terms

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

3.2 Assemblies of switchgear and controlgear

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

3.3 Parts of assemblies

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

3.4 Switching devices

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

3.4.101
switch-fuse combination
combination of a three-pole switch with three fuses provided with strikers, the operation of any striker causing all three poles of the switch to open automatically

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

3.4.102
switch-fuse combination base
combination base
switch-fuse combination without fuse-links mounted

3.4.103
switch-fuse
switch in which one or more poles have a fuse in series in a composite unit

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

3.4.104
fuse-switch
switch in which a fuse-link or a fuse-carrier with fuse-link forms the moving contact

[SOURCE: IEC 60050-441:2007, 441-14-17]

3.4.105
switch-disconnector
switch which, in the open position, satisfies the isolating requirements specified for a disconnector

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

3.4.106
release operated combination
combination in which automatic opening of the switch can also be initiated by either an over-current release or a shunt release

3.5 Parts of switchgear and controlgear

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

3.5.101
release (of a mechanical switching device)
device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

[SOURCE: IEC 60050-441:2007, 441-15-17]

3.5.102
over-current release

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

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

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

3.5.103
shunt release
release energized by a source of voltage

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

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

3.6 Operation

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

3.6.101
independent manual operation (of a mechanical switching device)
stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

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

3.6.102
stored energy operation (of a mechanical switching device)
operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

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

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

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

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

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

3.7 Characteristic quantities

Subclause 3.7 of IEC 62271-1:2007 is applicable, 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, 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, 441-17-02]

3.7.103
maximum prospective peak current (of an a.c. 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, 441-17-04]

3.7.104
prospective breaking current (for a pole of a switching device or a fuse)
prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

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

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

3.7.105
breaking current (of a switching device or a fuse)
current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[SOURCE: IEC 60050-441:2007, 441-17-07]

3.7.106
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, 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, 441-17-10]

3.7.108
cut-off current
let-through current (of a fuse)
maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

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

[SOURCE: IEC 60050-441:2007, 441-17-12]

3.7.109
transfer current (striker operation*)*
$I_{\mathbf{transfer}}$
value of the three-phase symmetrical current at which the fuses and the switch exchange breaking duties

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

3.7.110
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, 441-17-16]

3.7.111
minimum take-over current (of a release-operated combination)
current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to

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

b) the minimum pre-arcing time of the fuse

3.7.112
maximum take-over current (of a release-operated combination)
current determined by the point of intersection of the time-current characteristics of the fuse and the switch corresponding to:

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

b) the maximum pre-arcing time of the fuse

3.7.113
fused short-circuit current
conditional short-circuit current when the current limiting device is a fuse

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

3.7.114
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, 441-17-24]

3.7.115
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, 441-17-25]

3.7.116
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, 441-17-26]

3.7.117
power-frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

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

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

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

[SOURCE: IEC 60050-441:2007, 441-17-29]

3.7.119
fuse-initiated opening time (of the switch-fuse combination)
time taken from the instant at which arcing in the fuse commences to the instant when the arcing contacts of the switch of the combination have separated in all poles (including all elements influencing this time)

3.7.120
release-initiated opening time (of the switch-fuse combination)
release-initiated opening time is defined according to the tripping method as stated below with any time-delay device forming an integral part of the switch adjusted to a specified setting:

a) for a switch tripped by any form of auxiliary power, interval of time between the instant of energizing the opening release, the switch being in the closed position, and the instant when the arcing contacts have separated in all poles;

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

3.7.121
minimum release-initiated opening time (of the switch-fuse combination)
release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its minimum setting

3.7.122
maximum release-initiated opening time (of the switch-fuse combination)
release-initiated opening time when the specified setting of any time-delay device forming an integral part of the switch is its maximum setting

3.7.123
break-time
interval of time between the beginning of the opening time of a mechanical switching device (or the pre-arcing time of a fuse) and the end of the arcing time

[SOURCE: IEC 60050-441:2007, 441-17-39]

3.7.124
arcing time (of a pole or a fuse)
interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

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

3.101 Fuses

3.101.1
reference list of fuses
list of fuses defined by the manufacturer for a given type of switch-fuse combination base, for which compliance to the present standard of all corresponding switch-fuse combinations is assessed

Note 1 to entry: This list can be updated. Conditions for extending the validity of the type tests are given in 6.105 and 8.102.

3.101.2
fuse-base
fuse mount
fixed part of a fuse provided with contacts and terminals

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

3.101.3
striker
mechanical device forming part of a fuse-link which, when the fuse operates, releases the energy required to cause operation of other apparatus or indicators or to provide interlocking

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

3.101.4
pre-arcing time
melting time
interval of time between the beginning of a current large enough to cause a break in the fuse-element(s) and the instant when an arc is initiated

[SOURCE: IEC 60050-441:2007, 441-18-21]

3.101.5
operating time
total clearing time
sum of the pre-arcing time and the arcing time

[SOURCE: IEC 60050-441:2007, 441-18-22]

3.101.6
arcing time (of a pole or a fuse)
interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

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

3.101.7
I^2t
Joule integral
integral of the square of the current over a given time interval:

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

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, 441-18-23]

4 Ratings

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

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

a) rated short-circuit breaking current,

b) rated transient recovery voltage,

c) rated short-circuit making current,

d) rated transfer current for striker operation,

e) rated take-over current for a release-operated combination.

4.1 Rated voltage (U_r)

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

4.2 Rated insulation level

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

4.3 Rated frequency (f_r)

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

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 applicable with the following addition:

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

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

4.4.2 Temperature rise

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

4.5 Rated short-time withstand current (I_k)

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

4.6 Rated peak withstand current (I_p)

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

4.7 Rated duration of short-circuit (t_k)

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

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.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 4.10 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.

4.101 Rated short-circuit breaking current

The rated short-circuit breaking current is the highest prospective short-circuit current which the combination shall be capable of breaking under the conditions of use and behaviour prescribed in this standard in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the combination and having a prospective transient recovery voltage equal to the rated value specified in 4.102.

The rated short-circuit breaking current is expressed by the r.m.s. value of its a.c. component.

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

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

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

a) a reduction of short-circuit current to a value appreciably below that which would otherwise be reached;

b) such rapid operation that the short-circuit current wave is distorted from its normal form. This is why the term "prospective current" is used when assessing breaking and making performances.

4.102 Rated transient recovery voltage

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

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

4.103 Rated short-circuit making current

The rated short-circuit making current is the highest prospective peak current which the combination 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 combination. It shall be 2,5 times (50 Hz) or 2,6 times (60 Hz) the value of the rated short-circuit breaking current.

NOTE See also the note in 4.101.

4.104 Rated transfer current (striker operation) ($I_{rtransfer}$)

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

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

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

5 Design and construction

5.1 Requirements for liquids in switch-fuse combinations

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

5.2 Requirements for gases in switch-fuse combinations

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

5.3 Earthing of switch-fuse combinations

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

5.4 Auxiliary and control equipment

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

5.5 Dependent power operation

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

Dependent manual operation is not allowed.

5.6 Stored energy operation

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

5.7 Independent manual or power operation (independent unlatched operation)

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

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

5.8 Operation of releases

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

5.9 Low- and high-pressure interlocking and monitoring devices

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

5.10 Nameplates

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

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

Table 1 – Nameplate markings

(1)	Abbreviation (2)	Unit (3)	Switch-fuse combination (4)	Operating device (5)	Condition for marking required (6)
Manufacturer			X	Y	Only if not integral with the combination and/or if manufacturers are different
Type designation			X	Y	Only if not integral with the combination and/or if manufacturers are different
Serial number			X	(Y)	Only if not integral with the combination and/or if manufacturers are different
Number of this standard			X		
Rated voltage	U_r	kV	X		
Rated lightning impulse withstand voltage	U_p	kV	X		
Rated frequency	f_r	Hz	X		
Rated normal current with fuses	See reference list		X		
Rated filling pressure for operation	P_{rm}	MPa		Y	When applicable
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_a	V		Y	When applicable
Year of manufacture			X		
Temperature class			Y		Different from –5 °C indoors –25 °C outdoors
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) may be used instead of the terms in column (1). When the terms in column (1) are used, the word “rated” need not appear.

5.11 Interlocking devices

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

5.12 Position indication

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

5.13 Degrees of protection provided by enclosures

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

5.14 Creepage distances for outdoor insulators

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

5.15 Gas and vacuum tightness

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

5.16 Liquid tightness

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

5.17 Fire hazard (flammability)

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

5.18 Electromagnetic compatibility (EMC)

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

5.19 X-ray emission

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

5.20 Corrosion

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

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

The linkages between the fuse striker(s) and the switch release shall be such that the switch operates satisfactorily under both three-phase and single-phase conditions at the minimum and maximum requirements of a given type of striker (medium or heavy) irrespective of the method of striker operation (spring or explosive). The requirements for strikers are given in IEC 60282-1.

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

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

a) time coordination between switch and fuse is provided by either 1), 2) or 3) below:

   1) the fuse-initiated opening time of the switch-fuse combination shall be shorter than the maximum arcing time the fuse can withstand as specified in IEC 60282-1,

      NOTE New tests have been introduced in IEC 60282-1 in order to assess that the maximum arcing withstand time of the fuse under long pre-arcing conditions is at least 100 ms.

   2) where the fuse manufacturer can show that the fuse has been satisfactorily proven at all values of breaking current from the rated maximum breaking current of the fuse down to the rated minimum melting current of the fuse in the combination (i.e. full range fuses) then the fuse-initiated opening time of the switch-fuse combination is deemed not relevant,

   3) where it can be shown that the thermal release of the fuse striker makes the switch clear the current before arcing in the fuse can occur, for all currents below I_3 (minimum breaking current of the fuse according to IEC 60282-1);

b) temperature rise under these conditions does not impair the performances of the combination as proven by the test described in 6.104.

6 Type tests

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

NOTE All tolerances are defined in Annex C.

6.1 General

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

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

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

Furthermore, it is understood that the fuses have been tested to the requirements of IEC 60282-1.

Type tests include:

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

For combinations, three groups of tests are involved:

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

In the case of a fuse-switch, the tests of IEC 62271-103 and the tests of 6.102 of this standard shall be carried out after replacing, as specified, the fuses with solid links of the same shape, dimension and mass as that of the fuses.

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

6.1.1 Grouping of tests

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

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

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 the type-test reports

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

6.2 Dielectric tests

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

6.2.9 Partial discharge tests

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

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

6.3 Radio interference voltage (r.i.v.) tests

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

6.4 Measurement of the resistance of circuits

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

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

6.5 Temperature-rise tests

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

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

6.6 Short-time withstand current and peak withstand current tests

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

6.7 Verification of the protection

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

6.8 Tightness tests

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

6.9 Electromagnetic compatibility tests (EMC)

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

6.10 Additional tests on auxiliary and control circuits

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

6.11 X-radiation test procedure for vacuum interrupters

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

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

6.101 Making and breaking tests

6.101.1 General

This clause contains four test duties:

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

6.101.2 Conditions for performing the tests

6.101.2.1 Condition of the combination before testing

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

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

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

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

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

6.101.2.2 Test frequency

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

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

6.101.2.3 Power factor

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

During the tests, the average value shall conform to the values given in 6.101.3.1, 6.101.3.2, 6.101.3.3 and 6.101.3.4.

6.101.2.4 Arrangement of test circuits

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

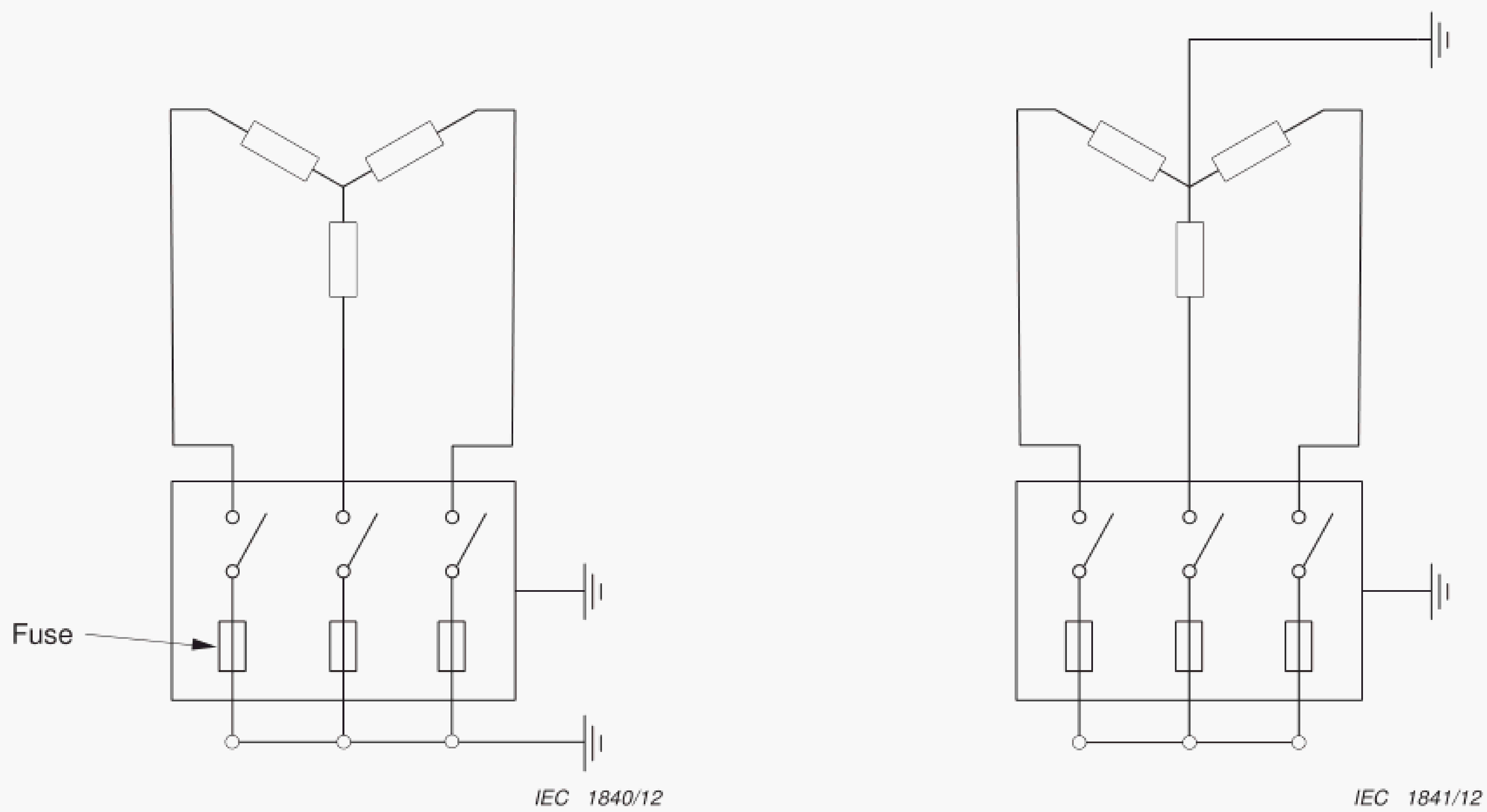


Figure 1a – Preferred earth point **Figure 1b – Alternative earth point**

Figure 1 – Arrangement of test circuits for test duties TD_{Isc} and TD_{IWmax}

For test duties $TD_{Itransfer}$ and TD_{Ito}, the combination shall be connected in a circuit as shown in Figures 2 and 3, respectively.

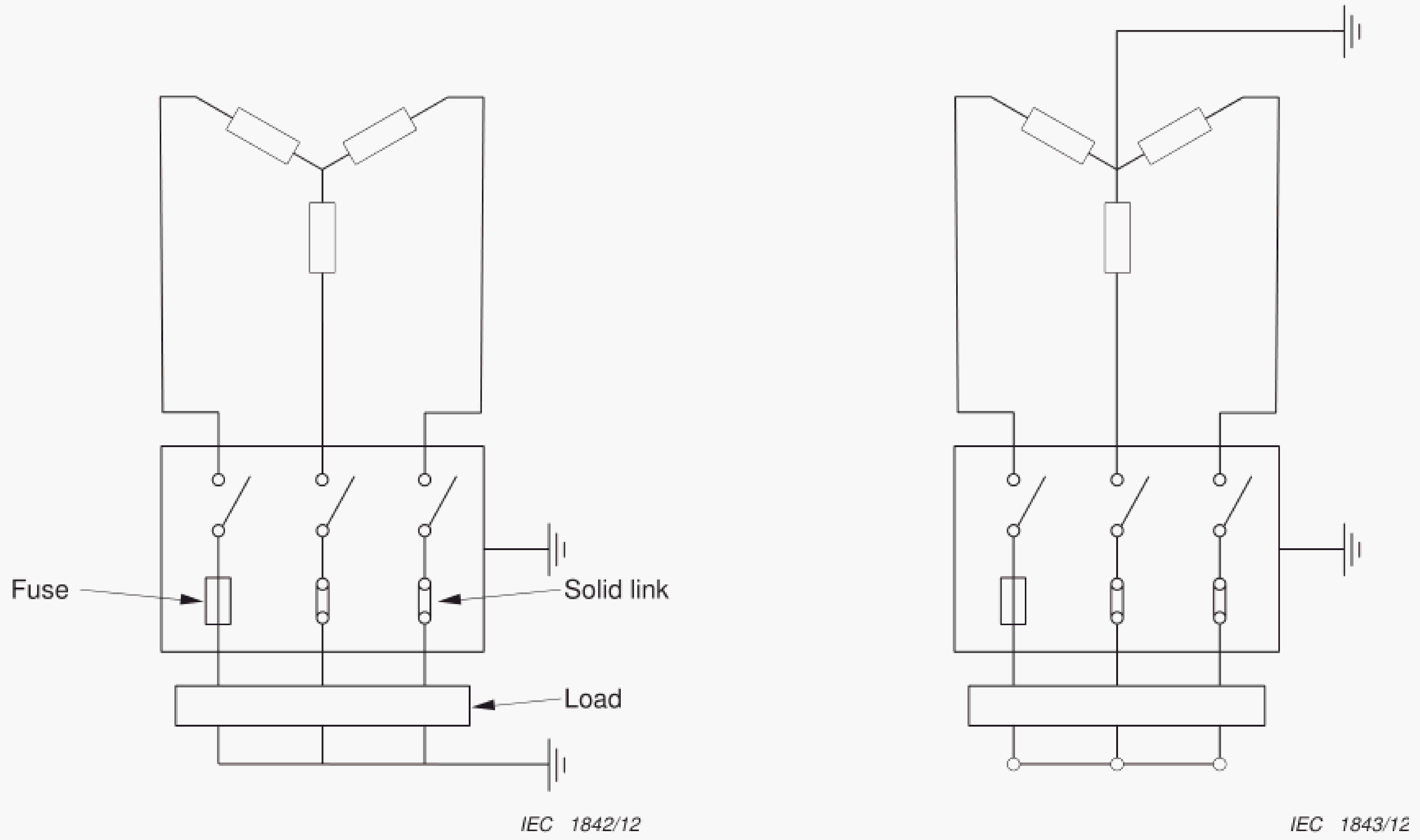


Figure 2a – Preferred earth point **Figure 2b – Alternative earth point**

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

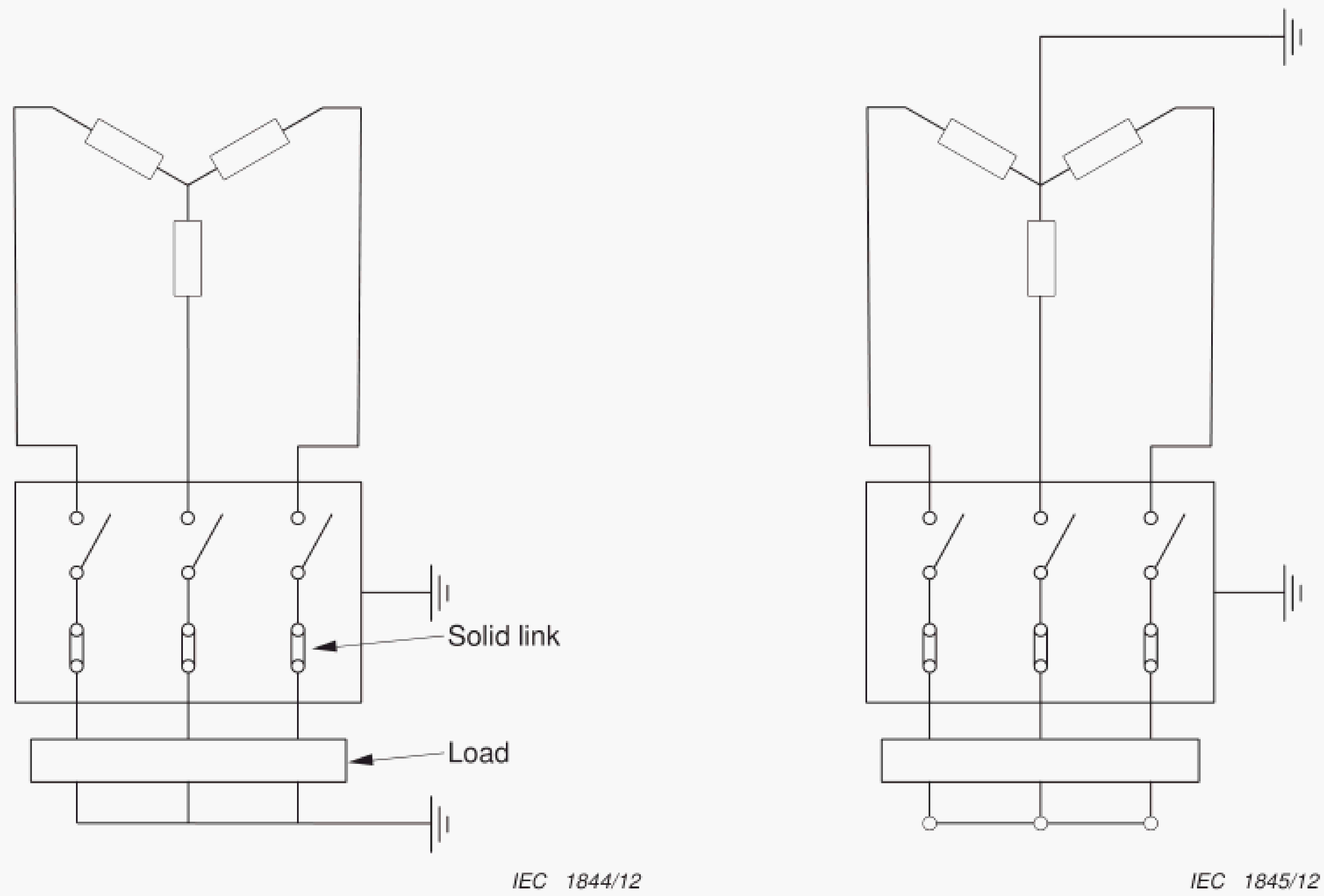


Figure 3a – Preferred earth point **Figure 3b – Alternative earth point**

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

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

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

6.101.2.5 Test voltage for breaking tests

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

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

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

The tolerance on the average value is ± 5 % of the specified value, and the tolerance on any phase to the average value is ± 20 %.

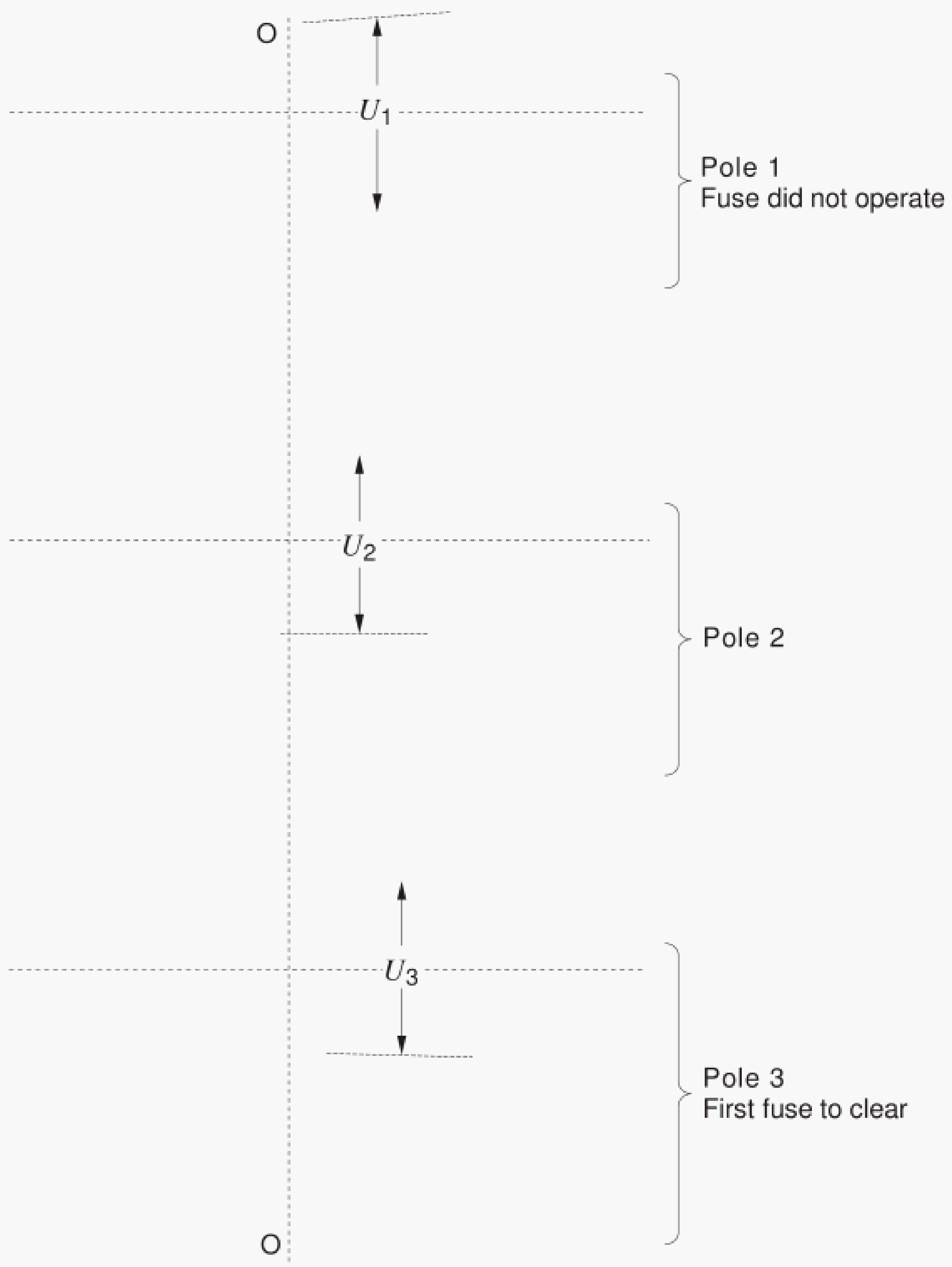
6.101.2.6 Power-frequency recovery voltage

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

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

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

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



Key

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

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

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

OO instant of opening of mechanical switching device

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

Figure 4 – Determination of power-frequency recovery voltage

6.101.2.7 Applied voltage before short-circuit making tests

The applied voltage (see 3.7.114) before the short-circuit making tests in test duties TD_{Isc} and TD_{IWmax} is the r.m.s. value of the voltage at the pole terminals immediately before the test.

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

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

6.101.2.8 Breaking current

For test duties TD_{Isc} and TD_{IWmax} the r.m.s. value of the a.c. component of the prospective short-circuit breaking current shall be measured one half-cycle after the initiation of the short-circuit in the prospective current test.

For test duties $TD_{Itransfer}$ and TD_{Ito} the breaking current shall be the r.m.s. value of the a.c. component measured at the initiation of arcing.

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

6.101.2.9 Transient recovery voltage

The prospective TRV of a test circuit shall be determined by such a method as will produce and measure the TRV wave without significantly influencing it and shall be measured at the terminals to which the combination will be connected with all necessary test-measuring devices, such as voltage dividers, included. Suitable methods are described in Annex F of IEC 62271-100:2008.

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 6.101.2.4.

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

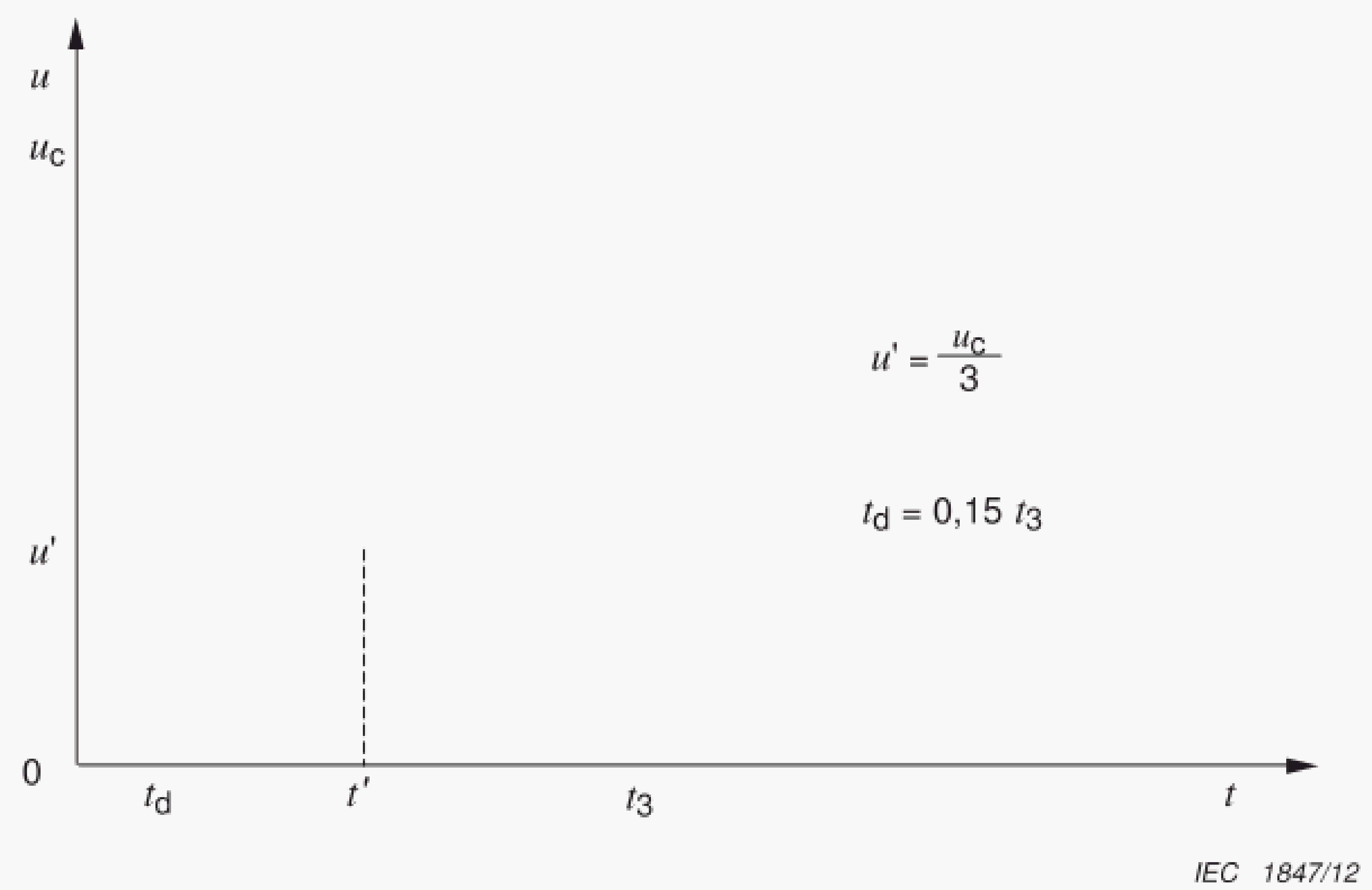


Figure 5 – Representation of a specified TRV by a two-parameter reference line and a delay line

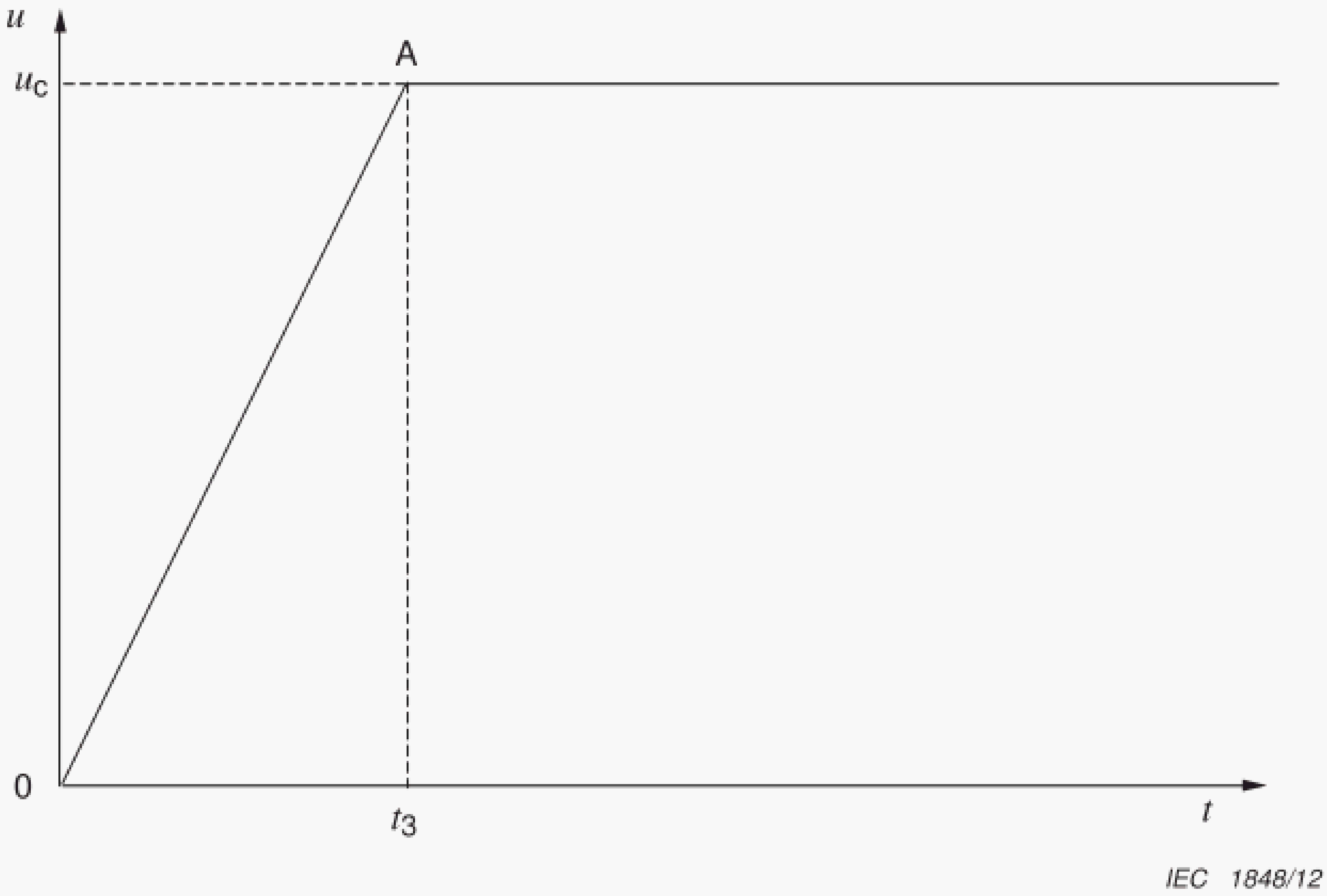


Figure 6 – Example of a two-parameter reference line for a TRV

The prospective 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;

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

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

6.101.3 Test-duty procedures

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

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

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

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

The applied voltage shall be in accordance with 6.101.2.7.

The power-frequency recovery voltage (see 6.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % of the specified value, and the tolerance on any phase to the average value is ± 20 %.

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

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

6.101.3.2 Test-duty TD_{IWmax} – Making and breaking tests at the maximum breaking I^2t

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

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

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

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

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

The applied voltage shall be in accordance with 6.101.2.7. For the breaking test of this test-duty, the operation shall be made with point-on-wave closure of the circuit so that current commences between 0 and 20 electrical degrees after voltage zero on any one phase.

The power-frequency recovery voltage (see 6.101.2.6) shall be equal to the rated voltage of the combination divided by $\sqrt{3}$. The tolerance on the average value is ± 5 % of the specified value, and the tolerance on any phase to the average value is ± 20 %.

The prospective transient recovery voltage shall be in accordance with 6.101.2.9 and the values specified in test-duty 2 of IEC 60282-1.

6.101.3.3 Test-duty $TD_{Itransfer}$ – Breaking tests at the rated transfer current

This test-duty is performed to prove the correct coordination between the switch and fuses in the current region where the breaking duty is transferred from the fuses to the switch (see 3.7.109).

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

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

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

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

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

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

a) the symmetrical component of the short-circuit breaking current of the supply circuit shall neither exceed the rated short-circuit breaking current of the combination nor be less than 5 % of this current;

b) the impedance of the supply circuit shall be between 12 % and 18 % of the total impedance of the test circuit for test-duty $TD_{Itransfer}$. If, due to limitations of the testing station, this condition cannot be met, the percentage may be lower, but it shall be ensured that the resulting prospective TRV is not less severe;

c) the prospective transient recovery voltage of the supply circuit under short-circuit conditions shall be in accordance with IEC 60282-1.

The power factor of the load circuit, determined in accordance with 6.101.2.3, shall be:

– between 0,2 to 0,3 lagging if the breaking current exceeds 400 A;

– between 0,3 to 0,4 lagging if the breaking current is equal to or less than 400 A.

The test voltage shall be in accordance with 6.101.2.5.

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

The prospective transient recovery voltage of the load circuit, for calibration purposes, shall be in accordance with 6.101.2.9 and Tables 2 or 3, as appropriate. A delay line is not specified.

Table 2 – Standard values of prospective TRV for test-duty $TD_{Itransfer}$ based on practice in Europe

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

Table 3 – Standard values of prospective TRV for test-duty $TD_{Itransfer}$ based on practice in the United States of America and Canada

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

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

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

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

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

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

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

The test current value corresponds to

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

b) the maximum operating time of the fuses of highest rated current.

See Figure 7.

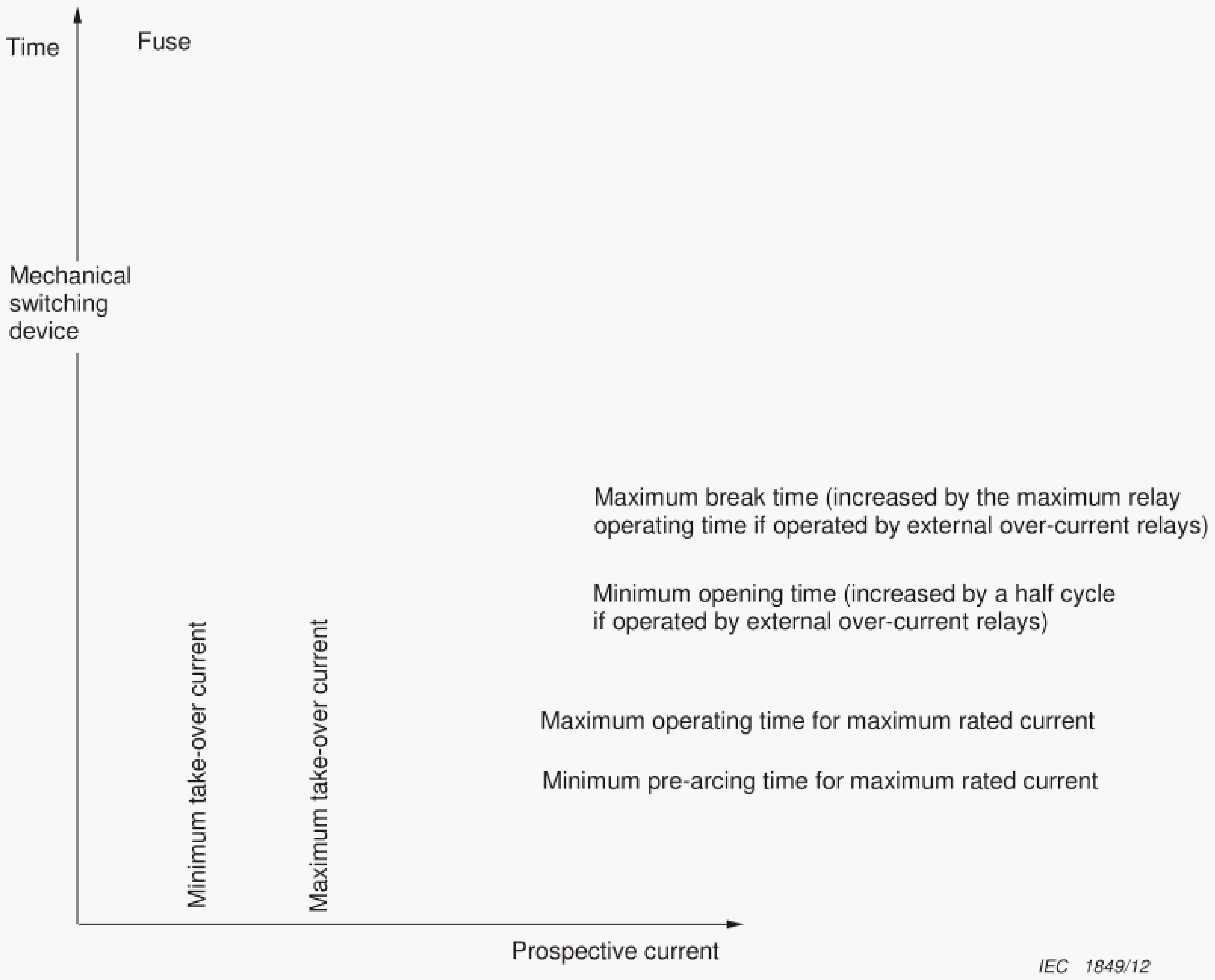


Figure 7 – Characteristics for determining take-over current

6.101.3.5 Summary of test parameters

A summary of the parameters to be used when performing test duties is given in Table 4.

Table 4 – Summary of test parameters for test duties

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

6.101.4 Behaviour of the combination during tests

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

During operation, the combination shall show neither signs of excessive distress nor phenomena that might endanger an operator.

From liquid-filled combinations there shall be no outward emission of flame, and the gases produced together with the liquid carried with the gases shall be allowed to escape in such a way as not to cause electrical breakdown.

For other types of combinations, flame or metallic particles such as might impair the insulation level of the combination shall not be projected beyond the boundaries specified by the manufacturer.

No significant leakage current is assumed to have flowed if the fuse wire defined in 6.101.2.4 is intact after the test.

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

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

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

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

6.101.5 Condition of the apparatus after testing

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

After performing each test-duty:

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

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

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

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

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

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

6.102 Mechanical operation tests

Tests of the trip linkages shall be performed as follows:

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

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

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

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

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

6.103 Mechanical shock tests on fuses

During the test of the trip linkages given in 6.102, two fuses shall be fitted in the two poles of the combination not fitted with the fuse striker simulating device for the three sets of 30 operations involved. Each of the two fuses used shall have the lowest rated current of the reference list. If this rating is listed with several fuse types, then the fuses used for the test shall be of different types.

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

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

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

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

6.104 Thermal test with long pre-arcing time of fuse

The test conditions are similar to the one used for the temperature-rise test (6.5 without measurement of temperature rise). However, the no-load voltage of the supply shall be sufficient to operate the striker.

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

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

The above test need not be repeated for alternative types of fuse having a stated lower peak body temperature than that tested.

The test is valid if

a) the striker and the switch have operated correctly,

b) there is no damage on the fuse as defined in 5.1.3 of IEC 60282-1:2009.

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

6.105 Extension of validity of type tests

6.105.1 Dielectric

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

6.105.2 Temperature rise

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

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

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

6.105.3 Making and breaking

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

a) any fuse considered shall comply with its standard (IEC 60282-1);

b) the same type of striker shall be fitted, i.e. medium or heavy in accordance with IEC 60282-1;

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, are not greater than those of the tested type similarly established;

d) for fuse-switches only, any change in fuse-link mass shall not invalidate breaking characteristics due to change in the mechanical operation (i.e. opening speed).

7 Routine tests

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

7.101 Mechanical operating tests

Operating tests shall be carried out to ensure that combinations 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 combinations open and close correctly when their operating devices are energized or under pressure. It shall also be verified that the operation will not cause any damage to the combinations. Fuses of maximum mass and dimensions shall be fitted for fuse-switch testing. For switch-fuse combinations, tests may be made without fuses.

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

a) under the conditions of 6.102 with the action of one fuse striker of minimum energy simulated: one opening operation on each phase.

Additionally, the following tests shall be performed where applicable:

b) at the specified maximum supply voltage and/or the maximum pressure of the compressed gas supply: five operating cycles;

c) at the specified minimum supply voltage and/or the minimum pressure of the compressed gas supply: five operating cycles;

d) if a combination can be operated by hand as well as by its normal electric or pneumatic operating device: five manually operated cycles;

e) for manually operated combinations only: ten operating cycles;

f) for release-operated combinations only, at rated supply voltage and/or rated pressure of the compressed gas supply: five operating cycles with a tripping circuit energized by the closing of the main contacts;

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

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

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

8 Guide for the selection of switch-fuse combinations

8.1 Selection of rated values

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

8.2 Continuous or temporary overload due to changed service conditions

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

8.101 Guide for the selection of switch-fuse combination for transformer protection

8.101.1 General

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

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

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

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

8.101.2 Rated short-circuit breaking current

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

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

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

$$I_{\mathrm{sc}} = \frac{100 I_{\mathrm{T}}}{Z}$$

where

I_{T} is the rated current of the transformer;

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

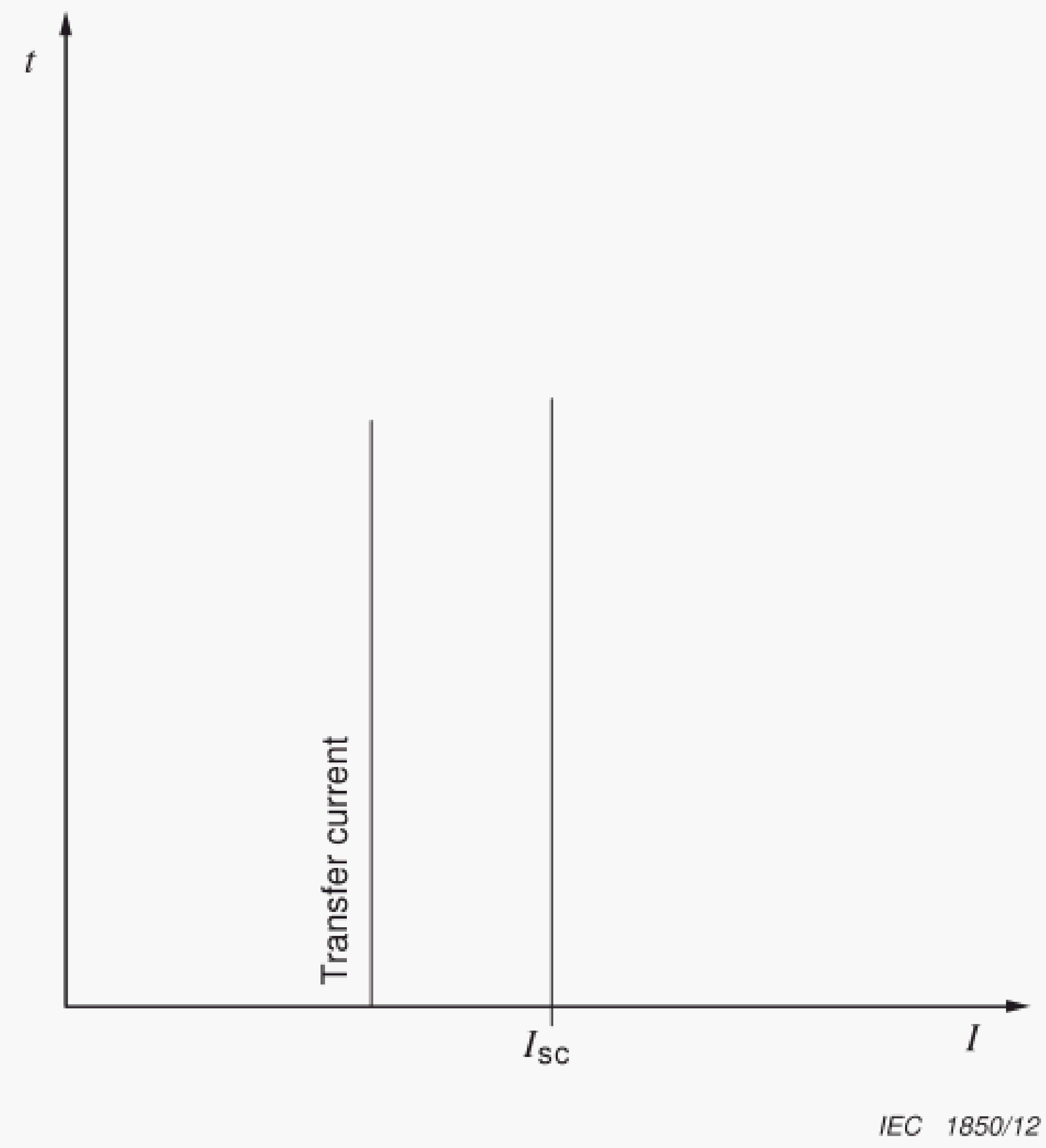


Figure 8 – Transfer current in relation to the primary fault current I_{SC} due to a solid short circuit in the transformer secondary terminal

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

An example is given in annex A.

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

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

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

8.102.1 General

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

8.102.2 Rated normal current

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

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

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

8.102.3 Low over-current performance

At values of fault current below the minimum breaking current of the fuses fitted in the combination, correct operation is assured by the ejection of one or more fuse strikers operating the switch tripping mechanism (and hence causing the switch to open) before the fuse has had time to be damaged by internal arcing (see 5.102). Additionally over-current relays could be used.

8.102.4 Transfer current

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

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

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

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

8.102.5 Take-over current

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

Relay behaviour and fuse characteristics should be such that take-over current is smaller than the maximum take-over current of the combination (see definition 3.7.112 and the test conditions in 6.101.3.4).

8.102.6 Extension of the validity of type tests

As it is recognized that it may well be impractical to test all combinations made of a combination base and fuses and to carry out repeat tests on combinations whenever the fuse is altered, this standard specifies conditions (see 6.105) whereby the validity of the temperature rise, making and breaking type tests may be extended to cover combinations other than that (those) tested.

8.103 Operation

a) The three fuses fitted in a given combination shall all be of the same type and current rating, otherwise the breaking performance of the combination could be adversely affected.

b) It is vital, for the correct operation of the combination, that the fuses are inserted with the strikers in the correct orientation.

c) When a switch-fuse has operated as a result of a three-phase fault, it is possible for

   1) only two out of the three fuses to have operated,

   2) all three fuses to have operated but for only two out of the three strikers to have ejected.

   Such partial operation of one fuse can occur under three-phase service conditions and is not to be considered abnormal.

d) Where a switch-fuse has operated without any obvious signs of a fault on the system, examination of the operated fuse or fuses may give an indication as to the type of fault current and its approximate value. Such an investigation is best carried out by the fuse manufacturer.

e) All three fuses shall be discarded and replaced if the fuse(s) in one or two poles of a combination has operated.

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

9 Information to be given with enquiries, tenders and orders

9.1 Information with enquiries and orders

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

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

9.2 Information with tenders

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

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

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

b) Filling medium (type and amount), when applicable.

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

- fuse length (6.105.2);
- fuse maximum rated current (6.105.2);
- fuse power dissipation (6.105.2);
- fuse derating (6.105.2);
- Joule integral (highest value of the fuse type used in 6.101.3.1 and 6.101.3.2).

10 Transport, storage, installation, operation and maintenance

Clause 10 of IEC 62271-1:2007 is applicable 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 switch-fuse unit, they should be temporarily removed while the unit is man-handled into position.

11 Safety

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

12 Influence of the product on the environment

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

Annex A
(informative)

Example of the coordination of fuses, switch and transformer

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

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

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

a) full load current is approximately 21 A;

b) permissible periodic overload is assumed to be 150 %, on the "–5 %" tapping of the transformer, i.e. approximately:

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

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

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

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

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

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

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

This list of fuses will have been drawn up by the switch-fuse manufacturer on the basis of appropriate type tests on the switch-fuse combination in accordance with this standard and by the application of its extension of validity clauses (see 8.102).

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

1) the fuse can withstand the 252 A magnetizing inrush current of the transformer for 0,1 s (Clause 5 a) of IEC/TR 60787:2007). He will normally do this by examining the fuse time-current characteristic, where the i.e. 252 A point at 0,1 s has a selectivity distance of 20 % to the time-current curve at this point, and/or consulting the fuse manufacturer.

2) the normal current rating of the switch-fuse combination when fitted with the fuses is adequate to allow for periodic overloading of the transformer up to 33 A in ambient air temperature conditions of 45 °C (Clause 5 b)1) of IEC/TR 60787:2007).

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

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

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

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

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

based on 5 % transformer impedance) is greater than the transfer current (see 3.7.109) of the combination when fitted with 40 A fuses. He will do this using the method explained in 8.102.3. Reference to Figure A.1 shows that the transfer current thus obtained is only 280 A, the fuse-initiated opening time of the switch being assumed to be 0,05 s for the purpose of this example.

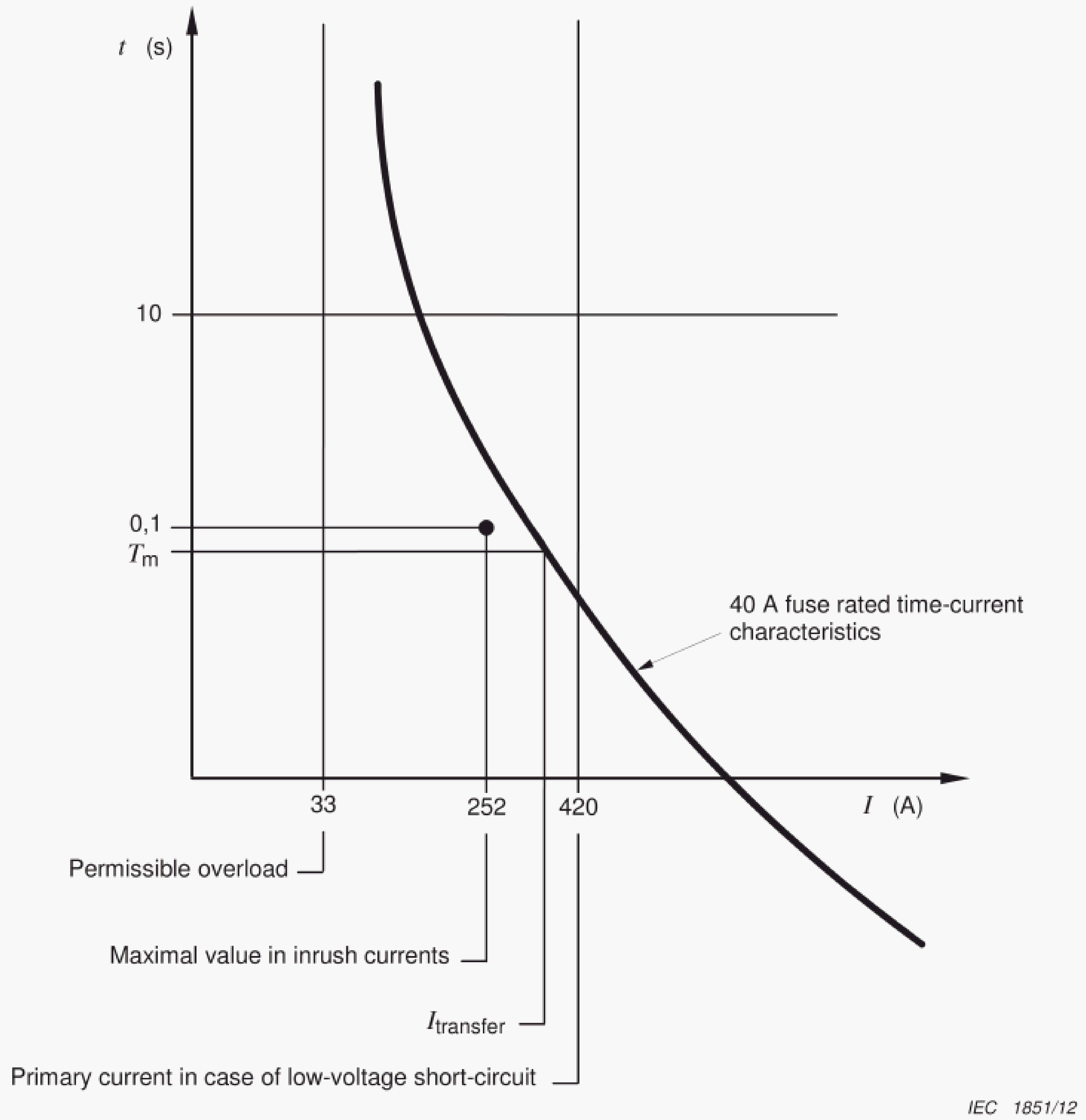


Figure A.1 – Characteristics relating to the protection of an 11 kV – 400 kVA transformer

5) the transfer current of the combination, when fitted with 40 A fuses, is less than its rated transfer current (see 4.104) which one can suppose to be 1 000 A.

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

NOTE This is usually the worst condition for discrimination.

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

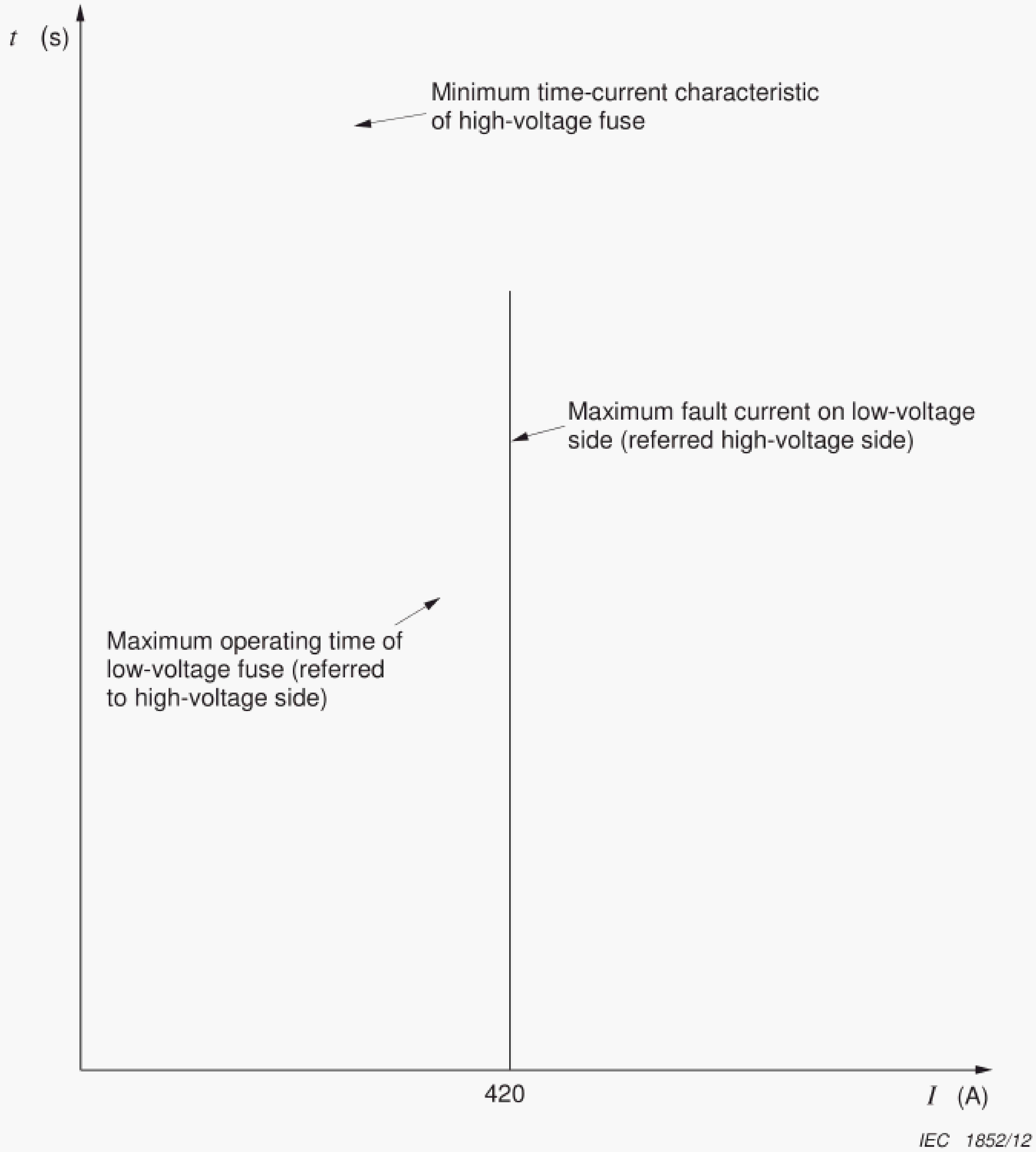


Figure A.2 – Discrimination between HV and LV fuses

Annex B
(normative)

Procedure for determining transfer current

B.1 Background

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

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

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

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

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

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 4.104 ensures that the fuses will melt before the switch-fuse combination can be opened by any tripping device. There is no reason for concern.

B.2 Mathematical determination of ΔT

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

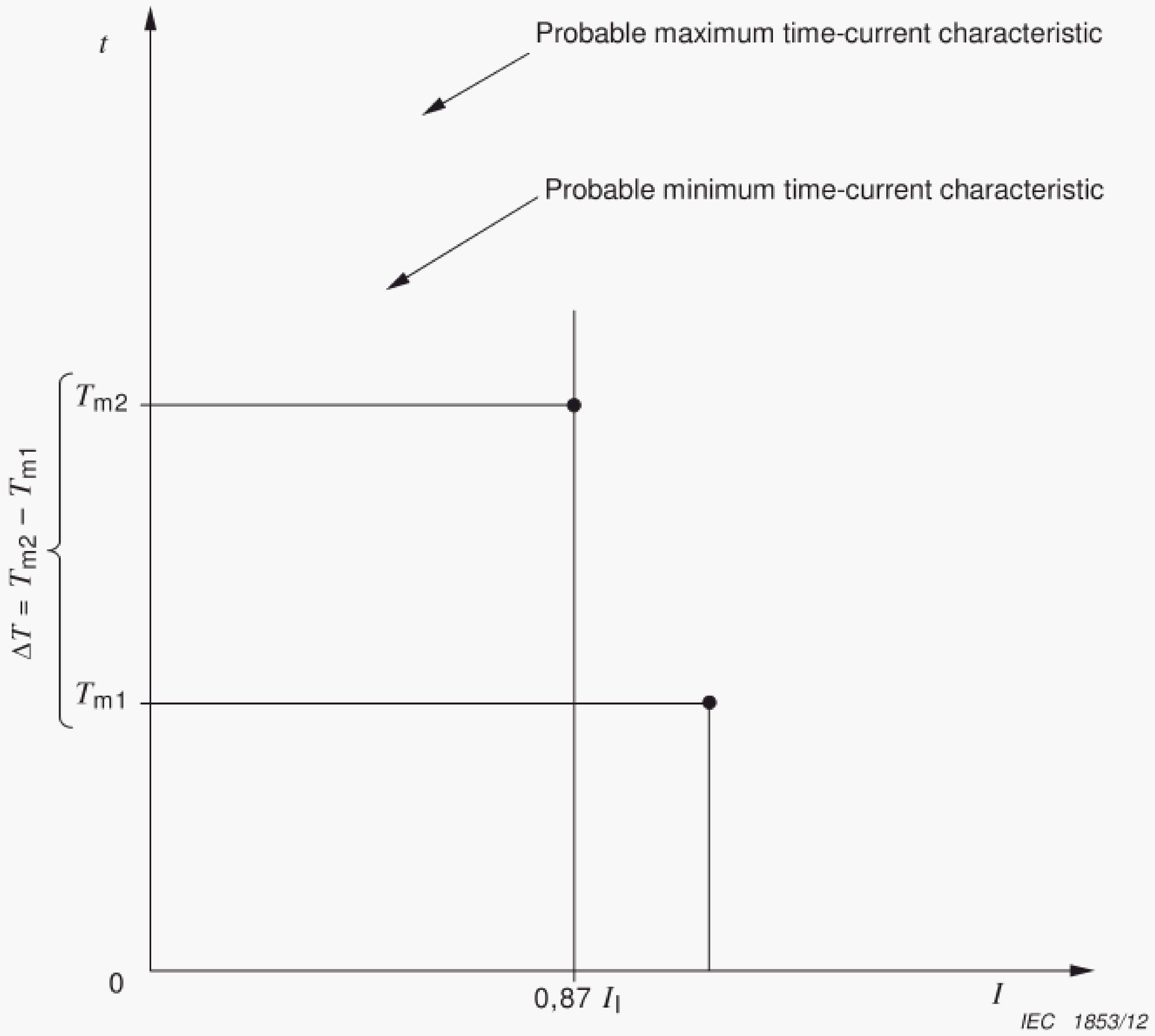


Figure B.1 – Practical determination of the transfer current

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

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

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

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

defining a relationship between I and T_m such that:

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

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

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

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

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

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

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

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

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

combining (B.3) and (B.4) one obtains:

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

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

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

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

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

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

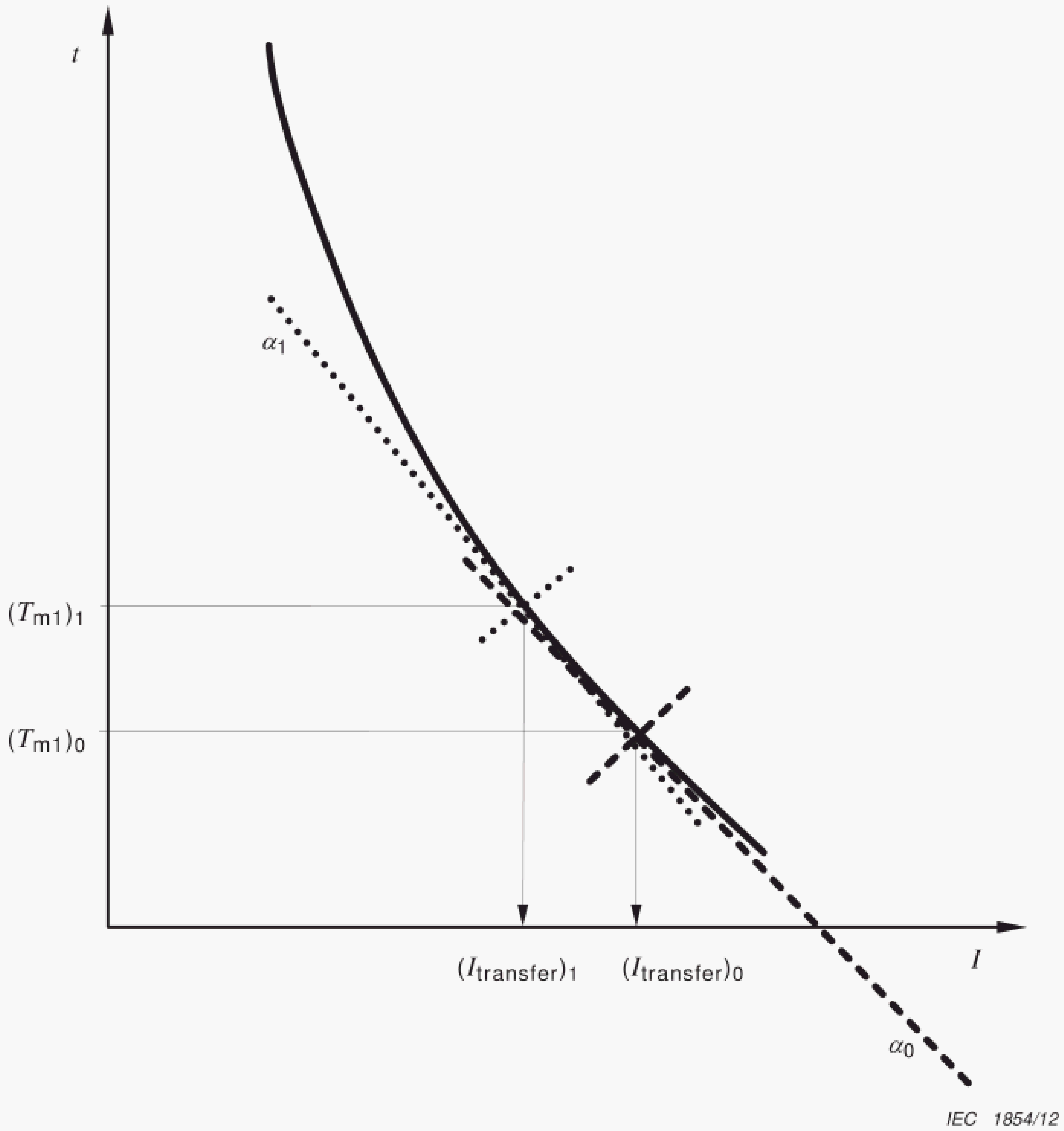


Figure B.2 – Determination of the transfer current with the iterative method

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

B.3 Simplified method for determination of transfer current

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

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

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

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

or

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

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

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

Annex C
(normative)

Tolerances on test quantities for type tests

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

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerance	Reference to
6.101	Making and breaking tests				
6.101.2.2	Test frequency	Test frequency	Rated frequency	± 8 %	
6.101.2.5	Test voltage for breaking tests	Power frequency recovery voltage	Rated voltage	± 5 %	
		Power frequency recovery voltage of any phase/average value	1	± 20 %	Figure 4
6.101.2.7	Applied voltage before short circuit tests	Applied voltage	Rated voltage	+10 % -0 %	
		Applied voltage of any phase /average value	1	± 5 %	
6.101.2.8	Breaking current	AC component of test current for TD_{ISC}, TD_{IWmax} and TD_{Ito} in any phase/average	1	± 10 %	
		AC component of test current for $TD_{Itransfer}$ in two phases fitted with solid links/phase with fuses	1	≥ √3/2	
6.101.3.1	Short circuit current	Prospective current	Rated value	+5 % -0 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1	+10 % -0 %	
6.101.3.2	Current with max. I^2t of the fuse	Prospective current	Specified value	± 10 %	
		Power factor		0,07 to 0,15	
		TRV of supply circuit	See IEC 60282-1 test-duty 2	+10 % -0 %	
6.101.3.3 and 6.101.3.4	Transfer current and Take over current	Prospective current	Rated value	+10 % -0 %	
		Power factor of load circuit	$I_{rtransfer} > 400$ A	0,2 to 0,3	
			$I_{rtransfer} \leq 400$ A	0,3 to 0,4	
		Power factor of supply circuit		< 0,2	
		TRV of supply circuit	See IEC 60282-1 test-duty 1	+10 % -0 %	
		TRV of load circuit	Tables 2 and 3	+10 % -0 %	
		Impedance of supply circuit/total impedance	0,15	± 0,03	

Bibliography

IEC 62271-107, *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 62271-202, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

____

NOTES

For information regarding the development of Standards contact:
Standards Australia Limited
GPO Box 476
Sydney NSW 2001
Phone: 02 9237 6000
Fax: 02 9237 6010
Email: mail@standards.org.au
Internet: www.standards.org.au

For information regarding the sale and distribution of Standards contact:
SAI Global Limited
Phone: 13 12 42
Fax: 1300 65 49 49
Email: sales@saiglobal.com

STANDARDS Australia

ISBN 978 1 74342 957 0

This page has been left intentionally blank.