BS EN 62271-100:2009+A2:2017

BSI Standards Publication

High-voltage switchgear and controlgear

Part 100: Alternating-current circuit-breakers (IEC 62271-100:2008)

bsi.

National foreword

This British Standard is the UK implementation of EN 62271-100:2009, incorporating amendment A1:2012 and including amendment A2:2017. It is identical to IEC 62271-100:2008, incorporating amendment 1:2017 and including amendment 2:2017 and corrigendum January 2018. It supersedes BS EN 62271-100:2009+A1:2012, which is withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum December 2012 is indicated in the text by [AC1) (AC1].

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by [A1) (A1].

The text of IEC amendment 2:2017 and IEC corrigendum January 2018 have been provided in their entirety at the beginning of this document. BSI's policy of providing consolidated content remains unchanged; however, in the interest of expediency, in this instance BSI have chosen to collate the relevant content at the beginning of this document.

The UK participation in its preparation was entrusted to Technical Committee PEL/17/1, High-voltage switchgear and controlgear.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2009.

Amendments/corrigenda issued since publication

Date	Text affected
30 April 2013	Implementation of IEC corrigendum December 2012
30 April 2013	Implementation of IEC amendment 1:2012 with CENELEC endorsement A1:2012
30 April 2018	Implementation of IEC amendment 2:2017 with CENELEC endorsement A2:2017
30 April 2018	Implementation of IEC corrigendum January 2018

EUROPÄISCHE NORM

April 2009

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Supersedes EN 62271-100:2001 + A1:2002 + A2:2006

English version

High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers
(IEC 62271-100:2008)

Appareillage à haute tension -
Partie 100: Disjoncteurs
à courant alternatif
(CEI 62271-100:2008)

Hochspannungs-Schaltgeräte
und -Schaltanlagen -
Teil 100: Wechselstrom-Leistungsschalter
(IEC 62271-100:2008)

This European Standard was approved by CENELEC on 2009-03-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 62271-100:2009 E

Foreword

The text of document 17A/815/FDIS, future edition 2 of IEC 62271-100, prepared by SC 17A, High-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62271-100 on 2009-03-01.

This European Standard supersedes EN 62271-100:2001 + A1:2002 + A2:2006 + A2:2006/corrigendum November 2006.

The main changes with respect to EN 62271-100:2001 are listed below:

– introduction of harmonised (IEC and IEEE) TRV waveshapes for rated voltages of 100 kV and above (amendment 1 to EN 62271-100:2001);

– introduction of cable and line systems with their associated TRVs for rated voltages below 100 kV (amendment 2 to EN 62271-100:2001);

– inclusion of IEC 61633 and IEC 62271-308.

This standard shall be read in conjunction with EN 62271-1:2008, 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 and subclauses is used as in EN 62271-1. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2012-03-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62271-100:2008 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60044-1	NOTE Harmonized as EN 60044-1:1999 (modified).
IEC 60044-2	NOTE Harmonized as EN 60044-2:1999 (modified).
IEC 60077	NOTE Harmonized in EN 60077 series (modified).
IEC 60099-4	NOTE Harmonized as EN 60099-4:2004 (modified).
IEC 60143-2	NOTE Harmonized as EN 60143-2:1994 (not modified).
IEC 62271-109	NOTE Harmonized as EN 62271-109:2009 (not modified).
IEC 62271-200	NOTE Harmonized as EN 62271-200:2004 (not modified).
IEC 62271-203	NOTE Harmonized as EN 62271-203:2004 (not modified).

NORME EUROPEENNE

EUROPÄISCHE NORM

December 2012

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High-voltage switchgear and controlgear -
Part 100: Alternating-current circuit-breakers
(IEC 62271-100:2008/A1:2012)

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(CEI 62271-100:2008/A1:2012)

Hochspannungs-Schaltgeräte und -Schaltanlagen -
Teil 100: Wechselstrom-Leistungsschalter
(IEC 62271-100:2008/A1:2012)

This amendment A1 modifies the European Standard EN 62271-100:2009; it was approved by CENELEC on 2012-11-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this amendment the status of a national standard without any alteration.

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Ref. No. EN 62271-100:2009/A1:2012 E

Foreword

The text of document 17A/1009/FDIS, future edition 1 of IEC 62271-100:2008/A1, prepared by SC 17A, "High-voltage switchgear and controlgear", of IEC TC 17, "Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62271-100:2009/A1:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-08-01
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-11-01

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62271-100:2008/A1:2012 was approved by CENELEC as a European Standard without any modification.

In the Bibliography of EN 62271-100:2009:

- replace reference to EN 62271-203 by the following note:

IEC 62271-203:2011 NOTE Harmonized as EN 62271-203:2012 (not modified).

- add the following note:

IEC 60071-1:2006 + A1:2010 NOTE Harmonized as EN 60071-1:2006 + A1:2010 (not modified).

EUROPEAN STANDARD EN 62271-100:2009/A2

EUROPÄISCHE NORM September 2017

ICS 29.130.10

English Version

High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers (IEC 62271-100:2008/A2:2017)

Appareillage à haute tension - Partie 100: Disjoncteurs à courant alternatif (IEC 62271-100:2008/A2:2017)

Hochspannungs-Schaltgeräte und -Schaltanlagen - Teil 100: Wechselstrom-Leistungsschalter (IEC 62271-100:2008/A2:2017)

This amendment A2 modifies the European Standard EN 62271-100:2009; it was approved by CENELEC on 2017-07-20. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this amendment the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This amendment exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
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The text of document 17A/1135/FDIS, future edition of IEC 62271-100:2009/A2, prepared by SC 17A "High-voltage switchgear and controlgear" of IEC/TC 17 "Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62271-100:2009/A2:2017.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2018-04-20
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2020-07-20

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Endorsement notice

The text of the International Standard IEC 62271-100:2009/A2:2017 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-151	2001	International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices	-	-
IEC 60050-441	1984	International Electrotechnical Vocabulary (IEV) - Chapter 441: Switchgear, controlgear and fuses	-	-
IEC 60050-601	1985	International Electrotechnical Vocabulary (IEV) - Chapter 601: Generation, transmission and distribution of electricity - General	-	-
IEC 60050-604	1987	International Electrotechnical Vocabulary (IEV) - Chapter 604: Generation, transmission and distribution of electricity - Operation	-	-
IEC 60059	- [1)]	IEC standard current ratings	EN 60059	1999 [2)]
IEC 60060-1 + corr. March	1989 1990	High-voltage test techniques - Part 1: General definitions and test requirements	HD 588.1 S1	1991
IEC 60071-2	- [1)]	Insulation co-ordination - Part 2: Application guide	EN 60071-2	1997 [2)]
IEC 60137	- [1)]	Insulated bushings for alternating voltages above 1 000 V	EN 60137	2008 [2)]
IEC 60255-3 (mod)	1989	Electrical relays - - Part 3: Single input energizing quantity measuring relays with dependent or independent time	EN 60255-3 + corr. January	1998 1998
IEC 60296	- [1)]	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear	EN 60296 + corr. September	2004 [2)] 2004
IEC 60376	- [1)]	Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment	EN 60376	2005 [2)]
IEC 60480	- [1)]	Guidelines for the checking and treatment of sulphur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use	EN 60480	2004 [2)]

[1)] Undated reference.

[2)] Valid edition at date of issue.

Publication	Year	Title	EN/HD	Year
IEC 60529	- [1)]	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 [2)] 1993
IEC/TS 61634	- [1)]	High-voltage switchgear and controlgear - Use and handling of sulphur hexafluoride (SF_6) in high-voltage switchgear and controlgear	-	-
IEC 62271-1	2007	High-voltage switchgear and controlgear - Part 1: Common specifications	EN 62271-1	2008
IEC 62271-101	2006	High-voltage switchgear and controlgear - Part 101: Synthetic testing	EN 62271-101	2006
IEC 62271-102 + corr. April + corr. May	2001 2002 2003	High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches	EN 62271-102 + corr. March	2002 2005
IEC 62271-110	- [1)]	High-voltage switchgear and controlgear - Part 110: Inductive load switching	EN 62271-110	2005 [2)]

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60137	2008	Insulated bushings for alternating voltages above 1 000 V	EN 60137	2008
IEC 60270	-	High-voltage test techniques - Partial discharge measurements	EN 60270	-

Edition 2.0 2017-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

AMENDMENT 2
AMENDEMENT 2

High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers

Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 29.130.10 ISBN 978-2-8322-4357-2

FOREWORD

This amendment has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

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

FDIS	Report on voting
17A/1135/FDIS	17A/1139/RVD

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

The contents of the corrigendum of January 2018 have been included in this copy.

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

INTRODUCTION to the Amendment

This amendment includes the following significant technical changes:

– the rated TRV has been replaced by a rated first-pole-to-clear factor;

– the rated time quantities have been moved to Clause 5 (Design and construction) and are no longer ratings. The determination of the break time has been moved to IEC 62271-306;

– the number of test specimens has been removed;

– new test procedure for test-duty T100a;

– TRVs for circuit-breakers having a rated voltage of 52 kV and below used in effectively earthed neutral systems have been added;

– 6.111 (capacitive current switching) has been rewritten;

– a number of informative annexes have been moved to IEC TR 62271-306.

1.1 Scope

Add, after the third existing paragraph, the following paragraph:

This standard only covers direct testing.

1.2 Normative references

Replace, in the existing list, the reference to IEC 60137 by the following new reference:

IEC 60137:2008, *Insulated bushings for alternating voltages above 1 000 V*

Add, to the existing list, the following reference:

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

3 Terms and definitions

3.1.132
cable system

Replace the existing references to "Table 1" *(2 occurrences) to* "Tables 24 and 44"*.*

3.1.133
line system
Replace the existing definition by the following new definition, without modifying the notes.

system in which the TRV during breaking of terminal fault at 100 % of short-circuit breaking current does not exceed the two-parameter envelope derived from Tables 25 and 45 of this standard

Add, after the existing definition 3.1.133, the following new terms and definitions:

3.1.134
belted cable
multi-conductor cable in which part of the insulation is applied to each conductor individually, and the remainder is applied over the assembled cores

[IEV 461-06-11]

3.1.135
individually screened cable
radial field cable
cable in which each core is covered with an individual screen

[IEV 461-06-12]

3.4.120
circuit-breaker class S2

Replace the existing definition by the following new definition:

circuit-breaker used in a line-system

Add, after definition 3.4.120, the following new term and definition:

3.4.121
current chopping
current interruption prior to the natural power frequency current zero of the circuit connected

3.7.133
opening time

Replace the existing term, definition and notes as follows:

opening time (of a mechanical switching device)

[IEV 441-17-36]

3.7.134
arcing time (of a multipole switching device)

Replace the existing term, definition and source as follows:

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

[IEV 441-17-37]

3.7.135
break-time

Replace the existing definition by the following:

interval of time between the beginning of the opening time of a mechanical switching device and the end of the total arcing time

[IEV 441-17-39, modified]

3.7.136
closing time

Add, after the existing definition, the following new source:

[IEV 441-17-41, modified]

3.7.137
make time

Replace the source of the definition as follows:

[IEV 441-17-40, modified]

3.7.140
dead time (during auto-reclosing)

Add, after the existing note, the following source:

[IEV 441-17-44, modified]

3.7.144
make-break time

Replace the existing definition together with the notes by the following:

interval of time between the initiation of current flow in the first pole during a closing operation and the end of the total arcing time during the subsequent opening operation

[IEV 441-17-43, modified]

3.7.159
minimum clearing time

Replace the definition and note as follows:

sum of the minimum opening time, minimum relay time (0,5 cycle) and the shortest arcing time of a minor loop interruption in the phase with intermediate asymmetry that starts with a minor loop at short-circuit current initiation

NOTE 1 This definition is applicable only for the determination of the test parameters during short-circuit breaking tests according to test duty T100a.

NOTE 2 For testing purposes the minimum arcing time found during test-duty T100s is used.

Add, after the existing definition 3.7.160 added by Amendment 1, the following new terms and definitions:

3.7.161
initiation of (opening or closing) operation
instant of receipt of command for operation at the control circuit

3.7.162
total arcing time
interval of time between the instant of the first initiation of an arc in a pole and the instant of arc extinction in all poles

3.7.163
direct connection to an overhead line
connection between a circuit-breaker and an overhead line having a capacitance less than 5 nF

NOTE When the cable capacitance per unit length is 0,3 nF/m, it corresponds to a length of cable shorter than approximately 17 m. For further information see IEC TR 62271-306.

3.8 Index of definitions

Add, to the existing alphabetical list, the following new lines:

4 Ratings

Replace item l) by the following new item:

l) rated first-pole-to-clear factor;

Replace the existing item o) by the following new item:

o) void.

Replace item q) by the following new item:

q) rated line-charging breaking current, for circuit-breakers switching overhead transmission lines (mandatory for circuit-breakers of rated voltages above 52 kV and circuit-breakers of class S2);

Delete the existing item r) from the end of the second existing list, and place it at the beginning of the third existing list before item s).

4.10 Rated pressures of compressed gas supply for insulation, operation and/or interruption

Replace the title by the following:

4.10 Rated pressure of compressed gas supply for controlled pressure systems

Add, between subclauses 4.10 and 4.101, the following new subclause 4.11:

4.11 Rated filling levels for insulation and/or operation

Subclause 4.11 of IEC 62271-1 is applicable.

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

Replace, in the first paragraph, "4.102" *by* "6.104.5.1" *and* "4.105" *by* "6.109.3".

4.102 Transient recovery voltage related to the rated short-circuit breaking current

Replace the complete subclause modified by Amendment 1 including Tables 1 to 7 by the following:

4.102 Rated first-pole-to-clear factor

The first-pole-to-clear factor (k_{pp}) is a function of the earthing of the system neutral. The rated values of k_{pp} are:

– 1,2 for terminal fault breaking by circuit-breakers with rated voltages higher than 800 kV in effectively earthed neutral systems;
– 1,3 for terminal fault breaking by circuit-breakers for rated voltages up to and including 800 kV in effectively earthed neutral systems;
– 1,5 for terminal fault breaking by circuit-breakers for rated voltages less than 245 kV in non-effectively earthed neutral systems.

In this standard, it is considered that circuit-breakers with rated voltages up to and including 170 kV can be either in effectively earthed neutral systems or in non-effectively earthed neutral systems. Circuit-breakers with rated voltages higher than 170 kV are in effectively-earthed systems.

NOTE The following associated first-pole-to-clear factors for out-of-phase conditions are not ratings:

– 2,0 for breaking in out-of-phase conditions in systems with effectively earthed neutral;
– 2,5 for breaking in out-of-phase conditions in systems with non-effectively earthed neutral.

4.105 Characteristics for short-line faults

Replace the title and text modified by Amendment 1 of the complete subclause, including Table 8, by the following:

4.105 Short-line fault breaking capability

A short-line fault breaking capability is required for circuit-breakers with a rated short-circuit breaking current exceeding 12,5 kA for direct connection to overhead lines.

4.106 Rated out-of-phase making and breaking current

Replace the existing text by the following:

The rated out-of-phase breaking current is the maximum out-of-phase current that the circuit-breaker shall be capable of breaking under the conditions of use and behaviour prescribed in this standard in a circuit having a recovery voltage as specified below.

The specification of a rated out-of-phase making and breaking current is not mandatory.

If a rated out-of-phase breaking current is assigned, the rated out-of-phase breaking current shall be 25 % of the rated short-circuit breaking current and the rated out-of-phase making current shall be the crest value of the rated out-of-phase breaking current, unless otherwise specified.

The standard conditions of use with respect to the rated out-of-phase making and breaking current are as follows:

– opening and closing operations carried out in conformity with the instructions given by the manufacturer for the operation and proper use of the circuit-breaker and its auxiliary equipment;
– earthing condition of the neutral for the power system corresponding to that for which the circuit-breaker has been tested;
– absence of a fault on either side of the circuit-breaker.

4.107.1 Rated line-charging breaking current

Replace the text by the following:

The rated line-charging breaking current is the line-charging current up to which the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard. The associated restrike class (C1 or C2) shall be assigned when a line-charging breaking current is assigned.

4.107.2 Rated cable-charging breaking current

Replace the text by the following:

The rated cable-charging breaking current is the cable-charging current up to which the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard. The associated restrike class (C1 or C2) shall be assigned when a cable-charging breaking current is assigned.

4.107.3 Rated single capacitor bank breaking current

Replace the first paragraph by the following:

The rated single capacitor bank breaking current is the single capacitor bank breaking current up to which the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard. This breaking current refers to the switching of a shunt capacitor bank where no shunt capacitors are connected to the source side of the circuit-breaker. The associated restrike class (C1 or C2) shall be assigned when a single capacitor bank breaking current is assigned.

Table 9 – Preferred values of rated capacitive switching currents

In NOTE 2 to the table replace "Annex H" *by* "IEC TR 62271-306".

4.107.4 Rated back-to-back capacitor bank breaking current

Replace the first paragraph by the following:

The rated back-to-back capacitor bank breaking current is the back-to-back capacitor bank current up to which the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard. The associated restrike class (C1 or C2) shall be assigned when a back-to-back capacitor bank breaking current is assigned.

4.107.6 Rated back-to-back capacitor bank inrush making current

Replace the existing text by the following:

The rated back-to-back capacitor bank inrush making current is the peak value of the current that the circuit-breaker shall be capable of making at its rated voltage and with a frequency of the inrush current during a simultaneous three-phase making operation (see Table 9).

4.109 Rated time quantities

Replace the title and text of the subclause, including 4.109.1 modified by Amendment 1, by the following:

4.109 Void.

Delete the entire subclause and title, including 4.109.1 modified by Amendment 1.

5.4 Auxiliary equipment

Delete, in the second dashed paragraph and in Note 2 the word "rated".

5.5 Dependent power closing

Replace the title by the following:

5.5 Dependent power operation

5.6 Stored energy closing

Replace the title by the following:

5.6 Stored energy operation

5.7 Independent manual operation

Replace the title by the following:

5.7 Independent manual or power operation

5.101 Requirements for simultaneity of poles during single closing and single opening operations

Replace the entire text of this subclause by the following:

The following requirements are applicable under rated conditions of the auxiliary and control voltage and pressure for operation:

- The maximum difference between the instants of contacts touching during closing in the individual poles shall not exceed a quarter of a cycle of rated frequency. If one pole consists of more than one interrupter unit connected in series, the maximum difference between the instants of contacts touching within these series connected interrupter units shall not exceed one sixth of a cycle of rated frequency. Where closing resistors are used, the maximum difference between the instants of contacts touching during closing in the individual closing resistors shall not exceed one half cycle of rated frequency. If on one pole more than one individual closing resistor is used, each assigned to one of the interrupter units which are connected in series, the maximum difference between the instants of contacts touching within these series connected closing resistors shall not exceed one third of a cycle of rated frequency;
- The maximum difference between the instants of contacts separating during opening shall not exceed one sixth of a cycle of rated frequency. If one pole consists of more than one interrupter unit connected in series, the maximum difference between the instants of contact separation within these series connected interrupter units shall not exceed one eighth of a cycle of rated frequency.

NOTE For a circuit-breaker having separate poles, the requirement is applicable when these operate in the same conditions; after a single-pole reclosing operation the conditions of operation for the three mechanisms may not be the same.

Add, after 5.104, the new subclauses and the new table as follows:

5.105 Time quantities

Refer to Figures 1, 2, 3, 4, 5, 6 and 7.

Values may be assigned to the following time quantities:

- opening time (no-load);
- break-time;
- closing time (no-load);
- open-close time (no-load);
- reclosing time (no-load);
- close-open time (no-load);
- pre-insertion time (no-load).

Time quantities are based on

- rated supply voltages of closing and opening devices and of auxiliary and control circuits (see 4.8);
- rated supply frequency of closing and opening devices and of auxiliary circuits (see 4.9);
- rated pressure of compressed gas supply for controlled pressure systems (see 4.10);
- rated filling levels for insulation and/or operation (see 4.11);
- an ambient air temperature of 20 °C ± 5 °C.

NOTE 1 It is not practical to assign a value of make-time or of make-break time due to the variation of the arcing time and the pre-arcing time.

NOTE 2 The break-time is determined using the calculation method given in IEC TR 62271-306 [4].

5.106 Static mechanical loads

Outdoor circuit-breakers shall be designed to withstand and operate correctly when mechanically loaded by stresses resulting from ice, wind and connected conductors. If required, this capability is demonstrated by means of calculations.

Ice coating and wind pressure on the circuit-breaker shall be in accordance with 2.1.2 of IEC 62271-1.

Some examples of static forces due to wind, ice and weight on flexible and tubular connected conductors are given as a guidance in Table 14.

The tensile force due to the connected conductors is assumed to act at the outermost end of the circuit-breaker terminal.

The manufacturer shall consider that these forces can be applied simultaneously.

Table 14 – Examples of static horizontal and vertical forces for static terminal load test

Rated voltage range U_r kV	Rated current range I_r A	Static horizontal force F_{th}		Static vertical force F_{tv} N
		Longitudinal F_{thA} N	Transversal F_{thB} N	
< 100	800 to 1 250	500	400	500
< 100	1 600 to 2 500	750	500	750
100 to 170	1 250 to 2 000	1 000	750	750
100 to 170	2 500 to 4 000	1 250	750	1 000
245 to 362	1 600 to 4 000	1 250	1 000	1 250
420 to 800	2 000 to 4 000	1 750	1 250	1 500
1 100 to 1 200	4 000 to 6 300	3 500	3 000	2 500

6 Type tests

Move the text currently under 6 (including Table 11 modified by Amendment 1) between 6.1 and 6.1.1.

Delete, in the second paragraph, the second sentence "The number of test samples…".

Replace the fifth paragraph starting with "The uncertainty….." *and the note by the following:*

The expanded uncertainty of a complete measuring system for determination of the ratings (for example short-circuit current, applied voltage and recovery voltage) shall be ≤ 5 %, evaluated with a coverage probability of 95 % corresponding to a coverage factor k = 2 under the assumption of a normal distribution.

NOTE Procedures for the determination of the uncertainty of measurements are given in ISO/IEC Guide 98-3 [6].

Add, before Table 11 modified by Amendment 1, the following paragraph:

If the circuit-breaker can be equipped with other operating mechanisms, complete type tests according to Table 11 shall be performed on the circuit-breaker equipped with one type of operating mechanism. The other operating mechanisms are considered being alternative operating mechanisms as defined in 3.5.126, provided they fulfil the related requirements as defined in 6.102.7. Tests to be repeated for alternative mechanisms are defined in 6.1.102.

Table 11 – Type tests

Replace the table, modified by Amendment 1, by the following:

Mandatory type tests	Subclauses
Dielectric tests	6.2
Measurement of the resistance of the main circuit	6.4
Temperature-rise tests	6.5
Short-time withstand current and peak withstand current tests	6.6
Additional tests on auxiliary and control circuits	6.10
Mechanical operation test at ambient temperature (class M1)	6.101.2.1 to 6.101.2.3
Short-circuit current making and breaking tests	6.102 to 6.106

Type tests depending on requirements	Condition requiring type test	Subclauses
Radio interference voltage tests	$U_r \geq 245$ kV	6.3
Verification of the degree of protection	Assigned IP class	6.7
Tightness test	Controlled, sealed or closed pressure systems	6.8
EMC tests	Electronic equipment or components are included in the secondary system	6.9
X-ray radiation test	Vacuum circuit-breaker	6.11
Extended mechanical endurance tests on circuit-breakers for special service conditions	Class M2 rating assigned	6.101.2.4
Low and high temperature tests	As required	6.101.3
Humidity test	Insulation subject to voltage stress and condensation	6.101.4
Critical current tests	Circuit-breaker performance against conditions in 6.107.1	6.107
Short-line fault tests	$U_r \geq 15$kV and $I_{sc} > 12{,}5$ kA, in case of direct connection to overhead lines	6.109
Out-of-phase making and breaking tests	Out-of-phase rating assigned	6.110
Electrical endurance tests (only for $U_r \leq 52$kV)	Class E2 rating assigned	6.112
Test to prove operation under severe ice conditions	Outdoor circuit-breakers with moving external parts and ice thickness 10 mm / 20mm	6.101.5
Single-phase fault test	Effectively earthed neutral systems	6.108
Double earth fault test	Non-effectively earthed neutral systems	
Capacitive current switching tests: – line-charging current breaking tests – cable-charging current breaking tests – single capacitor bank switching tests – back-to-back capacitor bank switching tests	Relevant rating and classification (C1 or C2) assigned	6.111
Switching of shunt reactors and motors	As specified	IEC 62271-110
Mandatory type tests, shown in the upper part of the table, are required for all circuit-breakers regardless of rated voltage, design or intended use. Other type tests, shown in the lower part of the table, are required for all circuit-breakers where the associated rating is specified, e.g. out-of-phase switching, or where a specific condition is met, for example RIV is required only for rated voltages of 245 kV and above.		

Add, after Table 12, the following new subclause:

6.1.102 Type tests to repeat for circuit-breakers with alternative operating mechanisms

The following type tests shall be repeated on circuit-breakers with alternative operating mechanisms:

– mechanical operation tests at ambient temperature (according to 6.101.2);

– high and low temperature tests (according to 6.101.3);

– short-circuit making and breaking tests (as defined in 6.102.7);

– short-time withstand current and peak withstand current tests on circuit-breakers having main contacts of the butt type (according to 6.6).

6.2.11 Voltage test as a condition check

Add, after the paragraph that starts with "Where after mechanical or environmental tests…" *added by Amendment 1, the following sentences:*

For multi-unit live tank circuit-breakers with identical units according to 6.102.4.2.3 the voltage test as a condition check may be performed as unit test.

Add, after 6.10.5, the following new subclauses:

6.10.6 Dielectric test

Subclause 6.10.6 of IEC 62271-1 is applicable with the following addition:

– the dielectric test shall be performed on the auxiliary and control circuits in new condition;

– during the test the motor(s) shall be disconnected, provided that it was or they were tested separately.

NOTE Repetition of dielectric tests on motor(s) results in accelerated ageing of the motor.

6.11 X-radiation test procedure for vacuum interrupters

Subclause 6.11 of IEC 62271-1 is applicable.

6.101.1.1 Mechanical characteristics

Replace the entire text of this subclause by the following:

At the beginning of the type tests, the mechanical characteristics of the circuit-breaker shall be established. IEC TR 62271-306 gives examples on how to measure the mechanical characteristics. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the circuit-breaker. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, making, breaking and switching type tests behave mechanically in a similar way. The reference mechanical characteristics are also used to confirm that production units behave mechanically in a similar way compared to the test samples used during type tests.

Following is an example of operating characteristics that can be recorded:

– no-load travel curves;

– closing and opening times;

– other mechanical parameters, if necessary.

The mechanical characteristics shall be produced during a no-load test made with a single O operation and a single C operation at rated supply voltage of operating devices and of auxiliary and control circuits, rated functional pressure for operation and, for convenience of testing, at the minimum functional pressure for interruption.

Annex N gives requirements and explanation on the use of mechanical characteristics.

6.101.1.4 Condition of the circuit-breaker during and after the tests

Add, at the end of the list, the following new dashed item:

– the increase of the resistance of the main circuit is less than or equal to 20 %. If the increase in resistance exceeds 20 % then a temperature rise test is applicable to determine if the test object can carry its rated normal current without exceeding the temperature limits given in Table 3 of IEC 62271-1 by more than 10 K.

6.101.2.1 General

Replace the last paragraph by the following:

During the test, lubrication of parts outside of the main circuit is allowed in accordance with the manufacturer's instructions, but no mechanical adjustment or other kind of maintenance is allowed.

6.101.2.4 Extended mechanical endurance tests on class M2 circuit-breakers for special service requirements

Replace the second dashed item by the following:

– between the test series specified, some maintenance, such as lubrication and mechanical adjustment, is allowed, and shall be performed in accordance with the manufacturer's instructions. Only change of parts outside of the main circuit and not being part of the kinematic chain, that are listed in the program of maintenance, is permitted;

6.101.3.1 General

Add, after NOTE 2, the following text:

For dead-tank circuit-breakers equipped with tank heater(s) for the purpose of avoiding gas liquefaction during low ambient temperature conditions, the test sequence prescribed in 6.101.3.3 is not sufficient to demonstrate that the gas heating element is properly designed to avoid gas liquefaction during low ambient temperature conditions. For such circuit-breakers, the test sequence prescribed in 6.101.3.3 shall be performed with a simulation of an average wind speed of 10 km/h (±20 %) applied perpendicularly to the longitudinal axis of an outer phase of the circuit-breaker. The wind shall be applied from step c) to j) of the test procedure described in 6.101.3.3.

The wind speed shall be measured by at least 5 positions along the longitudinal axis of the circuit-breaker and at a distance of 0,5 m (±0,1 m) to the outer circuit-breaker tank (see Figure 59). Each measurement shall be spaced by approximately 0,3 m. The number of measurements shall be such that the measurement length exceeds the circuit-breaker length by at least 0,5 m on each end. The wind speed for each of the individual measurement shall be within ±50 % of the average wind value.

It is recognised that the wind speed measurements in relatively small climatic room (in relation to the circuit-breaker dimensions) can be difficult and that wind turbulences from the neighbouring test cell walls cannot be avoided. In such cases, greater deviations as required above should be accepted.

The application of a transversal wind may make the measurement of the gas tightness impossible. If this is the case, it is allowed to split the low temperature test procedure in two parts. After having performed the required test sequence with the simulation of the transversal wind, the low temperature test sequence shall be repeated, without transverse wind and without gas heater, at low temperature T_L equal to or lower than the lowest temperature measured during the first test on the circuit-breaker tank surface close to sealing joints. A minimum of ten temperature measuring points shall be used to measure the tank surface temperature close to sealing joints.

6.101.4.1 General

Replace, in the second paragraph, the word "specimen" *by* "object"*.*

6.101.6 Static terminal load test

Delete this subclause, modified by Amendment 1, including its title and Table 14.

6.102 Miscellaneous provisions for making and breaking tests

Replace subclauses 6.102.1 and 6.102.2 modified by Amendment 1 by the following:

6.102.1 General

The following subclauses are applicable to all making and breaking tests unless otherwise specified in the relevant clauses.

Where applicable, prior to the commencement of the tests, the manufacturer shall declare the values of

– minimum conditions of the operating mechanism guaranteeing the rated operating sequence (for example the minimum functional pressure for operation in case of a hydraulic operating mechanism);

– minimum conditions of the interrupting device guaranteeing the rated operating sequence (for example the minimum functional pressure for interruption in case of a SF_6 circuit-breaker).

6.102.2 Additional requirements

Circuit-breakers shall be capable of making and breaking all short-circuit currents, symmetrical and asymmetrical, up to and including the rated short-circuit breaking currents: this is demonstrated, when the circuit-breakers make and break the specified three-phase symmetrical and asymmetrical currents between 10 % (or such lower currents as specified in 6.107.2 if 6.107.1 is applicable) and 100 % of the rated short-circuit breaking current at rated voltage.

In addition, circuit-breakers rated for k_{pp} = 1,2 or 1,3 shall be capable of breaking single-phase short-circuit currents (see 6.108). Furthermore, circuit-breakers rated for k_{pp} = 1,5 shall be capable of breaking short-circuit currents in case of double earth faults (see 6.108).

Making and breaking tests according to class S2 cover making and breaking tests according to class S1.

Circuit-breakers to which any capacitive current switching rating has been assigned shall be capable of switching capacitive currents up to and including the rated capacitive switching current at a voltage level up to and including the specified one (see 6.111.7). This is demonstrated when the circuit-breakers switch the rated capacitive switching current at the specified test voltage.

Three-phase making and breaking requirements should preferably be proved in three-phase circuits.

If the tests are carried out in a laboratory, the applied voltage, current, transient and power-frequency recovery voltages may all be obtained from a single power source (direct tests) or from several sources where all of the current, or a major portion of it, is obtained from one source, and the TRV is obtained wholly or in part from one or more separate sources (synthetic tests).

If, due to limitations of the testing facilities, the short-circuit performance of the circuit-breaker cannot be proved in the above way, several methods employing either direct or synthetic test methods may be used either singly or in combination, depending on the circuit-breaker type:

a) single-pole testing (see 6.102.4.1);

b) unit testing (see 6.102.4.2);

c) multi-part testing (see 6.102.4.3).

The operating time of some circuit-breakers may vary when the supply voltage to the coils is at the minimum value specified in 5.8 of IEC 62271-1, while the operating times are reasonably constant at their rated supply voltages. Performing a test duty with correct arcing times can be difficult to achieve in such a case, especially where steps of 18 electrical degrees need to be made to prove the arcing window. Additionally, the scattering of the closing time may prevent the possibility to perform the making test with the rated short-circuit making current.

For circuit-breakers where the operation of the coils does not affect contact travel characteristics, it is permitted to increase the supply voltage of the coils from the minimum value to 110 % of the rated supply voltage. No-load operations performed at the rated and minimum supply voltage shall be included in the test report to show that the contact travel characteristics are not affected by the increased voltage of the coil.

At least one making and one breaking operation shall be performed for test-duty T100s with minimum supply voltage to prove the ability of the circuit-breaker to operate correctly up to its rated short-circuit current under minimum control voltage conditions.

6.102.4.1 Single-phase testing of a single pole of a three-pole circuit-breaker

Add, at the end of the subclause, the following new paragraph:

When testing a circuit-breaker for 50 Hz and 60 Hz, verification tests need only to be performed at 50 Hz or 60 Hz, provided the following two conditions are met:

– the arcing time for breaking shall be the longest expected arcing time in the last-pole-to-clear at 50 Hz;

– during the making operation with asymmetrical current the rated short-circuit making current for 60 Hz shall be achieved.

6.102.4.2.2 Voltage distribution

Replace the paragraph below NOTE 2 by the following paragraph:

Where short-line fault tests are performed with unit test method, both source and line side TRV shall be determined with the single voltage distribution factor, corresponding to the voltage distribution of the line side TRV.

6.102.4.3 Multi-part testing

Replace the existing text with the following:

If all recovery voltage requirements for the given test-duty cannot be met simultaneously, the test may be carried out in two successive parts, for example as illustrated in Figure 43.

In the test circuit used for the first part, the initial portion of the TRV shall not cross the straight line defining the delay time and shall meet the specified reference line up to the voltage u_1 and the time t_1.

In the test circuit used for the second part, the voltage u_c and the time t_2 shall be attained.

Multi-part testing may also be carried out in order to obtain the power frequency recovery voltage of $\frac{U_r}{\sqrt{3}}$ for terminal fault after one half-cycle of rated frequency during single-phase tests in substitution for three-phase tests as specified in 6.104.7 b).

The number of tests for each part shall be the same as the number required for the test-duty, and the arcing times for each part shall meet the requirements of 6.102.10. The arcing times in separate tests forming part of one multi-part test shall be the same with a tolerance of ±1 ms. Moreover if the minimum arcing time in one part differs from that established in the other part by more than 1 ms then the maximum arcing time associated with the longer of the two minimum arcing times shall be used for both parts.

When multi-part testing is used to separately meet the requirements for TRV and for the power frequency recovery voltage, during tests with power frequency recovery voltage it is not necessary to search for the minimum arcing time. Arcing times shall be based on the minimum arcing time obtained during tests with TRV.

The circuit-breaker may be re-conditioned between the parts of the multi-part testing procedure in accordance with 6.102.9.5.

In rare cases, it may be necessary to perform the test in more than two parts. In such cases, the principles stated above shall be applied.

6.102.6 No-load operations before tests

Replace the existing text by the following:

Before commencing making, breaking and switching tests, C and O operations shall be made and the mechanical characteristics recorded. Details such as closing time and opening time shall be recorded. For these no-load operations, conditions stated in 6.101.1.1 apply. Additional no-load operations may be necessary (see also 6.102.3.1).

In addition, it shall be demonstrated that the mechanical behaviour of the circuit-breaker under test, conforms to that of the reference mechanical travel characteristics required in 6.101.1.1. After a change of contacts or any kind of maintenance, these mechanical travel characteristics shall be reconfirmed by repeating these no-load tests.

For a circuit-breaker fitted with a making current release, it shall be shown that this does not operate on no-load.

The pressure of the compressed gas for interruption shall be set at the value corresponding to that required for the test-duty to be performed.

For electrically or spring-operated circuit-breakers, operations shall be made with the closing solenoid or shunt-closing releases energised at 100 % and 85 % of the rated supply voltage of the closing device and with the shunt-opening release energised at 100 % and 85 % in the case of a.c., and 100 % and 70 % in the case of d.c. of the rated supply voltage.

6.102.7 Alternative operating mechanisms

Replace existing text with following:

In this subclause, it is considered that one version of the circuit-breaker using an original operating mechanism, is completely type-tested in accordance with this standard; this version is referred to as the completely tested circuit-breaker. The other versions, differing in the operating mechanisms (see definition in 3.5.124), are referred to as circuit-breakers with alternative operating mechanisms.

For a circuit-breaker equipped with alternative operating mechanisms, repetition of T100s and T100a (if required in c) below) only is required for the demonstration of the making, breaking and switching capabilities.

Therefore, the tests to be performed on the circuit-breaker equipped with the alternative operating mechanism are as follows:

a) the mechanical characteristics shall be recorded and compared with the completely tested circuit-breaker in accordance with 6.101.1.1 and comply with the requirements given in Annex N;
b) test-duty T100s shall be performed. In addition the mechanical characteristics during the breaking operations with the longest arcing time shall be compared with the completely tested circuit-breaker according to the method prescribed in 6.101.1.1 and comply with the requirements given in Annex N;
c) in the particular case where the minimum clearing time (see 3.7.159) is shorter, test-duty T100a shall be performed.

If requirements a), b), and c) are met, the reference mechanical characteristics of the completely tested circuit-breaker shall apply also for the circuit-breakers equipped with alternative operating mechanisms.

6.102.8 Behaviour of circuit-breaker during tests

*Add, just before the paragraph starting with "*NSDDs may occur…..*", the following paragraph:*

Resumption of power-frequency current in any pole more than one cycle after interruption of the short-circuit in all poles is a failure.

6.102.9.2 Condition after short-circuit test duty

Replace the first paragraph by the following:

After each short-circuit test-duty, the circuit-breaker shall be capable of making and breaking its rated normal current at the rated voltage, although its short-circuit making and breaking performance may be impaired.

After test-duty L_{90} a condition check according to 6.2.11 shall be performed to verify the voltage withstand of the circuit-breaker. If no short-line fault rating is assigned, the condition check shall be carried out after test-duty T100s as follows:

– in case of a single-phase test the condition check shall be carried out on the pole tested;
– in case of three-phase tests the condition check shall be carried out on the pole that was subjected to the maximum arcing time with an extended loop;
– terminals to which no test voltage is applied shall be earthed during the condition check.

Replace the first and second sentences of the second paragraph by the following:

If interrupter units are placed in an insulating fluid with different characteristics and other than air at atmospheric pressure, that also might withstand the test voltages when replacing the original arc extinguishing medium (for example a vacuum interrupter unit in an enclosure filled with SF_6) the condition checking test, as requested in 6.2.11 may not be adequate to verify the integrity of the device. In such cases short-circuit breaking tests in a circuit which supplies at least 10 % of the rated short-circuit breaking current and at least 50 % of the rated voltage shall be made in addition.

Replace the two indents by the following:

– if performed three-phase in a circuit with effectively or solidly earthed neutral, one opening operation shall be performed with both the source side neutral and the short-circuit point earthed;
– if performed three-phase in a circuit with non-effectively earthed neutral, three opening operations shall be performed. The first-pole-to-clear conditions have to be demonstrated for each pole of the circuit-breaker;
– if performed single-phase, one opening shall be performed. The test has to be repeated on each pole.

6.102.9.3 Condition after a short-circuit test series

Replace the first paragraph by the following:

In order to check the operation of the circuit-breaker after a short-circuit test series, the no-load operating sequence of 6.102.6 shall be repeated at the completion of the entire test series of short-circuit or switching tests. These no-load tests shall be compared with the corresponding operations made in accordance with 6.102.6. The requirements of 6.101.1.1 and of Annex N shall be fulfilled. The circuit-breaker shall close and latch satisfactorily.

6.102.9.4 Condition after a capacitive current switching test series

Add the following new paragraph before the first existing paragraph:

In order to check the operation of the circuit-breaker after a capacitive current switching test series, the no-load operating sequence of 6.102.6 shall be repeated at the completion of the entire test series of short-circuit or switching tests. These no-load tests shall be compared with the corresponding operations made in accordance with 6.102.6. The requirements of 6.101.1.1 and of Annex N shall be fulfilled. The circuit-breaker shall close and latch satisfactorily.

6.102.10 Demonstration of arcing times

Replace the existing subclause modified by Amendment 1, including tables and figures up to Table 23 included, by the following:

6.102.10 Demonstration of arcing times

6.102.10.1 General

The requirements described in this subclause are relevant for the adjustment of prospective arcing times. The actual arcing times may vary from the prospective ones. Tests are valid as long as the actual arcing times are within the tolerances given in Annex B.

The terminal fault tests T100a in 6.102.10.2.2 and 6.102.10.3.3 consist of three valid breaking operations independent of the rated operating sequence.

NOTE The arcing times prescribed in this subclause are adequate to cover the effect of the unintentional non-simultaneity of the circuit-breaker poles.

Throughout this subclause the following symbols are used:

T is the duration of one cycle of rated frequency;

t_{a100s} in case of a three-phase test t_{a100s} is the minimum of the arcing times of any first-poles-to-clear during the breaking operations of test-duty T100s;

in case of a single-phase test t_{a100s} is the minimum arcing time of terminal fault test-duty T100s;

$d\alpha$ = 18°;

τ is the DC time constant of the rated short-circuit breaking current;

$\hat{I}$ is the p.u. value of the peak current of the first-pole-to-clear, the last-pole-to-clear for k_{pp} = 1,5 and the second-pole-to-clear for k_{pp} = 1,3 or 1,2 related to the peak value of the symmetrical short-circuit current;

Δt_1 is the duration of the major loop of the first-pole-to-clear;

Δt_2 is the duration of the extended major loop of the last-pole-to-clear for k_{pp} = 1,5;

Δt_3 is the duration of the extended major loop of the second-pole-to-clear for k_{pp} = 1,3 or 1,2;

Δt_{a1} is the time interval between the moment of current interruption in the first-pole-to-clear after a major loop with the required asymmetry and the moment of the first preceding current zero;

Δt_{a2} is the time interval between the moment of current interruption in the last-pole-to-clear after an extended major loop with the required asymmetry for k_{pp} = 1,5 and the moment of the second preceding current zero;

Δt_{a3} is the time interval between the moment of current interruption in the second-pole-to-clear after an extended major loop with the required asymmetry for k_{pp} = 1,3 or 1,2 and the moment of the second preceding current zero.

For explanation of Δt_1, Δt_2, Δt_3, Δt_{a1}, Δt_{a2} and Δt_{a3} see Figure 60.

6.102.10.2 Three-phase tests

6.102.10.2.1 Test-duty T10, T30, T60, T100s, T100s(b)

For these tests, the tripping impulse shall be advanced by 40 electrical degrees (40°) between each opening operation. For T100s(b), see note in 6.106.

A graphical representation of an example of the three valid breaking operations for the first-pole-to-clear factor 1,5 is given in Figure 29 and for the first-pole-to-clear factor 1,3 or 1,2 in Figure 30.

6.102.10.2.2 Test-duty T100a

The initiation of the short-circuit shall be changed between tests in order to transfer the required asymmetry criteria from phase to phase.

The breaking operations are valid if the prospective current meets the following asymmetry criteria:

– the peak short-circuit current $\hat{I}$ during the last loop prior to interruption is between 90 % and 110 % of the required value and

– the duration of the short-circuit current loop Δt prior to interruption is between 90 % and 110 % of the required value.

Tables 39 and 40 give the required prospective values of the peak short-circuit current and loop duration that shall be attained by the last major loop prior to the interruption. In these tables the k_{pp} factors of 1,3 and 1,2 are combined because of very small differences in arcing time requirements.

When the last current loop parameters are within the prescribed tolerances, the resulting deviations on the DC component at current zero, the associated di/dt and the following TRV peak value are within acceptable limits compared to those calculated with rated values.

The intention is to achieve three valid tests and the duty is satisfactory if following conditions are met. There is no preferred order to demonstrate the three valid tests.

a) One operation where arc extinction occurs in the first-pole-to-clear at the end of a major current loop in the phase with the required asymmetry criteria and with the longest possible arcing time.

   The longest possible arcing time t_{arc1} for the first-pole-to-clear is achieved, when following condition is met:

$$t_{arc1} = (t_{a100s} - T \times \frac{d\alpha}{360°}) + \Delta t_{a1}$$

b) One operation where arc extinction occurs at the end of an extended major current loop in the last-pole-to-clear or in the second-pole-to-clear with the required asymmetry criteria and with the longest possible arcing time.

   – The longest possible arcing time t_{arc2} for the last-pole-to-clear for circuit-breakers rated for k_{pp} = 1,5 is achieved, when following condition is met:

$$t_{arc2} = (t_{a100s} - T \times \frac{d\alpha}{360°}) + \Delta t_{a2}$$

   – The longest possible arcing time t_{arc3} for the second-pole-to-clear for circuit-breakers rated for k_{pp} = 1,3 or 1,2 is achieved, when following condition is met:

$$t_{arc3} = (t_{a100s} - T \times \frac{d\alpha}{360°}) + \Delta t_{a3}$$

c) If the required conditions of a) and b) are fulfilled in a third operation, arc extinction may occur at the end

   – of a major current loop for first-pole-to-clear conditions, or
   – of an extended major current loop for last-pole-to-clear conditions for circuit-breakers rated for k_{pp} = 1,5, or
   – of an extended major current loop for second-pole-to-clear conditions for circuit-breakers rated for k_{pp} = 1,3 or 1,2.

   There are no further requirements regarding arcing times.

Δt_{a1}, Δt_{a2} and Δt_{a3} are the relevant time parameters to be selected from Tables 39 and 40.

The conditions for current interruption in test-duty T100a for the last-pole-to-clear for circuit-breakers rated for k_{pp} = 1,3 or 1,2 are covered by the tests in test-duty T100s.

Some circuit-breakers will not clear at the end of a major loop after the required arcing time. However, this test is valid if the circuit-breaker cleared the subsequent minor current loop and it is proven that the longest possible arc-duration was achieved.

If the behaviour of the circuit-breaker is such that the required conditions of a) and b) are not fulfilled, the relevant tests shall be continued by changing the tripping of the circuit-breaker in steps of 18°. If during tests the required arcing times are not achieved because of minimum arcing times differing from t_{a100s} the maximum achievable arcing times shall be demonstrated. The total number of tests is limited to 6, when attempting to meet the above mentioned requirements. The test duty is valid no matter which arcing times have been obtained.

The circuit-breaker may be reconditioned with renewable parts or replaced by a second one before the extended operations (see 6.102.9.5).

A graphical representation of an example of the three valid breaking operations for the first-pole-to-clear factor k_{pp} = 1,5 is given in Figure 31 and for the first-pole-to-clear factor k_{pp} = 1,3 or 1,2 in Figure 32.

Table 39 – Last current loop parameters in three-phase tests and in single-phase tests in substitution for three-phase conditions in relation with short-circuit test-duty T100a – Tests for 50 Hz operation

τ ms	Minimum clearing time ms	$\hat{I}$ p.u.	k_{pp} = 1,5 , 1,3 or 1,2 Δt_1 ms	Δt_{a1} ms	k_{pp} = 1,5 Δt_2 ms	Δt_{a2} ms	k_{pp} = 1,3 or 1,2 Δt_3 ms	Δt_{a3} ms
45	10,0 < t ≤ 27,0	1,52	13,6	4,1	15,0	10,6	14,4	10,0
	27,0< t ≤ 47,5	1,33	12,2	3,8	13,7	9,8	13,1	9,1
	47,5 < t ≤ 68,0	1,21	11,4	3,7	12,9	9,2	12,3	8,6
60	10,0 < t ≤ 27,0	1,61	14,2	4,3	15,6	11,1	15,1	10,5
	27,0 < t ≤ 47,5	1,44	12,9	4,0	14,3	10,2	13,8	9,6
	47,5 < t ≤ 67,5	1,31	12,1	3,8	13,6	9,7	12,9	9,1
	67,5 < t ≤ 88,0	1,22	11,4	3,7	13,0	9,3	12,3	8,6
75	10,0 < t ≤ 27,0	1,67	14,8	4,4	16,1	11,3	15,6	10,8
	27,0 < t ≤ 47,5	1,51	13,4	4,2	14,9	10,6	14,3	10,0
	47,5 < t ≤ 67,5	1,39	12,6	3,9	14,1	10,1	13,4	9,4
	67,5 < t ≤ 87,5	1,30	12,0	3,8	13,5	9,7	12,8	9,0
	87,5< t ≤ 108,0	1,23	11,5	3,7	13,1	9,3	12,4	8,7
120	10,0 < t ≤ 27,0	1,78	15,7	4,8	17,0	11,9	16,6	11,4
	27,0 < t ≤ 47,0	1,66	14,6	4,4	15,9	11,3	15,3	10,8
	47,0 < t ≤ 67,5	1,56	13,8	4,3	15,2	10,8	14,6	10,3
	67,5 < t ≤ 87,5	1,47	13,2	4,1	14,6	10,4	14,0	9,8
	87,5 < t ≤ 108,0	1,40	12,6	4,0	14,1	10,1	13,5	9,5

Table 40 – Last current loop parameters in three-phase tests and in single-phase tests in substitution for three-phase conditions in relation with short-circuit test-duty T100a – Tests for 60 Hz operation

τ ms	Minimum clearing time ms	$\hat{I}$ p.u.	k_{pp} = 1,5 , 1,3 or 1,2 Δt_1 ms	Δt_{a1} ms	k_{pp} = 1,5 Δt_2 ms	Δt_{a2} ms	k_{pp} = 1,3 or 1,2 Δt_3 ms	Δt_{a3} ms
45	8,5 < t ≤ 22,5	1,58	11,6	3,5	12,8	9,1	12,4	8,6
	22,5 < t ≤ 39,5	1,40	10,5	3,3	11,8	8,4	11,2	7,9
	39,5 < t ≤ 56,5	1,27	9,8	3,1	11,1	7,9	10,6	7,4
	56,5 < t ≤ 73,0	1,19	9,3	3,0	10,7	7,6	10,1	7,1
60	8,5 < t ≤ 22,5	1,66	12,2	3,7	13,3	9,4	12,9	9,0
	22,5 < t ≤ 39,5	1,50	11,1	3,4	12,4	8,8	11,8	8,3
	39,5 < t ≤ 56,5	1,38	10,4	3,3	11,7	8,3	11,2	7,8
	56,5 < t ≤ 73,0	1,29	9,9	3,1	11,2	8,0	10,6	7,5
	73,0 < t ≤ 90,0	1,22	9,5	3,1	10,8	7,7	10,2	7,2
75	8,5 < t ≤ 22,5	1,72	12,6	3,8	13,7	9,6	13,3	9,2
	22,5 < t ≤ 39,5	1,57	11,6	3,6	12,8	9,1	12,3	8,6
	39,5 < t ≤ 56,0	1,46	10,9	3,4	12,1	8,6	11,6	8,1
	56,0 < t ≤ 73,0	1,37	10,3	3,2	11,6	8,3	11,1	7,8
	73,0 < t ≤ 90,0	1,30	9,9	3,1	11,2	8,0	10,7	7,5
	90,0 < t ≤ 106,5	1,24	9,6	3,1	10,9	7,8	10,4	7,3
120	8,5 < t ≤ 22,5	1,81	13,4	4,1	14,4	10,1	14,1	9,7
	22,5 < t ≤ 39,0	1,71	12,5	3,8	13,6	9,6	13,2	9,2
	39,0 < t ≤ 56,0	1,62	11,8	3,7	13,0	9,3	12,5	8,8
	56,0 < t ≤ 73,0	1,54	11,3	3,5	12,5	8,9	12,0	8,5
	73,0 < t ≤ 89,5	1,47	10,9	3,4	12,1	8,7	11,6	8,1
	89,5 < t ≤ 106,5	1,41	10,6	3,3	11,8	8,4	11,3	7,9

6.102.10.2.3 Tests for covering the conditions for k_{pp} = 1,3 and k_{pp} = 1,5

In order to cover the performance for k_{pp} = 1,3 and k_{pp} = 1,5, two separate series of duties with their specific earthing of test circuits as described in 6.103.3 should be performed.

If a complete series of test-duties demonstrating the circuit-breaker performance for k_{pp} = 1,5 is already performed, it is not necessary to repeat all terminal fault test-duties prescribed by this standard for demonstrating the performance of the circuit-breaker for k_{pp} = 1,3. In that case, test-duties T100s and T100a shall be repeated with a test-circuit simulating the earthing condition of an effectively earthed neutral system (k_{pp} = 1,3, see 6.103.3).

The repetition of test-duties T100s and T100a with a three-phase circuit for an effectively earthed neutral system can, as an alternative, be replaced by additional single-phase tests specified below. In this case the three-phase verification test according to 6.102.4.1 is not required. Single-phase tests are allowed for all types of circuit-breakers except for metal enclosed circuit-breakers with three phases in one enclosure where direct gas dynamic interaction between phases is involved, as per 6.102.3.2 and O.4.1.

The tests shall be carried with the following parameters:

– a first test shall demonstrate the performance of the second-pole-to-clear under symmetrical fault conditions in an effectively earthed neutral system. The arcing time shall be set to:

$$t_{arc} = t_{a100s} + T \times \frac{119°}{360°}$$

The TRV parameters shall be adjusted in accordance with Table 41.

The test voltage is $1{,}26 \times \frac{U_r}{\sqrt{3}}$ and may be reduced to $U_r/\sqrt{3}$ after one half cycle of rated frequency after current interruption.

Table 41 – TRV parameters for single-phase tests in substitution for three-phase tests to demonstrate the interruption of the second-pole-to-clear for k_{pp} = 1,3

k_{pp}	Rated voltage					
	U_r < 100 kV 2-parameter-TRV		$U_r \geq$ 100 kV 4-parameter-TRV			
	$u_{c,sp}$	$t_{3,sp}$	$u_{1,sp}$	$t_{1,sp}$	$u_{c,sp}$	$t_{2,sp}$
1,3	$1{,}26 \times k_{af} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_3 \times u_{c,sp}/u_c$	$0{,}95 \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_1 \times u_{1,sp}/u_1$	$1{,}26 \times k_{af} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	a

a 4 × $t_{1,sp}$ for rated voltages from 100 kV up to and including 800 kV.

– a second test shall demonstrate the performance of the third-pole-to-clear under symmetrical fault conditions in an effectively earthed neutral system. The arcing time shall be set to:

$$t_{arc} = t_{a100s} + T \times \frac{162°}{360°}$$

The TRV-parameters have to be adjusted according to Table 42:

Table 42 – TRV parameters for single-phase tests in substitution for three-phase tests to demonstrate the interruption of the third-pole-to-clear for k_{pp} = 1,3

k_{pp}	Rated voltage					
	U_r < 100 kV 2-parameter-TRV		$U_r \geq$ 100 kV 4-parameter-TRV			
	$u_{c,sp}$	$t_{3,sp}$	$u_{1,sp}$	$t_{1,sp}$	$u_{c,sp}$	$t_{2,sp}$
1,3	$k_{af} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_3 \times u_{c,sp}/u_c$	$0{,}75 \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_1 \times u_{1,sp}/u_1$	$k_{af} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	a

a 4 × $t_{1,sp}$ for rated voltages from 100 kV up to and including 800 kV, 3 × $t_{1,sp}$ for rated voltages above 800 kV.

The single-phase tests with symmetrical currents can be combined using the prospective TRV peak value required for the second-pole-to-clear with the arcing time prescribed for the third-pole-to-clear.

– an additional single-phase fault test with an asymmetrical current that fulfils the asymmetry criteria as defined in 6.102.10.2.2 shall be performed. This additional test demonstrates the performance of the second and third-pole-to-clear under asymmetrical fault current on the extended major loop.

The test voltage to be applied is $1{,}26 \times \frac{U_r}{\sqrt{3}}$ for the verification of k_{pp} = 1,3;

and may be reduced to $U_r/\sqrt{3}$ after one quarter of a cycle of rated frequency after current interruption.

When the last current loop parameters are within the prescribed tolerances, the resulting deviations on the DC component at current zero, the associated di/dt and the following TRV peak value are within acceptable limits compared to those calculated with rated values.

The arcing time shall be the maximum arcing time calculated for a three-phase condition considering the minimum arcing time value found during test-duty T100s performed for k_{pp} = 1,5.

$$t_{arc} = (t_{a100s} - T \times \frac{d\alpha}{360°}) + \Delta t_{a3}$$

where

Δt_{a3} is the relevant time parameter to be selected from Tables 39 and 40.

6.102.10.3 Single-phase tests in substitution for three-phase conditions, out-of-phase and short-line fault tests

6.102.10.3.1 General

The procedure for establishing a minimum arcing time might result in a test with maximum arcing time or with an arcing time in excess of the maximum arcing time. The aim of the following single-phase tests is to satisfy the conditions of the first-pole-to-clear, the second-pole-to-clear and the last pole-to-clear for each test-duty in one test circuit.

The following procedures are applicable if all operations of the rated operating sequence fulfil the requirements of 5.101.

6.102.10.3.2 Test-duties T10, T30, T60, T100s and T100s(b), OP1 and OP2, L_{90}, L_{75} and L_{60}

A valid breaking operation shall demonstrate interruption with an arcing time as small as possible. The resultant arcing time is known as the minimum arcing time ($t_{arc\ min}$). This is established when any extra delay in the contact separation with respect to the current waveform results in interruption at the next current zero. This minimum arcing time is found by changing the setting of the tripping impulse by steps of 18°.

Another valid breaking operation shall demonstrate interruption with the maximum arcing time. The required maximum arcing time is known as $t_{arc\ max}$ and is determined as follows:

– for circuit-breakers rated for k_{pp} = 1,5, by

$$t_{arc\ max} = t_{arc\ min} + T \times \frac{132°}{360°};$$

– for circuit-breakers rated for k_{pp} = 1,3 or 1,2 and short-line fault tests, by

$$t_{arc\ max} = t_{arc\ min} + T \times \frac{162°}{360°};$$

where

$t_{arc\ min}$ is the minimum arcing time obtained from the first valid operation;

Another valid breaking operation shall demonstrate interruption with an arcing time which is approximately equal to the average value of the minimum arcing time and the required maximum arcing time. This arcing time is known as the medium arcing time ($t_{arc\ med}$) and is determined by

$$t_{arc\ med} = (t_{arc\ max} + t_{arc\ min})/2$$

If the circuit-breaker does not interrupt at the expected current zero with medium and/or maximum arcing time but at a subsequent current zero no additional testing is required.

A graphical representation of an example of the three valid breaking operations for the first-pole-to-clear factor 1,5 is given in Figure 33 and for the first-pole-to-clear factor 1,3 or 1,2 in Figure 34.

6.102.10.3.3 Test-duty T100a

The breaking operations are valid if the prospective current meets the following asymmetry criteria as given in 6.102.10.2.2:

Tables 39 and 40 give the required values of the peak short-circuit current and loop duration that shall be attained by the last loop prior to the interruption. All tests shall be performed with the current parameters of the first pole-to-clear.

A breaking operation shall demonstrate interruption at the end of the major loop with an arcing time equivalent to the maximum arcing time under three-phase conditions t_{arc1} of the first pole-to-clear.

This is achieved, when following condition is met:

$$t_{arc1} = t_{a100s} + \Delta_{ta1} - T \times \frac{d\alpha}{360^\circ}$$

Another breaking operation shall demonstrate interruption at the end of the major loop with an arcing time equivalent to the maximum arcing time under three-phase conditions

– t_{arc2} for the last-pole-to clear of circuit-breakers rated for k_{pp} = 1,5

  This is achieved, when following condition is met:

$$t_{arc2} = t_{a100s} + \Delta t_{a2} - T \times \frac{d\alpha}{360^\circ}$$

– t_{arc3} for the second-pole-to-clear for circuit-breakers rated for k_{pp} = 1,3 or 1,2.

  This is achieved, when following condition is met:

$$t_{arc3} = t_{a100s} + \Delta t_{a3} - T \times \frac{d\alpha}{360^\circ}$$

Δt_{a1}, Δt_{a2} and Δt_{a3} are the relevant time parameters to be selected from Tables 39 and 40.

Another breaking operation shall demonstrate the conditions of interruption after a major loop as first-pole-to-clear or after a major extended loop as last-pole-to-clear for circuit-breakers rated for k_{pp} = 1,5 or after a major extended loop as second-pole-to-clear for circuit-breakers rated for k_{pp} = 1,2 or 1,3. There are no further requirements regarding arcing times.

If the circuit-breaker fails to interrupt after the required major loop and interrupts after the subsequent minor loop, the required maximum arcing time is extended by the duration of this minor loop.

If the behaviour of the circuit-breaker is such that the required conditions are not fulfilled, the relevant tests shall be repeated by changing the tripping of the circuit-breaker accordingly. The total number of tests is limited to 6, when attempting to meet the above mentioned requirements. After 6 tests the test duty is valid regardless of the arcing times that have been obtained.

The circuit-breaker may be reconditioned with renewable parts before the extended operations (see 6.102.9.5). Another test sample can also be used for the extended operations.

A graphical representation of an example of the three valid breaking operations for k_{pp} = 1,5 is given in Figure 35 and for k_{pp} = 1,3 and 1,2 in Figure 36.

6.102.10.3.4 Tests combining the conditions for effectively and non-effectively earthed neutral systems

Both conditions, k_{pp} = 1,5 and k_{pp} = 1,3 may be combined in one test series. The transient and power frequency voltages to be used shall be those applicable to a non-effectively earthed neutral system and the arcing times shall be those applicable to an effectively earthed neutral system.

For test-duty T100a the arcing times shall be those applicable to a non-effectively earthed neutral system.

6.102.10.3.5 Splitting of test-duties in test series taking into account the associated TRV for each pole-to-clear

It is recognised that single-phase tests in substitution of three-phase conditions are more severe than three-phase tests because the arcing time of the last-pole-to-clear is used together with the prospective TRV of the first-pole-to-clear. As an alternative, the manufacturer may choose to split each test-duty into two or three separate test series, each test series demonstrating a successful interruption with the minimum and maximum arcing times for each pole-to-clear with its associated prospective TRV. The standard multipliers for the prospective TRV values for the second and third clearing poles for rated voltages above 72,5 kV are given in Table 6. They are applicable for test duties T10, T30, T60, T100s, OP1 and OP2.

Reconditioning of the circuit-breaker is permitted after a minimum of three interruptions and shall comply with the requirements of 6.102.9.5.

Assuming that the simultaneity of poles during all operations of the rated operating sequence is within the tolerances of 5.101, for tests with symmetrical current the interrupting window for each phase is within the band stated in Table 23, if the instant of interruption for the first clearing pole with the minimum arcing time is taken as reference. A graphical representation of the interrupting window and the voltage factor k_p, determining the TRV of the individual pole, is given for terminal fault in Figure 37 and Figure 58 for systems with a first-pole-to-clear factor of 1,2 and 1,3 and in Figure 38 for systems with a first-pole-to-clear factor of 1,5.

Table 23 – Interrupting window for tests with symmetrical current

First-pole-to-clear factor	First clearing pole °	Second clearing pole °	Third clearing pole °
1,5 (Terminal fault) 2,5 (Out-of-phase)	0 to 42	90 to 132	90 to 132
1,3 (Terminal fault) 2,0 (Out-of-phase)	0 to 42	77 to 119	120 to 162
1,2 (Terminal fault) 2,0 (Out-of-phase)	0 to 42	71 to 113	120 to 162

6.103.4 Connection of the test circuit to circuit-breaker

Delete, in the first paragraph, "with respect to voltage to earth"*.*

6.104.2.1 General

Replace the first dashed item of the list as follows:

– making at the peak of the voltage wave (within the range between –15 ° and +15 °), leading to a symmetrical short-circuit current and the longest pre-striking arc;

Delete NOTE 1, renumber NOTE 2 to NOTE 1 and NOTE 3 to NOTE 2.

6.104.4 DC component of short-circuit breaking current

Delete the last two paragraphs.

6.104.5.1 General

Replace, in the fourth paragraph added by Amendment 1, the reference 4.102.2 to 6.104.6.

Add, after the fourth paragraph added by Amendment 1, the following new paragraph:

The special case of circuit-breakers with a connection of low capacitance to a transformer is covered in Annex M.

Replace the fifth paragraph and item a) added by Amendment 1, by the following:

TRV parameters are a function of the rated voltage (U_r), the rated first-pole-to-clear factor (k_{pp}) and the amplitude factor (k_{af}). The values of k_{pp} and k_{af} are stated in Tables 24, 25, 26, 27, 43, 44, 45, 46, 47, 48, 49 and 50. The first-pole-to-clear factor k_{pp} is given in 4.102.

a) *For rated voltages less than 100 kV*

A representation by two parameters of the prospective TRV is used for all test-duties.

– In Tables 24 and 43, for class S1 circuit-breakers.

TRV peak value $u_c = k_{pp} \times k_{af} \sqrt{(2/3)} \times U_r$ where k_{af} is equal to 1,4 for test-duty T100, 1,5 for test-duty T60, 1,6 for test duty T30 and 1,7 for test duty T10, 1,25 for out-of-phase breaking.

Time t_3 for test-duty T100 is taken from Tables 24 and 43. Time t_3 for test-duties T60, T30 and T10 is obtained by multiplying the time t_3 for test-duty T100 by 0,44 (for T60), 0,22 (for T30) and 0,22 (for T10).

– In Table 25 and 44, for class S2 circuit-breakers.

TRV peak value $u_c = k_{pp} \times k_{af} \sqrt{(2/3)} \times U_r$ where k_{af} is equal to 1,54 for test-duty T100 and the supply side circuit for short-line fault, 1,65 for test-duty T60, 1,74 for test duty T30 and 1,8 for test duty T10, 1,25 for out-of-phase breaking.

Time t_3 for test-duty T100 is taken from Tables 25 and 44. Time t_3 for test-duties T60, T30 and T10 is obtained by multiplying the time t_3 for test-duty T100 by 0,67 (for T60), 0,40 (for T30) and 0,40 (for T10).

– Time delay t_d for test-duty T100 is 0,15t_3 for cable systems, 0,05t_3 for line systems, 0,05t_3 for the supply side circuit for short-line fault.
– Time delay t_d is 0,15t_3 for test-duties T60, T30 and T10 and for out-of-phase breaking.
– Voltage $u' = u_c/3$.
– Time t' is derived from u', t_3 and t_d according to Figure 11, $t' = t_d + t_3/3$.

Table 24 – Standard values of prospective transient recovery voltage for class S1 circuit-breakers – Rated voltage higher than 1 kV and less than 100 kV – Representation by two parameters

Replace the existing title by the as follows:

Table 24 – Values of prospective TRV for class S1 circuit-breakers for k_{pp} = 1,5

Add, after Table 24, the following table:

Table 43 – Values of prospective TRV for class S1 circuit-breakers for k_{pp} = 1,3

Rated voltage U_r kV	Test-duty	k_{pp} p.u	Amplitude factor k_{af} p.u	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV[a] u_c/t_3 kV/µs
3,6	T100	1,3	1,4	5,3	35	5	1,8	17	0,15
	T60	1,3	1,5	5,7	15	2	1,9	7	0,37
	T30	1,3	1,6	6,1	8	1,2	2,0	3,8	0,79
	T10	1,5	1,7	7,5	9	1,4	2,5	4,4	0,83
4,76[b]	T100	1,3	1,4	7,1	37	6	2,4	18	0,19
	T60	1,3	1,5	7,6	17	3	2,5	8	0,46
	T30	1,3	1,6	8,1	8,7	1,3	2,7	4,2	0,93
	T10	1,5	1,7	9,9	10	1,5	3,3	4,8	0,99
7,2	T100	1,3	1,4	10,7	45	7	4,1	22	0,24
	T60	1,3	1,5	11,5	19	3	3,8	9	0,60
	T30	1,3	1,6	12,2	10	1,5	4,1	5	1,28
	T10	1,5	1,7	15,0	11	2	5,0	5	1,36
8,25[b]	T100	1,3	1,4	12,3	45	7	4,1	22	0,27
	T60	1,3	1,5	13,1	20	3	4,4	10	0,66
	T30	1,3	1,6	14,0	10	1,5	4,7	5	1,47
	T10	1,5	1,7	17,2	11	2	5,7	6	1,56
12	T100	1,3	1,4	17,8	52	8	5,9	25	0,34
	T60	1,3	1,5	19,1	24	4	6,4	12	0,81
	T30	1,3	1,6	20,4	11	2	6,8	5	1,81
	T10	1,5	1,7	25,0	13	2	8,3	6	1,92
15[b]	T100	1,3	1,4	22,3	57	9	7,4	28	0,39
	T60	1,3	1,5	23,9	25	4	8,0	12	0,95
	T30	1,3	1,6	25,5	13	2	8,5	6	1,96

Rated voltage U_r kV	Test-duty	k_{pp} p.u	Amplitude factor k_{af} p.u	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV[a] u_c/t_3 kV/µs
	T10	1,5	1,7	31,2	15	2	9,8	7	2,08
17,5	T100	1,3	1,4	26,0	62	9	8,7	30	0,42
	T60	1,3	1,5	27,9	27	4	9,3	13	1,04
	T30	1,3	1,6	29,7	14	2	9,9	7	2,14
	T10	1,5	1,7	36,4	16	2	12,1	8	2,28
24	T100	1,3	1,4	35,7	76	11	11,9	37	0,47
	T60	1,3	1,5	38,2	33	5	12,7	16	1,16
	T30	1,3	1,6	40,8	17	3	13,6	8	2,47
	T10	1,5	1,7	50	19	3	16,7	9	2,63
27[b]	T100	1,3	1,4	40,1	78	12	12,8	38	0,51
	T60	1,3	1,5	43,0	35	5	13,7	17	1,25
	T30	1,3	1,6	45,8	17	3	14,6	8	2,65
	T10	1,5	1,7	56,2	20	3	17,9	10	2,82
36	T100	1,3	1,4	53,5	94	14	17,8	45	0,57
	T60	1,3	1,5	57,3	42	6	19,1	20	1,38
	T30	1,3	1,6	61,1	21	3	20,4	10	2,94
	T10	1,5	1,7	75,0	24	4	25,0	12	3,13
38[b]	T100	1,3	1,4	56,5	94	14	18,8	46	0,60
	T60	1,3	1,5	60,5	42	6	20,2	20	1,45
	T30	1,3	1,6	64,5	21	3	21,5	10	3,10
	T10	1,5	1,7	79,1	24	4	26,4	12	3,30
52	T100	1,3	1,4	77,3	114	17	25,8	55	0,68
	T60	1,3	1,5	82,8	50	8	27,6	24	1,65
	T30	1,3	1,6	88,3	25	4	29,4	12	3,52
	T10	1,5	1,7	108	29	4	36,1	14	3,72
72,5	T100	1,3	1,4	108	144	22	36,0	70	0,75
	T60	1,3	1,5	115	63	10	38,3	31	1,82
	T30	1,3	1,6	123	31	5	41,0	15	3,94
	T10	1,5	1,7	151	36	5	50,3	18	4,19

[a] RRRV = rate-of-rise of recovery voltage.

[b] Used in some countries.

NOTE First-pole-to-clear factor k_{pp} = 1,5 is specified to cover transformer-limited fault conditions with X_0/X_1 higher than 3,0 (for example non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems). The TRV specified covers also cases of 3-phase line faults with effectively earthed neutral systems (k_{pp} = 1,3) where coupling between phases can lead to an amplitude factor of 1,76.

Table 25 – Standard values of prospective transient recovery voltage[c] for class S2 circuit-breakers – Rated voltage equal to or higher than 15 kV and less than 100 kV – Representation by two parameters

Replace the title of the existing table as follows:

Table 25 – Values of prospective TRV for class S2 circuit-breakers for k_{pp} = 1,5

*Replace " c " at the bottom of the table by the word "*NOTE*".*

Add, after Table 25, the following table:

Table 44 – Values of prospective TRV for class S2 circuit-breakers for for k_{pp} = 1,3

Rated voltage U_r kV	Test-duty	First-pole-to-clear factor k_{pp} p.u	Amplitude factor k_{af} p.u	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV[a] u_c/t_3 kV/µs
15,5[b]	T100	1,3	1,54	25,3	27	2 (4)	8,2	11 (13)	0,94
	T60	1,3	1,65	27,2	18	3	8,8	9	1,49
	T30	1,3	1,74	28,0	11	2	9,2	5	2,65
	T10	1,5	1,80	34,2	12,5	2	11,0	6	2,76
17,5	T100	1,3	1,54	28,6	30	2 (5)	9,5	12 (15)	0,97
	T60	1,3	1,65	30,7	20	3	10,2	10	1,53
	T30	1,3	1,74	32,3	12	2	10,8	6	2,66
	T10	1,5	1,80	38,6	14	2	12,9	7	2,76
24	T100	1,3	1,54	39,2	37	2 (6)	13,1	14 (18)	1,05
	T60	1,3	1,65	42,0	25	4	14,0	12	1,67
	T30	1,3	1,74	44,3	15	2	14,8	7	3,01
	T10	1,5	1,80	52,9	17	3	17,6	8	3,11
25,8[b]	T100	1,3	1,54	42,2	39	2 (6)	12,8	15 (19)	1,08
	T60	1,3	1,65	45,2	26	4	15,1	13	1,74
	T30	1,3	1,74	47,7	16	2	15,9	8	3,06
	T10	1,5	1,80	56,9	18	3	19,0	9	3,16
36	T100	1,3	1,54	58,9	50	3 (8)	19,6	20 (25)	1,19
	T60	1,3	1,65	63,1	33	5	21,0	16	1,91
	T30	1,3	1,74	66,5	20	3	22,2	10	3,33
	T10	1,5	1,80	79,4	23	3	26,5	11	3,45
38[b]	T100	1,3	1,54	62,1	51	3 (8)	20,7	20 (25)	1,22
	T60	1,3	1,65	66,6	35	5	22,2	17	1,92
	T30	1,3	1,74	70,2	21	3	23,4	10	3,38
	T10	1,5	1,80	83,8	24	4	28,0	12	3,49
48,3[b]	T100	1,3	1,54	79,0	61	3 (9)	26,3	23 (29)	1,30
	T60	1,3	1,65	84,6	41	6	28,2	20	2,07
	T30	1,3	1,74	89,2	24	4	29,7	12	3,68
	T10	1,5	1,80	107	28	4	35,5	13,5	3,82
52	T100	1,3	1,54	85,0	64	3 (10)	28,3	24 (31)	1,33
	T60	1,3	1,65	91,1	43	7	30,4	21	2,10
	T30	1,3	1,74	96,0	26	4	32,0	13	3,70
	T10	1,5	1,80	115	30	4	38,3	14	3,83
72,5	T100	1,3	1,54	119	81	4 (12)	39,5	31 (39)	1,47
	T60	1,3	1,65	127	54	8	42,3	26	2,35
	T30	1,3	1,74	134	32	5	44,6	16	4,19
	T10	1,5	1,80	160	37	6	53,3	18	4,32

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

NOTE k_{pp} = 1,5 is specified to cover transformer-limited fault conditions with X_0/X_1 higher than 3,0 (for example non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems). The TRV specified covers also cases of 3-phase line faults with effectively earthed neutral systems (k_{pp} = 1,3) where coupling between phases can lead to an amplitude factor of 1,76.

6.104.5.2 Test-duties T100s and T100a

Replace the first three paragraphs by the following:

For rated voltages less than 100 kV, the specified values are given in

– Tables 24 and 43 for class S1 circuit-breakers;

– Tables 25 and 44 for class S2 circuit-breakers.

For rated voltages of 100 kV and above, the specified values are given in Tables 26 and 27.

The specific reference lines, delay lines and ITRV are given by the values in Tables 6, 7, 24, 25, 26 and 27.

*Replace, in the last two paragraphs added by Amendment 1, "*SLF*" by "*L_{90}" (2 occurrences).

Replace the last sentence of the penultimate paragraph added by Amendment 1 by the following:

Therefore the ITRV requirements for test-duties T100s and T100a are considered to be covered when L_{90} is performed using a line with a time delay less than 100 ns and a surge impedance of 450 Ω.

Replace, in the last paragraph added by Amendment 1 the phrase " Where short-line fault duties with a time delay less than 100 ns are used" by the following "Where short-line fault test-duty L_{90} with a time delay less than 100 ns is used".

6.104.5.3 Test duty T60

Replace the first paragraph by the following:

For rated voltages less than 100 kV, the specified values are given in

– Tables 24 and 43 for class S1 circuit-breakers;

– Tables 25 and 44 for class S2 circuit-breakers.

6.104.5.4 Test duty T30

Replace item a) modified by Amendment 1 by the following:

a) For rated voltages less than 100 kV, the specified values are given in
   - Tables 24 and 43 for class S1 circuit-breakers;
   - Tables 25 and 44 for class S2 circuit-breakers.

In case that small values of time $t3$ cannot be met, the shortest time that can be met shall be used. The values used shall be stated in the test report.

6.104.5.5 Test duty T10

Modify item a) modified by Amendment 1 by the following:

a) For rated voltages less than 100 kV, the specified values are given in
   - Tables 24 and 43 for class S1 circuit-breakers;
   - Tables 25 and 44 for class S2 circuit-breakers.

6.104.5.6 Test-duties OP1 and OP2

Replace the existing text by the following new text and new tables:

For rated voltages up to and including 72,5 kV, the specified values are given in the following tables:

- Table 45 for class S1 circuit-breakers for use in non-effectively earthed neutral systems;
- Table 46 for class S2 circuit-breakers for use in non-effectively earthed neutral systems;
- Table 47 for class S1 circuit-breakers for use in effectively earthed neutral systems;
- Table 48 for class S2 circuit-breakers for use in effectively earthed neutral systems.

For rated voltages of 100 kV and above, the specified values are given in Tables 26 and 27. Where two values of time, t_2, t_d and t', are given, they indicate the lower and the upper limits that shall be used for testing.

Table 45 – Values of prospective TRV for out-of-phase tests on class S1 circuit-breakers for k_{pp} = 2,5

Rated voltage U_r kV	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_c/t_3 kV/µs
3,6	2,5	1,25	9,2	82	12	3,1	40	0,11
4,76 [b]	2,5	1,25	12,1	88	13	4,0	43	0,14
7,2	2,5	1,25	18,4	102	15	6,1	49	0,18
8,25 [b]	2,5	1,25	21,1	104	16	7,0	50	0,20
12	2,5	1,25	30,6	122	18	10,2	59	0,25
15 [b]	2,5	1,25	38,3	132	20	12,8	64	0,29
17,5	2,5	1,25	44,7	142	21	14,9	69	0,31
24	2,5	1,25	61,2	174	26	20,4	84	0,35
27 [b]	2,5	1,25	68,9	182	27	22,9	88	0,38
36	2,5	1,25	91,9	218	33	30,6	105	0,42
38 [b]	2,5	1,25	97,0	218	33	32,3	105	0,45
48,3 [b]	2,5	1,25	123	250	38	41,1	121	0,49
52	2,5	1,25	133	262	39	44,2	127	0,51
72,5	2,5	1,25	185	330	50	61,7	160	0,56

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

Table 46 – Values of prospective TRV for out-of-phase tests on class S2 circuit-breakers for k_{pp} = 2,5

Rated voltage U_r kV	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_c/t_3 kV/µs
15 [b]	2,5	1,25	38,3	62	9	12,8	30	0,62
17,5	2,5	1,25	45	68	10	14,9	33	0,65
24	2,5	1,25	61	86	13	20,4	42	0,71
25,8 [b]	2,5	1,25	66	90	14	21,9	44	0,73
36	2,5	1,25	92	114	17	30,6	55	0,81
38 [b]	2,5	1,25	97	118	18	32,3	57	0,82
48,3 [b]	2,5	1,25	123	140	21	41,1	68	0,88
52	2,5	1,25	133	148	22	44,2	72	0,90
72,5	2,5	1,25	185	186	28	61,7	90	0,99

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

Table 47 – Values of prospective TRV for out-of-phase tests on class S1 circuit-breakers for k_{pp} = 2,0

Rated voltage U_r kV	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_c/t_3 kV/µs
3,6	2,0	1,25	7,3	67	10	2,4	32	0,11
4,76 [b]	2,0	1,25	9,7	69	10	3,2	33	0,14
7,2	2,0	1,25	14,7	82	12	4,9	39	0,18
8,25 [b]	2,0	1,25	16,8	84	13	5,6	41	0,20
12	2,0	1,25	24,5	98	15	8,2	47	0,25
15 [b]	2,0	1,25	30,6	106	16	10,2	51	0,29
17,5	2,0	1,25	35,7	115	17	11,9	56	0,31
24	2,0	1,25	49,0	140	21	16,3	68	0,35
27	2,0	1,25	55,2	146	22	17,6	71	0,38
36	2,0	1,25	73,5	175	26	24,5	86	0,42
38 [b]	2,0	1,25	77,6	172	26	25,9	83	0,45
52	2,0	1,25	106	208	31	35,4	101	0,51
72,5	2,0	1,25	148	264	40	49,3	128	0,56

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

Table 48 – Values of prospective TRV for out-of-phase tests on class S2 circuit-breakers for k_{pp} = 2,0

Rated voltage U_r kV	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_c/t_3 kV/µs
15,5	2,0	1,25	31,6	49	7	10,2	24	0,64
17,5	2,0	1,25	35,7	55	8	11,9	26	0,65
24	2,0	1,25	49,0	69	10	16,3	33	0,71
25,8 [b]	2,0	1,25	52,7	72	11	17,6	35	0,73
36	2,0	1,25	73,5	91	14	24,5	44	0,81
38 [b]	2,0	1,25	77,6	95	14	25,9	46	0,82
48,3 [b]	2,0	1,25	98,6	112	17	32,9	54	0,88
52	2,0	1,25	106	118	18	35,4	57	0,90
72,5	2,0	1,25	148	150	22	49,3	72	0,99

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

Table 26 – Standard values of prospective transient recovery voltage – Rated voltages of 100 kV and above

Replace Table 26, modified by Amendment 1, by the following:

Table 26 – Values of prospective TRV for circuit-breakers rated for k_{pp} = 1,2 or 1,3 – Rated voltages of 100 kV and above

Rated voltage U_r kV	Test-duty	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	First reference voltage u_1 kV	Time t_1 µs	TRV peak value u_c kV	Time t_2 or t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	Rate-of-rise u_1/t_1 u_c/t_3 kV/µs
100	T100	1,3	1,40	80	40	149	160	2 (11)	40	22 (31)	2
	T60	1,3	1,50	80	27	159	162	2-8	40	15-21	3
	T30	1,3	1,54	-	-	163	33	5	54	16	5
	T10	1,5	0,9 × 1,7	-	-	187	27	4	62	13	7
	OP1-OP2	2	1,25	122	80	204	160-320	2-8	61	42-48	1,54
123	T100	1,3	1,40	98	49	183	196	2 (14)	49	26 (38)	2
	T60	1,3	1,50	98	33	196	198	2-10	49	18-26	3
	T30	1,3	1,54	-	-	201	40	6	67	19	5
	T10	1,5	0,9 × 1,7	-	-	230	33	5	77	16	7
	OP1-OP2	2	1,25	151	98	251	196-392	2-10	75	51-59	1,54
145	T100	1,3	1,40	115	58	215	232	2 (16)	58	31 (45)	2
	T60	1,3	1,50	115	38	231	228	2-12	58	21-31	3
	T30	1,3	1,54	-	-	237	47	7	79	23	5
	T10	1,5	0,9 × 1,7	-	-	272	39	6	91	19	7
	OP1-OP2	2	1,25	178	116	296	232-464	2-12	89	60-70	1,54
170	T100	1,3	1,40	135	68	253	272	2 (19)	68	36 (53)	2
	T60	1,3	1,50	135	45	271	270	2-14	68	25-36	3
	T30	1,3	1,54	-	-	278	56	8	93	27	5
	T10	1,5	0,9 × 1,7	-	-	319	46	7	106	22	7
	OP1-OP2	2	1,25	208	136	347	272-544	2-14	104	70-82	1,54
245	T100	1,3	1,40	195	98	364	392	2 (27)	98	51 (76)	2
	T60	1,3	1,50	195	65	390	390	2-20	98	35-52	3
	T30	1,3	1,54	-	-	400	80	12	133	39	5
	T10	1,3	1,76	-	-	459	66	10	153	32	7
	OP1-OP2	2	1,25	300	196	500	392-784	2-20	150	99-117	1,54
300	T100	1,3	1,40	239	119	446	476	2 (33)	119	62 (93)	2
	T60	1,3	1,50	239	80	478	480	2-24	119	42-64	3
	T30	1,3	1,54	-	-	490	98	15	163	47	5
	T10	1,3	1,76	-	-	562	80	12	187	39	7
	OP1-OP2	2	1,25	367	238	612	476-952	2-24	184	121-143	1,54
362	T100	1,3	1,40	288	144	538	576	2 (40)	144	74 (112)	2
	T60	1,3	1,50	288	96	576	576	2-29	144	50-77	3
	T30	1,3	1,54	-	-	592	118	18	197	57	5
	T10	1,3	1,76	-	-	678	97	15	226	47	7

Rated voltage U_r	Test-duty	First-pole-to-clear factor k_{pp}	Amplitude factor k_{af}	First reference voltage u_1	Time t_1	TRV peak value u_c	Time t_2 or t_3	Time delay t_d	Voltage u'	Time t'	Rate-of-rise u_1/t_1 u_c/t_3
	OP1-OP2	2	1,25	443	288	739	576-1152	2-29	222	146-173	1,54
420	T100	1,3	1,40	334	167	624	668	2 (47)	167	86 (130)	2
	T60	1,3	1,50	334	111	669	666	2-33	167	58-89	3
	T30	1,3	1,54	-	-	687	137	21	229	66	5
	T10	1,3	1,76	-	-	787	112	17	262	54	7
	OP1-OP2	2	1,25	514	334	857	668-1336	2-33	257	169-200	1,54
550	T100	1,3	1,40	438	219	817	876	2 (61)	219	111 (171)	2
	T60	1,3	1,50	438	146	876	876	2-44	219	75-117	3
	T30	1,3	1,54	-	-	899	180	27	300	87	5
	T10	1,3	1,76	-	-	1031	147	22	344	71	7
	OP1-OP2	2	1,25	674	438	1123	876-1752	2-44	337	221-263	1,54
800	T100	1,3	1,40	637	318	1189	1272	2 (89)	318	161 (248)	2
	T60	1,3	1,50	637	212	1274	1272	2-64	318	108-170	3
	T30	1,3	1,54	-	-	1308	262	39	436	126	5
	T10	1,3	1,76	-	-	1499	214	32	500	103	7
	OP1-OP2	2	1,25	980	636	1633	1272-2544	2-64	490	320-382	1,54
1 100	T100	1,2	1,50	808	404	1617	1212	2 (113)	404	204 (315)	2
	T60	1,2	1,50	808	269	1617	1212	2-81	404	137-216	3
	T30	1,2	1,54	-	-	1660	332	50	553	161	5
	T10	1,2	1,76	-	-	1897	271	41	632	131	7
	OP1-OP2	2	1,25	-	-	2245	1458	2-73	748	488-559	1,54
1 200	T100	1,2	1,50	882	441	1764	1323	2 (123)	441	222 (343)	2
	T60	1,2	1,50	882	294	1764	1323	2-88	441	149-235	3
	T30	1,2	1,54	-	-	1811	362	54	604	175	5
	T10	1,2	1,76	-	-	2069	296	44	690	143	7
	OP1-OP2	2	1,25	-	-	2449	1590	2-80	816	532-610	1,54

NOTE 1 Where two values of times t_d and t' are given for test duty T100 separated by brackets, the time t_d in brackets is the upper limit of the time delay t_d that can be used for test-duty T100 if short-line fault tests are also made. For such cases, the delay line terminates at t' given in brackets. If this is not the case, the lower values of t_d and t' apply.

Where two values of times t_2, t_d and t' are given for terminal fault test duties T60 and out-of-phase test duties OP1 and OP2, those indicate the lower and upper limits which should be used for testing. The time delay t_d and the time t' during testing should not be shorter than their respective lower limits and should not be longer than their respective upper limits.

NOTE 2 k_{pp} = 1,5 is specified for test-duty T10 for rated voltages of 100 kV up to and including 170 kV to cover transformer-limited fault conditions with X_0/X_1 higher than 3,0 (for example non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems). The TRV specified covers also cases of 3-phase line faults with effectively earthed neutral systems (k_{pp} = 1,3) where coupling between phases can lead to an amplitude factor of 1,76.

Table 27 – Standard values of prospective transient recovery voltage – Rated voltages of 100 kV to 170 kV for non-effectively earthed neutral systems – Representation by four parameters (T100, T60, OP1 and OP2) or two parameters (T30 and T10)

Replace the existing title of as follows:

Table 27 – Values of prospective TRV for circuit-breakers rated for k_{pp} = 1,5 – Rated voltages of 100 kV to 170 kV

Replace NOTE 1, modified by Amendment 1, and NOTE 2 in Table 27 by the following:

NOTE 1 Where two values of times t_d and t' are given for test duty T100 separated by brackets, the time t_d in brackets is the upper limit of the time delay t_d that can be used for test-duty T100 if short-line fault tests are also made. For such cases, the delay line terminates at t' given in brackets. If this is not the case, the lower values of t_d and t' apply.

Where two values of times t_2, t_d and t' are given for terminal fault test duties T60 and out-of-phase test duties OP1 and OP2, those indicate the lower and upper limits which should be used for testing. The time delay t_d and the time t' during testing should not be shorter than their respective lower limits and should not be longer than their respective upper limits.

NOTE 2 k_{pp} = 1,5 is specified for test-duty T10 for rated voltages of 100 kV up to and including 170 kV to cover transformer-limited fault conditions with X_0/X_1 higher than 3,0 (for example non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems).

Add, at the end of 6.104.7, the following new subclauses

6.104.8 Initial transient recovery voltage (ITRV)

Every part of the TRV wave may influence the interrupting capability of a circuit-breaker. The very beginning of the TRV may be of importance for some types of circuit-breakers. This part of the TRV, called initial TRV (ITRV), is caused by the initial oscillation of small amplitude due to reflections from the first major discontinuity along the busbar. Standard values are given in Table 7.

If a circuit-breaker for use in systems with a rated voltage equal to or less than 800 kV has a short-line fault rating, the ITRV requirements are covered if the short-line fault test-duty L_{90} is carried out using a line with a time delay less than 100 ns (see 6.104.5.2 and 6.109.3) unless both terminals are not identical from an electrical point of view (for instance when an additional capacitance is used as mentioned in Note 4 of 6.109.3). When terminals are not identical from an electrical point of view, test circuits which produce an equivalent TRV stress across the circuit-breaker may be used.

For circuit-breakers for use in systems with a rated voltage higher than 800 kV, the ITRV requirements are considered to be covered if the short-line fault test-duty L_{90} is carried out using a line with a time delay less than 100 ns and a surge impedance of 450 Ω unless both terminals are not identical from an electrical point of view (for instance when an additional capacitance is used as mentioned in Note 4 of 6.109.3). When terminals are not identical from an electrical point of view, test circuits which produce an equivalent TRV stress across the circuit-breaker may be used.

Since the ITRV is proportional to the busbar surge impedance and to the current, the ITRV requirements can be neglected for all circuit-breakers with a rated short-circuit breaking current of less than 25 kA and for circuit-breakers with a rated voltage below 100 kV. In addition the ITRV requirements can be neglected for circuit-breakers installed in metal enclosed gas insulated switchgear (GIS) because of the low surge impedance. ITRV requirements can also be neglected for circuit-breakers directly connected to a busbar with a total source side capacitance of more than 800 pF.

Table 7 – Standard values of ITRV – Rated voltages 100 kV and above

Rated voltage U_r kV	Multiplying factor to determine u_i as function of the r.m.s. value of the short-circuit breaking current I_{sc}* f_i kV/kA		Time t_i µs
	50 Hz	60 Hz	
100	0,046	0,055	0,4
123	0,046	0,055	0,4
145	0,046	0,055	0,4
170	0,058	0,069	0,5
245	0,069	0,083	0,6
300	0,081	0,097	0,7
362	0,092	0,111	0,8
420	0,092	0,111	0,8
550	0,116	0,139	1,0
800	0,159	0,191	1,1
1 100	0,173	0,208	1,5
1 200	0,173	0,208	1,5

NOTE These values cover both three-phase and single-phase faults and are based on the assumption that the busbar, including the elements connected to it (supports, current and voltage transformers, disconnectors, etc.), can be roughly represented by a resulting surge impedance Z_i of about 260 Ω with the exception of a rated voltage 800 kV for which the resulting surge impedance Z_i is about 325 Ω. The relation between f_i and t_i is then:

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

where

$\omega = 2\pi f_r$ is the angular frequency corresponding to the rated frequency f_r of the circuit-breaker.

* The actual initial peak voltages are obtained by multiplying the values in these columns by the r.m.s. value of the short-circuit current.

6.104.9 Multipliers for TRV for second and third clearing poles

The TRV is defined for the first-pole-to-clear. In order to obtain the values of RRRV and u_c for the second and third clearing poles, a multiplier shall be applied to the values of RRRV and u_c of the first clearing pole at the relevant first-pole-to-clear factor. The values of these multipliers are given in Table 6.

Table 6 – Standard multipliers for TRV values for second and third clearing poles for rated voltages above 1 kV

First-pole-to-clear factor k_{pp}	Multipliers			
	2nd clearing pole		3rd clearing pole	
	RRRV	u_c	RRRV	u_c
1,2 (terminal fault) 2,0 (out-of-phase)	0,95	0,95	0,83	0,83
1,3 (terminal fault) 2,0 (out-of-phase)	0,95	0,97	0,70	0,77
1,5 (terminal fault) 2,5 (out-of-phase)	0,70	0,58	0,70	0,58

The multipliers of Table 6 have been calculated under the following assumptions:

- only three-phase earthed faults are considered;
- the rate of rise of recovery voltage (RRRV) at 100 % short-circuit currents is mainly determined by overhead lines and is calculated as the product of di/dt at current zero and the equivalent surge impedance;
- the equivalent surge impedance is calculated from the zero sequence (Z_0) and positive sequence (Z_1) surge impedances seen from the terminals of the circuit-breaker. For the relation of Z_0/Z_1 a value of approximately 2 has been chosen;
- the peak value of TRV (u_c) is proportional to the instantaneous value of power frequency recovery voltage at interruption.

See also Figures 13 and 14 and IEC TR 62271-306.

NOTE 1 This table is valid for test-duties T10, T30, T60, T100s, T100a, OP1 and OP2.

NOTE 2 The values are rounded values, depending on Z_0/Z_1 of the TRV circuits, the time constant of the system and the rated voltages.

For three-phase testing the test circuit shall be designed to achieve the prospective u_c values for the second and third clearing poles. It is not necessary to achieve the prospective RRRV values.

6.106 Basic short-circuit test-duties

Add, at the end of the first paragraph, the following sentence:

Tests carried out with rapid auto-reclosing sequence cover testing without rapid auto-reclosing.

6.106.1 Test-duty T10

Replace the paragraph by the following:

Test-duty T10 consists of the rated operating sequence at 10 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.5 and 6.104.7 (see also Tables 24, 25, 43, 44, 26 and 27).

6.106.2 Test-duty T30

Replace the paragraph by the following:

Test-duty T30 consists of the rated operating sequence at 30 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.4 and 6.104.7 (see also Tables 24, 25, 43, 44, 26 and 27).

6.106.3 Test-duty T60

Replace the paragraph by the following:

Test-duty T60 consists of the rated operating sequence at 60 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.3 and 6.104.7 (see also Tables 24, 25, 43, 44, 26 and 27).

6.106.4 Test-duty T100s

Replace the first paragraph by the following:

Test-duty T100s consists of the rated operating sequence at 100 % of the rated short-circuit breaking current taking account of 6.104.3, and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7 (see also Tables 24, 25, 43, 44, 26 and 27) and 100 % of the rated short-circuit making current taking account of 6.104.2 and an applied voltage as specified in 6.104.1.

6.106.5 Test-duty T100a

*Replace the paragraph starting with "*Test-duty T100a consists*" by the following:*

Test-duty T100a consists of three opening operations at 100 % of the rated short-circuit breaking current with the required asymmetry criteria regarding the peak and duration of the last major loop and the related arcing time conditions given in 6.102.10 and a transient and prosepective power frequency recovery voltage under symmetrical conditions as specified in 6.104.5.2 and 6.104.7.

Delete the paragraph above the note.

Replace the note by the following paragraph:

The change of an opening or a closing release does not constitute an alternative operating mechanism. If the opening time of the circuit-breaker is reduced due exclusively, to the use of a faster acting release, it should be checked whether the range of the minimum clearing time, as stated in Tables 39 and 40 for this release, is still covered by tests performed with the initial release. If the circuit-breaker falls into a range with shorter minimum clearing times, it is sufficient to repeat test-duty T100a only for that range, the rest of the type tests remains valid, provided the release is tested to the relevant subclauses and standards.

6.106.6 Asymmetry criteria

Delete the entire subclause, including 6.106.1 to 6.106.6.3.

6.109.1 Applicability

Replace the second paragraph, added by Amendment 1, by the following:

Short-line faults tests are required for circuit-breakers intended for direct connection to overhead lines, having a rated voltage equal to or higher than 15 kV and a rated short-circuit breaking current exceeding 12,5 kA (see 4.105).

6.109.2 Test current

In the last sentence of this subclause replace "Annex J and Clause L.3" *by "*IEC TR 62271-306"*.*

6.109.3 Test circuit

Replace the first paragraph by the following:

The test circuit shall be single-phase and consists of a supply circuit and a line circuit (see Figures 46, 47 and 48). The source side TRV shall be based on a first-pole-to-clear factor of 1,0. The values of line characteristics are given in Table 8.The basic requirements are:

– values of the RRRV factor, based on the line surge impedance Z, the peak factor k and the line side time delay t_{dL} are given in Table 8. For determination of the line side time delay and the rate-of-rise of the line side voltage, see Figure 16;

– the method for calculation of TRVs from the characteristics is given in Annex A.

Table 8 – Values of line characteristics for short-line faults

Rated voltage	Surge impedance	Peak factor	RRRV factor 50 Hz	60 Hz	Time delay
U_r kV	Z Ω	k	s[b] kV/μskA		t_{dL} μs
$15 \leq U_r \leq 38$	450	1,6	0,200	0,240	0,1
$48{,}3 \leq U_r \leq 170$	450	1,6	0,200	0,240	0,2
$245 \leq U_r \leq 800$	450	1,6	0,200	0,240	0,5
$U_r > 800$	330 [a]	1,6	0,147	0,176	0,5

NOTE These values cover the short-line faults dealt with in this standard. For very short lines ($t_L < 5t_{dL}$) not all requirements as given in the table can be met. The procedures for approaching very short lines are given in IEC TR 62271-306 [4].

[a] As described in 4.104.7, a value of 450 Ω may be used during testing to cover ITRV requirements.

[b] For the RRRV factor s, see Annex A.

Replace the last sentence of the second paragraph after b2), added by Amendment 1, as follows:

The tangent on the portion between 0 and $0{,}2 \times u_L$ on the line-side TRV drawn in parallel to the line through $0{,}2 \times u_L$ and $0{,}8 \times u_L$ crosses the zero line at a time t_{dL}. See also 7.3.1.1 of IEC 62271-306:2012.

6.109.4 Test-duties

Add the following sentence and new Table 49 after the second paragraph:

The prospective TRV of the supply circuit shall be in accordance with Table 49.

Table 49 – Values of prospective TRV for the supply circuit of short-line fault tests

Rated voltage U_r kV	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	First reference voltage u_1 kV	Time t_1 µs	TRV peak value u_c kV	Time t_2 or t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_1/t_1 u_c/t_3 kV/µs
15	1	1,54	-	-	18,9	31	2	6,3	12	0,61
15,5 [b]	1	1,54	-	-	19,5	31	2	6,5	12	0,63
17,5	1	1,54	-	-	22,0	34	2	7,3	13	0,65
24	1	1,54	-	-	30,2	43	2	10,1	16	0,70
25,8 [b]	1	1,54	-	-	32,4	45	2	10,8	17	0,72
27 [b]	1	1,54	-	-	33,9	45	2	11,3	17	0,75
36	1	1,54	-	-	45,3	57	3	15,1	22	0,79
38 [b]	1	1,54	-	-	47,8	59	3	15,9	23	0,81
48,3 [b]	1	1,54	-	-	60,7	70	4	20,2	27	0,87
52	1	1,54	-	-	65,4	74	4	21,8	28	0,88
72,5	1	1,54	-	-	91,2	93	5	30,4	36	0,98
100	1	1,40	61	31	114	124	2	31	17	2
123	1	1,40	75	38	141	152	2	38	21	2
145	1	1,40	89	44	166	176	2	44	24	2
170	1	1,40	104	52	194	208	2	52	28	2
245	1	1,40	150	75	280	300	2	75	40	2
300	1	1,40	184	92	343	368	2	92	48	2
362	1	1,40	222	111	414	444	2	111	57	2
420	1	1,40	257	129	480	516	2	129	66	2
550	1	1,40	337	168	629	672	2	168	86	2
800	1	1,40	490	245	914	980	2	245	124	2
1 100	1	1,50	674	337	1 347	1 011	2	337	170	2
1 200	1	1,50	735	367	1 470	1 101	2	367	186	2

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

6.110.2 Test voltage

Replace the last sentence by the following:

The TRV shall be in accordance with 6.104.5.6.

6.111 Capacitive current switching tests

Replace the entire subclause by the following:

6.111 Capacitive current switching tests

6.111.1 General

This subclause describes capacitive current tests procedures for the different ratings defined in 4.107 and their associated restrike class.

Ratings and class demonstrated for back-to-back capacitor bank current switching are also valid for single capacitor bank current switching.

Tests at 60 Hz cover tests for 50 Hz for same class of probability of restrike.

Tests at 50 Hz cover tests for 60 Hz, provided that the voltage across the circuit-breaker is not less during the first 8,3 ms than it would be during a test at 60 Hz.

6.111.2 Applicability

Capacitive current switching tests are applicable to all circuit-breakers to which one or more of the following ratings have been assigned:

– rated line-charging breaking current;
– rated cable-charging breaking current;
– rated single-capacitor bank breaking current;
– rated back-to-back capacitor bank breaking and inrush making current.

Preferred values of rated capacitive switching currents are given in Table 9.

Tests specified for these ratings are individual type tests, each comprising a tests series with two test-duties.

NOTE 1 The determination of overvoltages when switching capacitive currents is not covered by this standard.

NOTE 2 Explanatory notes on capacitive current switching are given in IEC TR 62271-306 [4].

6.111.3 Characteristics of supply circuits

In laboratory tests the lines and cables may be partly or fully replaced by artificial circuits with lumped elements of capacitors, reactors or resistors.

The test circuit shall fulfil the following requirements:

a) the characteristics of the test circuit should be such that the power frequency voltage variation, when switching, should be less than 2 % for test-duty 1 (LC1, CC1 and BC1) and less than 5 % for test-duty 2 (LC2, CC2 and BC2). Where the voltage variation is higher than the values specified, it is alternatively permissible to perform tests with the specified recovery voltage (6.111.10) or synthetic tests;
b) the impedance of the supply circuit shall not be so low that its short-circuit current exceeds the rated short-circuit current of the circuit-breaker.

For line-charging, cable-charging and single capacitor bank current switching tests the prospective TRV of the supply circuit shall not be more severe than the TRV specified for test-duty T100s in 6.104.5.2.

For back-to-back capacitor bank current switching tests, the capacitance of the supply circuit and the impedance between the capacitors on the supply and load sides shall be such as to give the rated back-to-back capacitor bank inrush making current when testing with 100 % of the rated back-to-back capacitor bank breaking current.

For back-to-back capacitor bank current switching tests where separate making tests are performed, a lower capacitance of the supply circuit may be chosen for the breaking tests. The capacitance should, however, not be so low that the prospective TRV of the supply side exceeds that specified for short-circuit in 6.104.5.2.

The test circuit frequency shall be the rated frequency with a tolerance of ± 2 %.

6.111.4 Earthing of the test circuit

6.111.4.1 Supply circuit

For single-phase laboratory tests, either terminal of the single-phase supply circuit can be earthed. However, when it is necessary to ensure that the correct voltage distribution exists between the units of the circuit-breaker, another point of the supply circuit may be connected to earth.

For three-phase tests, the earthing of the supply circuit shall be as follows:

a) for capacitor bank current switching tests, the neutral of the supply circuit shall be earthed. For capacitor banks with effectively earthed neutral, the zero sequence impedance shall not be more than three times its positive sequence impedance. For capacitor banks with isolated neutral this ratio is not relevant;
b) for line-charging and cable-charging current switching tests, the earthing of the supply circuit should correspond to the earthing conditions in circuits for which the circuit-breaker is to be used:
   - for three-phase tests of a circuit-breaker intended for use in effectively earthed neutral systems, the neutral point of the supply circuit shall be earthed and its zero sequence impedance shall be no more than three times its positive sequence impedance;
   - for three-phase tests of a circuit-breaker intended for use in non-effectively earthed neutral systems, the neutral point of the supply side shall be isolated.

For convenience of testing, an alternative test circuit can be used as long as the equivalent values of the recovery voltage as given in Tables O.1 and O.2 will be obtained.

Attention should be given to the influence of TRV control capacitors on the values of the recovery voltage especially for low capacitive currents. Table 32 gives values of the required recovery voltage.

6.111.4.2 Load circuit for three-phase capacitor bank current switching tests

Tests performed with an isolated capacitor bank neutral do cover the switching performance of capacitor banks having an earthed neutral. However, tests performed with an earthed supply and an earthed capacitor bank neutral are not valid for demonstrating the switching performance of capacitor banks with isolated neutral.

6.111.5 Characteristics of the capacitive circuit to be switched

6.111.5.1 General

There are three possibilities:

a) three-phase tests, where in case of line- or cable-charging current switching tests it is permissible to use parallel lines or cables respectively or to partly, or fully, replace the real three-phase line or cable with concentrated capacitor banks. The resulting positive sequence capacitance shall be twice the zero sequence capacitance for tests representing three-core belted cables for rated voltages higher than 72,5 kV, and three times the zero sequence capacitance for rated voltages up to and including 72,5 kV;

b) single-phase tests in a three-phase test circuit with two phases of the capacitive circuit connected directly to the three-phase supply circuit and one phase connected to the supply circuit through the circuit-breaker pole to be tested;

c) single-phase laboratory tests, where in case of line- or cable-charging current switching tests it is allowed to replace partly or fully the real lines or cables respectively by concentrated capacitor banks and to use any parallel connection of the conductors in the individual phases with the return current through earth or through a conductor.

The characteristics of the capacitive circuit shall, with all necessary measuring devices such as voltage dividers included, be such that the decay of the voltage at load side does not exceed 10 % at the end of an interval of 0,3 s after final arc extinction, except for test-duty LC1 and/or CC1 as the withstand capability during an interval of 0,3 s is demonstrated by any test-duty 2.

In laboratory tests the lines and cables may be partly or fully replaced by artificial circuits with lumped elements of capacitors, reactors or resistors.

6.111.5.2 Line-charging and cable-charging current switching tests

When capacitors are used to simulate overhead lines or cables, a non-inductive resistor of a maximum value of 5 % of the capacitive impedance may be inserted in series with the capacitors. Higher values may unduly influence the recovery voltage. If, with this resistor connected, the peak inrush current is still unacceptably high, then an alternative impedance (for example LR) may be used instead of the resistor.

Caution is needed when using such alternative impedances, since this impedance can generate an overvoltage after re-ignition, which may lead to further re-ignitions or restrikes.

6.111.5.3 Capacitor bank current switching tests

The back-to-back capacitor bank making performance is covered when:

– the prospective peak inrush making current is equal to or greater than the rated value and

– the frequency of the inrush current used during tests is equal to or greater than 77 % of the rated value. The applicability of this rule is limited to frequencies below 6 000 Hz.

The prospective damping factor for the inrush current during back-to-back switching, i.e. the ratio between the second peak and the first peak of the same polarity, shall be equal to or greater than 0,75 for circuit-breakers having a rated voltage up to and including 72,5 kV and equal to or greater than 0,85 for circuit-breakers having a rated voltage higher than 72,5 kV.

A non-inductive resistor of a maximum value of 5 % of the capacitive impedance may be inserted in series with the capacitors for testing single-capacitor bank current switching (making and breaking) and for back-to-back capacitor bank current switching (breaking). Higher values may unduly influence the recovery voltage and the inrush making current.

6.111.6 Waveform of the current

The waveform of the current to be interrupted should, as nearly as possible, be sinusoidal. This condition is considered to be complied with if the ratio of the r.m.s. value of the current to the r.m.s. value of the fundamental component does not exceed 1,2.

The current to be interrupted shall not go through zero more than once per half-cycle of power frequency.

6.111.7 Test voltage

For direct three-phase tests and for single-phase tests with the capacitive circuit to be switched according to the arrangement in item b) of 6.111.5.1, the test voltage measured between the phases across the capacitive load circuit immediately prior to opening shall be not less than the rated voltage U_r of the circuit-breaker.

For direct single-phase laboratory tests, the test voltage measured at the circuit-breaker location immediately prior to opening shall be not less than the product of $U_r/\sqrt{3}$ and the following capacitive voltage factor k_c:

a) $\boldsymbol{k_c}$ **= 1,0** for tests corresponding to normal service in effectively earthed neutral systems without significant mutual influence of adjacent phases of the capacitive circuit, typically capacitor banks with earthed neutral and individually screened cables.

b) $\boldsymbol{k_c}$ **= 1,2** for tests on belted cables and for line-charging current switching tests according to item c) of 6.111.5.1 corresponding to normal service conditions in effectively earthed neutral systems for rated voltages higher than 72,5 kV.

c) $\boldsymbol{k_c}$ **= 1,4** for tests corresponding to

   – breaking during normal service conditions in non-effectively earthed neutral systems;

   – breaking of capacitor banks with isolated neutral.

   Moreover, the k_c = 1,4 is applicable for tests on belted cables and for line-charging current switching according to item c) of 6.111.5.1 corresponding to normal service conditions in effectively earthed neutral systems for rated voltages up to and including 72,5 kV.

For unit tests, the test voltage shall be chosen to correspond to the most stressed unit of the pole of the circuit-breaker.

The power frequency test voltage and the d.c. voltage resulting from the trapped charge on the capacitive circuit shall be maintained for a period of at least 0,3 s after breaking.

NOTE The voltage factors in b) and c) above are applicable to single circuit line construction. Switching test requirements for multiple circuit overhead line constructions may be greater than these factors.

Switching capacitive currents under earth fault conditions is treated in Annex S.

6.111.8 Test current

The test currents for the various test-duties can be derived using Table 30.

6.111.9 Test-duties

6.111.9.1 General

The two test-duties for LC, CC or BC shall be performed on one test object without any maintenance. The following abbreviations apply:

– line-charging current, test-duty 1 LC1;
– line-charging current, test-duty 2 LC2;
– cable-charging current, test-duty 1 CC1;
– cable-charging current, test-duty 2 CC2;
– capacitor bank current, test-duty 1 BC1;
– capacitor bank current, test-duty 2 BC2.

These test-duties may be combined for the same class of restrike performance in order to demonstrate the performance of a circuit-breaker for covering several ratings (for example LC and/or CC and/or BC). If such combination method is used, the following rules apply:

The test-duties and test currents shall be as follows:

– a test-duty 2, covering all test-duties 2 of the combination, with a current not less than 100 % of the highest capacitive current rating to be demonstrated;

– a test-duty 1 with a current between 10 % and 40 % of the highest capacitive current rating to be demonstrated;

– a test-duty 1 for each lower capacitive current rating if the range of 10 % to 40 % of that rating is not covered by a previous test-duty 1;

– all other requirements for the individual test-duties shall also be met (for example type, order and number of operations, pressure conditions and test circuits). Where CO operations are specified for one application and O operations for a different one, CO operations are considered to cover O operations if the testing conditions are the same.

NOTE IEC TR 62271-306 [4] provides examples of the application of the rules for combining test duties

6.111.9.2 Common test conditions for class C1 and C2 performance

For the make-break tests, the contacts of the circuit-breaker shall not be separated until the transient currents have subsided. To achieve this, the time between the closing and opening operations may need to be adjusted but shall remain as close as possible to the close-open time as defined in 3.7.143.

Common requirements for capacitive current switching test duties are given in Table 30.

Table 30 – Common requirements for test-duties

Test-duty	Operating voltage of the releases	Pressure for operation and interruption	Test current as percentage of the rated capacitive breaking current %	Type of operation or operating sequence
LC1, CC1 and BC1	Maximum voltage	Minimum functional pressure	10 to 40	O
LC2, CC2 and BC2	Maximum voltage	Rated pressure	Not less than 100	O and CO or CO

NOTE 1 The tests are performed at maximum operating voltage of the releases in order to facilitate consistent control during operation.

NOTE 2 For convenience of testing, CO operating cycles may be performed in test-duty 1 (LC1, CC1 and BC1).

For sealed pressure system circuit-breakers, the minimum functional pressure is replaced by the rated pressure for interruption reduced by the pressure drop due to leakage during life duration. For vacuum circuit-breakers the pressure conditions for interruption are not applicable

No appreciable charge shall remain on the capacitive circuits before the making operations.

In case of three-phase back-to-back capacitor bank current switching tests with non-effectively earthed neutral on supply side and/or load side the making operation is considered to be valid if the following conditions are met:

– the target phase was involved in two-phase making where the making shall occur within ±25° of the peak value of the line-to-line voltage of these two phases, or

– the making in the target phase shall occur within ±25° of the peak value of the applied voltage in case of a three-phase simultaneous making.

For single-phase back-to-back making operations, the making shall occur within ±25° of the peak value of the applied voltage and evenly distributed in both polarities.

For line-charging and cable-charging switching tests the C operations may be no-load operations. For the C operations in single capacitor bank tests the making current provided by the test circuit is considered to be sufficient.

Where in case of back-to-back capacitor bank current switching tests it is not possible to comply with the requirements during the CO operating cycles, then it is permitted to perform the requirements of test-duty 2 (BC2) as a series of separate making tests followed by a series of CO tests.

It is also permitted to perform these split tests not in two subsequent blocks, one consisting of all C operations and one of all CO operations, but to mix C and CO operations provided the number of making operations is larger than or equal to the number of breaking operations at any time during this test.

The separate making tests of this test series shall comprise the following:

– the same number of operations, when testing back-to-back capacitor bank current switching the prospective inrush making current shall be at least equal to the rated back-to-back capacitor bank inrush making current;
– the target phase was involved in two-phase making where the making shall occur within ±25° of the peak value of the line-to-line voltage of these two phases, or
– the making in the target phase shall occur within ±25° of the peak value of the applied voltage in case of a three-phase simultaneous making.

For single-phase back-to-back making operations, the making shall occur within ±25° of the peak value of the applied voltage and evenly distributed in both polarities.

The test voltage shall be the phase-to-earth voltage.

After the separate making operations, the CO operations shall be performed with no-load conditions on the closing. The CO operations shall be carried out on the same pole without intermediate re-conditioning.

NOTE When switching capacitive currents, the opening operation in a CO operating cycle is not influenced by the pre-arc of the preceding closing operation but can be impacted by the actual behaviour of the fluid for interruption caused by the closing operation (for example local differences in density, turbulence, fluid motion). Therefore, the closing and opening operations may be separated as mentioned above with regard to the electrical stress but not with regard to the motion conditions of the fluid for interruption. A no-load closing operation prior to the opening operation is necessary for these reasons.

For opening operations, the minimum arcing time is determined by changing the setting of the contact separation on opening by steps of approximately 6°. Using this method, several tests may be necessary to demonstrate the minimum arcing time.

If a different arcing time is obtained instead of an expected minimum arcing time, this is a valid test and shall be included in the count for the total requirement. In such an event the following will be necessary:

– advance the setting of the control of the tripping impulse by 6° and repeat the test. The new setting shall be kept for other tests at minimum arcing time;
– make one less opening operation to retain the overall total count of tests.

A re-ignition followed by interruption at a later current zero shall be treated as a breaking operation with a long arcing time.

The specified arcing times generally refer to the first pole-to-clear. No arcing times are specified for the additional tests.

All required minimum arcing times shall be obtained on the same phase. In case of capacitor bank current switching the inrush current shall be achieved also in that phase. Within each test-duty, the order of the operations as written in 6.111.9.3.2, 6.111.9.3.3 and 6.111.9.4.2 to 6.111.9.4.4 is not mandatory.

For circuit-breakers with a non-symmetrical current path, the terminal connections shall be reversed between test-duty 1 (LC1, CC1 and BC1) and test-duty 2 (LC2, CC2 and BC2). The test arrangement should be such that no interference with the circuit-breaker between the test-duties is necessary. However, if this is not possible, it is allowed to decrease the pressure in the circuit-breaker, in this case the circuit-breaker has to be refilled with at least 50 % of the used gas.

6.111.9.3 Class C1 test-duties

6.111.9.3.1 General

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 36 for each test-duty.

There is no preferred order for the following tests:

– capacitive current switching, test-duty 1 (LC1 or CC1 or BC1);
– capacitive current switching, test-duty 2 (LC2 or CC2 or BC2).

6.111.9.3.2 Three-phase capacitive current switching tests

Test-duty 1 (LC1, CC1 and BC1) shall comprise a total of 24 O tests. Test-duty 2 (LC2, CC2 and BC2) shall comprise a total of 24 CO tests.

Test-duty 1 (LC1, CC1 and BC1):

– 6 O, distributed on one polarity (step: 10°);
– 3 O at minimum arcing time on one polarity;
– 6 O, distributed on the other polarity (step: 10°);
– 3 O at minimum arcing time on the other polarity;
– additional tests to achieve 24 O, distributed.

Test-duty 2 (LC2, CC2 and BC2):

– 6 CO, distributed on one polarity (step: 10°);
– 3 CO at minimum arcing time on one polarity;
– 6 CO, distributed on the other polarity (step: 10°);
– 3 CO at minimum arcing time on the other polarity;
– additional tests to achieve 24 CO, distributed.

6.111.9.3.3 Single-phase capacitive current switching tests

Test-duty 1 (LC1, CC1 and BC1) shall comprise a total of 24 O tests. Test-duty 2 (LC2, CC2 and BC2) shall comprise a total of 24 CO tests.

Test-duty 1 (LC1, CC1 and BC1):

– 6 O, distributed on one polarity (step: 30°);
– 3 O at minimum arcing time on one polarity;
– 6 O, distributed on the other polarity (step: 30°);
– 3 O at minimum arcing time on the other polarity;

– additional tests to achieve 24 O, distributed.

Test-duty 2 (LC2, CC2 and BC2):

– 6 CO, distributed on one polarity (step: 30°);
– 3 CO at minimum arcing time on one polarity;
– 6 CO, distributed on the other polarity (step: 30°);
– 3 CO at minimum arcing time on the other polarity;
– additional tests to achieve 24 CO, distributed.

6.111.9.4 Class C2 test-duties

6.111.9.4.1 General

Capacitive current switching tests for class C2 circuit-breakers shall be made after performing test-duty T60 as a preconditioning test (T60 is related to the a.c. component of the rated short-circuit breaking current).

As an alternative, the preconditioning may be performed at reduced voltage under the following conditions:

– same current as test-duty T60;
– reduced voltage and no specified TRV;
– three breaking operations;
– arcing times: as for test-duty T60 given by the manufacturer;
– rated or minimum functional pressure for operation and interruption.

NOTE 1 For practical reasons the manufacturer can choose to add other test-duties to the T60 preconditioning tests.

NOTE 2 If several capacitive current switching tests, for instance line-charging, cable-charging and capacitor bank current switching tests, are performed with the same circuit-breaker without reconditioning, the T60 preconditioning tests need to be performed only once at the beginning of the capacitive current switching tests.

For the line-charging or cable-charging current switching tests, there is no preferred order between test-duty 1 and test-duty 2.

The mandatory order for capacitor bank (single or back-to-back) current switching tests is as follows:

– capacitive current switching, test-duty 2 (BC2);
– capacitive current switching, test-duty 1 (BC1).

6.111.9.4.2 Three-phase line-charging and cable-charging current switching tests

Each test-duty shall comprise a total of 24 operations or operating cycles as follows:

Test-duty 1 (LC1 and CC1):

– 4 O, distributed on one polarity (step: 15°);
– 6 O at minimum arcing time on one polarity;
– 4 O, distributed on the other polarity (step: 15°);
– 6 O at minimum arcing time on the other polarity;
– additional tests to achieve 24 O, distributed.

Test-duty 2 (LC2 and CC2):

– 4 CO, distributed on one polarity (step: 15°);

– 6 CO at minimum arcing time on one polarity;
– 4 CO, distributed on the other polarity (step: 15°);
– 6 CO at minimum arcing time on the other polarity;
– additional tests to achieve 24 CO, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 36 for each test-duty independent from arcing times obtained.

6.111.9.4.3 Single-phase line-charging and cable-charging current switching tests

Each test-duty shall comprise a total requirement of 48 operations or operating cycles as follows:

Test-duty 1 (LC1 and CC1):

– 12 O, distributed on one polarity (step: 15°);
– 6 O at minimum arcing time on one polarity;
– 12 O, distributed on the other polarity (step: 15°);
– 6 O at minimum arcing time on the other polarity;
– additional tests to achieve 48 O, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 72 independent from arcing times obtained.

Test-duty 2 (LC2 and CC2):

– 6 O and 6 CO, distributed on one polarity (step 30°);
– 3 O and 3 CO at minimum arcing time on one polarity;
– 6 O and 6 CO, distributed on the other polarity (step: 30°);
– 3 O and 3 CO at minimum arcing time on the other polarity;
– additional tests to achieve 24 O and 24 CO, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 36 O and 36 CO independent from arcing times obtained.

6.111.9.4.4 Three-phase capacitor bank (single or back-to-back) current switching tests

Test-duty 1 (BC1) shall comprise a total of 24 O tests. Test-duty 2 (BC2) shall comprise a total of 80 CO tests as follows:

Test-duty 1 (BC1):

– 4 O, distributed on one polarity (step:15°);
– 6 O at minimum arcing time on one polarity;
– 4 O, distributed on the other polarity (step: 15°);
– 6 O at minimum arcing time on the other polarity;
– additional tests to achieve 24 O, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 36 independent from arcing times obtained.

Test-duty 2 (BC2):

– 4 CO, distributed on one polarity (step 15°);
– 32 CO at minimum arcing time on one polarity;
– 4 CO, distributed on the other polarity (step: 15°);
– 32 CO at minimum arcing time on the other polarity;
– additional tests to achieve 80 CO, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 100 independent from arcing times and making conditions obtained.

6.111.9.4.5 Single-phase capacitor bank (single or back-to-back) current switching tests

Test-duty 1 (BC1) shall comprise a total of 48 O tests. Test-duty 2 (BC2) shall comprise a total of 80 CO tests at minimum arcing time with the making within ±25° of the peak value of the applied voltage and 40 CO tests, where the C operations may be no-load operations.

Test-duty 1 (BC1):

– 12 O, distributed on one polarity (step: 15°);
– 6 O at minimum arcing time on one polarity;
– 12 O, distributed on the other polarity (step: 15°);
– 6 O at minimum arcing time on the other polarity;
– additional tests to achieve 48 O, distributed.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 72 independent from arcing times obtained.

Test-duty 2 (BC2):

– 12 CO, distributed on one polarity (step: 15°);
– 40 CO at minimum arcing time on one polarity;
– 12 CO, distributed on the other polarity (step: 15°);
– 40 CO at minimum arcing time on the other polarity;
– Additional tests to achieve 120 CO, distributed (step: 15°).

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests to meet the requirement for making angle is limited to 100 and the total number of tests is limited to 158 independent of the arcing times obtained.

6.111.10 Tests with specified recovery voltage

As an alternative to using the test circuits defined in 6.111.3 through 6.111.5, switching tests may be performed in circuits which fulfil the following requirements for the prospective recovery voltage:

– with the envelope of the prospective test recovery voltage defined as (see Figure 54)

  $u'_c \geq u_c$

  $t'_2 \leq t_2$;
– in addition the initial part of the prospective recovery voltage shall remain below the line from the origin to the point defined by u_1 and t_1;
– care should be taken in order to assure that the actual recovery voltage shall not exceed the theoretical test voltage of the corresponding single-phase direct test (1-cos curve) by more than 6 % of the peak value of the test voltage (i.e. approximately 3 % of the peak recovery voltage u_c shown in Figure 54).

NOTE The use of a series resistor (6.111.5.2 and 6.111.5.3) in the load circuit causes a phase shift which may lead to the above given limit be exceeded. In those cases the value of the resistor may be decreased or an appropriate LR circuit may be used instead (6.111.5.2 and 6.111.5.3).

Specified values of u_1, t_1, u_c and t_2 for single-phase testing are given in Table 32.

For three-phase testing the same principle is used to define the initial part of the recovery voltage for the first-pole-to-clear.

Table 32 – Specified values of u_1, t_1, u_c and t_2

Test-duties	Recovery voltage values of Figure 54 in relation to the peak value of the test voltage		Time values of Figure 54	
	u_c p.u.	u_1 p.u.	t_1	t_2
1	≥ 1,98	≤ 0,02k_{af} *	≥ t_1 or t_3 in 6.104.5.1 for terminal fault	8,7 ms for 50 Hz 7,3 ms for 60 Hz
2	≥ 1,95	≤ 0,05k_{af} *		
NOTE For tests with specified recovery voltage the prospective recovery voltage is calculated based on the test voltage of the corresponding single-phase direct test.				
* k_{af} = amplitude factor = 1,4 (see Tables 24, 26 and 27) for class S1 circuit-breakers and for circuit-breakers with rated voltage of 100 kV up to and including 800 kV. k_{af} = amplitude factor = 1,5 (see Table 26) for circuit-breakers with rated voltage higher than 800 kV. k_{af} = amplitude factor = 1,54 (see Table 25) for class S2 circuit-breakers.				

6.111.11 Criteria to pass the test

6.111.11.1 General

The circuit-breakers of the individual classes shall have successfully passed the tests if the following conditions are fulfilled:

a) the behaviour of the circuit-breaker during making and breaking of the capacitive currents in all prescribed test-duties fulfils the conditions given in 6.102.8;

b) the condition of the circuit-breaker after the test series corresponds to the conditions given in 6.102.9.4. If no restrike occurred during test-duties 1 (LC1 or CC1 or BC1) and 2 (LC2 or CC2 or BC2), visual inspection is sufficient.

Where combined testing in accordance with 6.111.9.1 is carried out, the criteria to pass the test apply to each combination of test-duties 1 and 2 relevant to cover the rating the tests have been carried out for.

6.111.11.2 Class C1 performance

The circuit-breaker has successfully passed the tests if up to one restrike occurred during the complete test-duties 1 (LC1 or CC1 or BC1) and 2 (LC2 or CC2 or BC2).

If two restrikes occurred during the complete test-duties 1 and 2 for LC, CC or BC, then both test-duties shall be repeated on the same apparatus without any maintenance. If no more than one additional restrike happens during this extended series of tests, the circuit-breaker has successfully passed the tests. External flashover and phase-to-ground flashover shall not take place.

In the case of combined testing according to 6.111.9.1, the circuit-breaker shall have passed the test for those ratings for which both, a test-duty 2 and a matching test-duty 1 were carried out with less than two restrikes in total. Where due to restrikes test-duties have to be repeated, the affected set of matching test-duties (test-duty 1 and test-duty 2) shall be repeated. If in more than one test-duty 1 restrikes occurred, each of them shall be repeated together with one single test-duty 2. If restrikes occurred only in test-duty 2, this one and any one of the test-duties 1 shall be repeated.

6.111.11.3 Class C2 performance

The circuit-breaker has successfully passed the tests if no restrike occurred during the complete test-duties 1 and 2 for LC, CC or BC.

If one restrike occurred during the complete test-duties 1 (LC1 or CC1 or BC1) and 2 (LC2 or CC2 or BC2), then both test-duties shall be repeated on the same apparatus without any maintenance. If no additional restrike occurs during this extended series of tests, the circuit-breaker has successfully passed the tests. External flashover and phase-to-ground flashover shall not take place.

In the case of combined testing according to 6.111.9.1, the circuit-breaker has passed the test for those applications or ratings for which both a test-duty 2 and a matching test-duty 1 were carried out without restrike. Where due to restrikes test-duties have to be repeated, the affected set of matching test-duties (test-duty 1 and test-duty 2) shall be repeated. If in more than one test-duty 1 one restrike occurred, each of them shall be repeated together with one single test-duty 2. If one restrike occurred in test-duty 2, this one and any one of the test-duties 1 shall be repeated.

6.111.11.4 Criteria for reclassification from class C2 performance to class C1

A circuit-breaker which has met the requirements for class C2 performance for a particular switching duty (LC, CC, BC) can be class C1 for the same duty without further testing.

A circuit-breaker tested in accordance with the class C2 test procedure but which has failed to pass class C2 performance can be qualified for class C1 performance if the requirements of 6.111.11.1 are fulfilled and if the following condition is met:

a) Line- or cable-charging current switching tests

   The total number of restrikes during line-charging current switching tests (LC1 and LC2) or cable-charging current switching tests (CC1 and CC2) does not exceed two in the first series of test operations i.e. 96 in case of single-phase tests and 48 in case of three-phase tests, see 6.111.9.4.2 or 6.111.9.4.3 respectively. In the event of a single restrike during the first series of test operations a repetition series may be carried out in accordance with 6.111.11.3. The behaviour of the circuit-breaker during the repetition series is not relevant for the purpose of reclassification. If during this repetition series a restrike occurs no further testing is required.

b) Capacitor bank current switching tests

   The total number of restrikes during capacitor bank current switching tests (BC1 and BC2) does not exceed five in the first series of operations, i.e. 168 in case of single-phase tests and 104 in case of three-phase tests, see 6.111.9.4.4 or 6.111.9.4.5 respectively. In the event of a single restrike during the first series of test operations a repetition series may be carried out in accordance with 6.111.11.3. The behaviour of the circuit-breaker during the repetition series is not relevant for the purpose of reclassification. If during this repetition series a restrike occurs no further testing is required.

The reclassification procedure is shown in Figures 55 and 56.

6.112.1 Class E2 circuit-breakers intended for use without auto-reclosing duty

Add, at the end of the last sentence of the first paragraph, the following wording:

…. independent of the rated operating sequence

7.1 Dielectric test on the main circuit

Add, at the end of the subclause, after the existing Table 34, the following text:

For circuit-breakers using compressed gas for insulation the gas pressure during the dielectric test on the main circuit shall be set at the minimum functional pressure for interruption and insulation. For sealed pressure systems, the gas pressure shall be the rated filling pressure for interruption and insulation.

In case of circuit-breakers using a gas mixture such as SF_6/CF_4 or SF_6/N_2, the test can be performed using the declared gas mixture at the minimum functional pressure for interruption and insulation or pure SF_6 at a total absolute pressure not exceeding the equivalent gas pressure (P_{test}) as calculated by the following equations (see Figure 4.1 of CIGRE TB 163 [13]):

– for circuit-breakers using a SF_6/N_2 mixture: $P_{test} = P_{SF6} + 0{,}7 \times P_{add\ N_2}$. The equation is valid for mixtures having at least 30 % of SF_6 gas volume; (see Note);

– for circuit-breakers using a SF_6/CF_4 mixture: $P_{test} = P_{SF6} + 0{,}45 \times P_{add\ CF4}$.

where

P_{test} is the total absolute SF_6 pressure at T = 20 °C during routine dielectric test on the main circuit;

P_{SF6} is the partial pressure of SF_6 at T = 20 °C at the minimum functional pressure for interruption and insulation according to the declared gas mixture;

P_{add} is the partial pressure of CF_4 or N_2 at T = 20 °C at the minimum functional pressure for interruption and insulation according to the declared gas mixture.

NOTE See CIGRE TB 163 [13] for mixtures having less than 30 % SF_6.

Add, after 7.1, the following new subclause:

7.1.101 Partial discharge measurement

For dead-tank circuit-breakers with rated voltage higher than 52 kV using solid insulating material to earth, a measurement of partial discharges shall be performed to detect possible material and manufacturing defects within these solid insulating parts.

The measurement of partial discharges should be preferably performed on the complete circuit-breaker. In this case, the measurement of partial discharges shall be performed during the dielectric test (7.1) and preferably after mechanical operating routine tests (7.101).

If a test on the complete circuit-breaker is impractical, it is allowed to replace the test on the complete circuit-breaker by partial discharge measurements on individual components, before assembly, such as bushings, insulators, partitions, insulated operating rods, etc. For partial discharge tests on bushings, subclause 9.4 of IEC 60137:2008 is applicable.

NOTE Partial discharge test on bushings is required for all types of bushings with the exception of gas-insulated bushings and ceramic, glass or analogous inorganic material bushings as defined respectively in 3.6 and 3.11 of IEC 60137:2008.

The measurement shall be made in accordance with IEC 60270.

The applied power-frequency voltage shall be raised to a pre-stress value which is identical to the power-frequency withstand voltage test and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage shall be decreased to the value defined in Table 50.

The extinction voltage shall be recorded during the reduction of the applied test voltage specified in Table 50.

Table 50 – Test voltage for partial discharge test

	Circuit-breaker rated for k_{pp} = 1,2 or 1,3		Circuit-breaker rated for k_{pp} = 1,5	
	Pre-stress voltage U_{ps} (1 min)	Test voltage for PD measurement U_{pd} (> 1 min)	Pre-stress voltage U_{ps} (1 min)	Test voltage for PD measurement U_{pd} (> 1 min)
Single-phase enclosure designs (phase-to-earth voltage)	U_d	$1,2 \times U_r/\sqrt{3}$	U_d	$1,2 \times U_r$
Three-phase enclosure designs	U_d	$U_{pd,\ pe} = 1,2 \times U_r/\sqrt{3}$ $U_{pd,\ pp} = 1,2 \times U_r$	U_d	$U_{pd,\ pe} = 1,2 \times U_r$

U_r voltage for equipment.

U_d power-frequency withstand test voltage as per Tables 1a, 1b, 2a or 2b of IEC 62271-1:2007 for dead-tank circuit-breakers.

U_{ps} pre-stress voltage.

U_{pd} test voltage for PD measurement.

$U_{pd,\ pe}$ test voltage for PD measurement, phase-to-earth.

$U_{pd,\ pp}$ test voltage for PD measurement, phase-to-phase.

The maximum permissible partial discharge level shall not exceed 10 pC for dead-tank circuit-breakers at the test voltage specified in Table 50.

7.101 Mechanical operating tests

Replace, in the paragraph starting with "Proof shall be given …"*,* "specimen" *by* "object"*.*

8.101 General

Replace the reference of "Characteristics for short-line faults" *from* "4.105" *to* "6.109"*.*

8.103.2 Selection of transient recovery voltage (TRV) for terminal faults, first-pole-to-clear factor and characteristics for short-line faults

Replace, in the first paragraph, "4.102.2" *by* "6.104.6"*.*

Replace the first sentence of the second paragraph under item c) by the following:

Short-line fault tests apply only to circuit-breakers having a rated voltage of 15 kV and above a rated short-circuit breaking current exceeding 12,5 kA for direct connection to overhead lines (see 4.105).

9.101 Information to be given with enquiries and orders

Replace, under c) line 10), the reference from "4.109" *to* "5.105"*.*

9.102 Information to be given with tenders

Delete, under a) line 10, the words "rated" (3 times), and replace the reference from "4.109" *to* "5.105"*.*

10.2.102.3.2 Measurement of the resistance of the main circuit

Add, at the end of the subclause, the following note:

NOTE Dynamic resistance measurements (DRM) could be carried out as an additional tool for the assessment of the condition of the circuit-breaker during life time for some designs.

Figure 1 – Typical oscillogram of a three-phase short-circuit make-break cycle

Replace the existing figure by the following, without modifying the key to Figure 1:

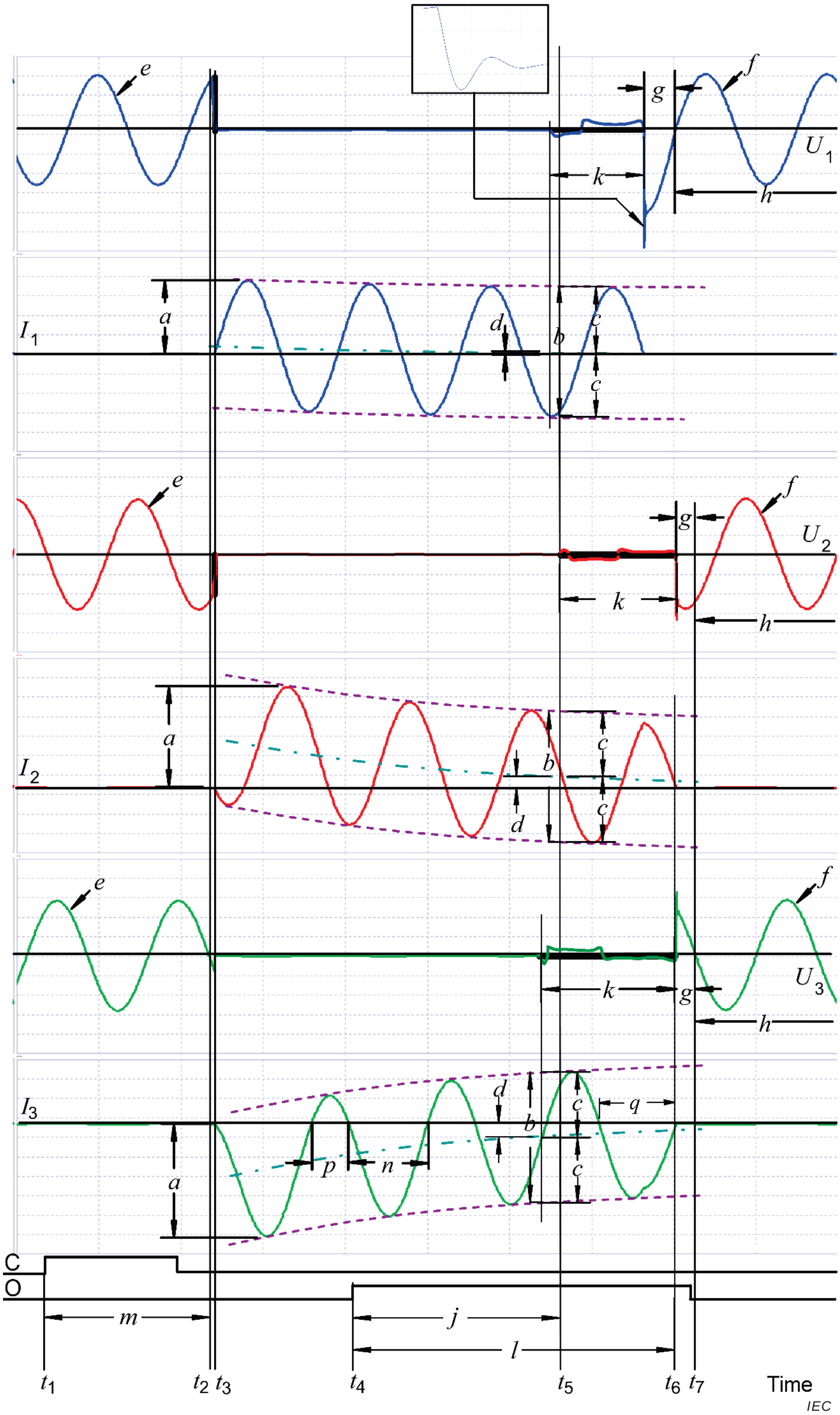


Figure 1 – Typical oscillogram of a three-phase short-circuit make-break cycle

Replace, in the legend to Figure 1, the lines for t_2, t_4 and b by the following:

t_2 instant of the voltage breakdown

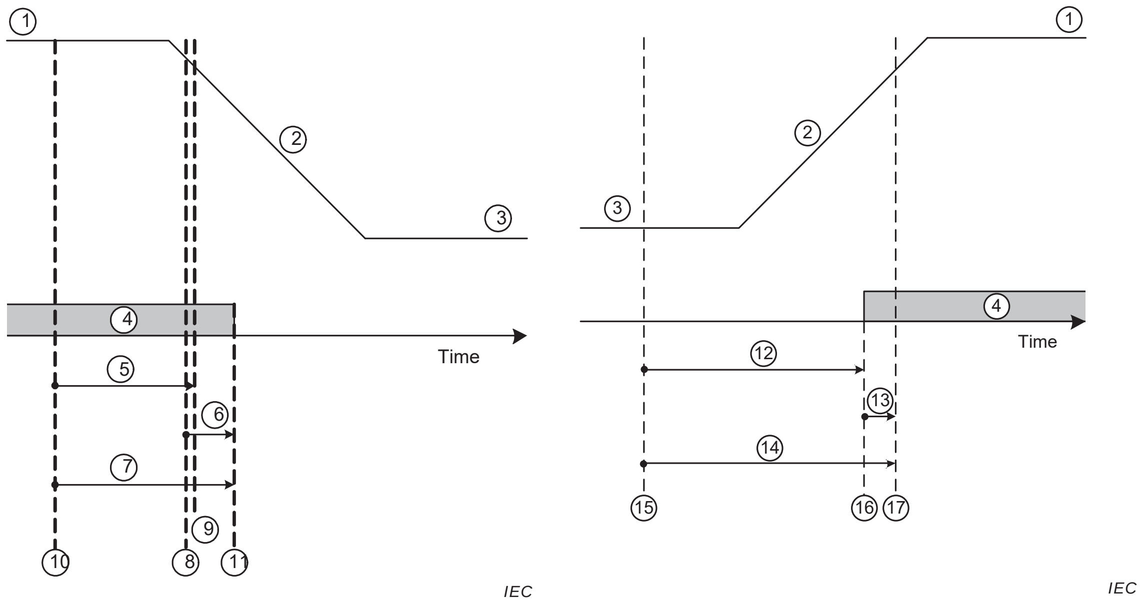
t_4 instant of the initiation of the opening operation

b peak-to-peak value of the breaking current

Add the following to the key to Figure 1:

q major extended loop

Replace the existing Figures 2 to 7 by the following:

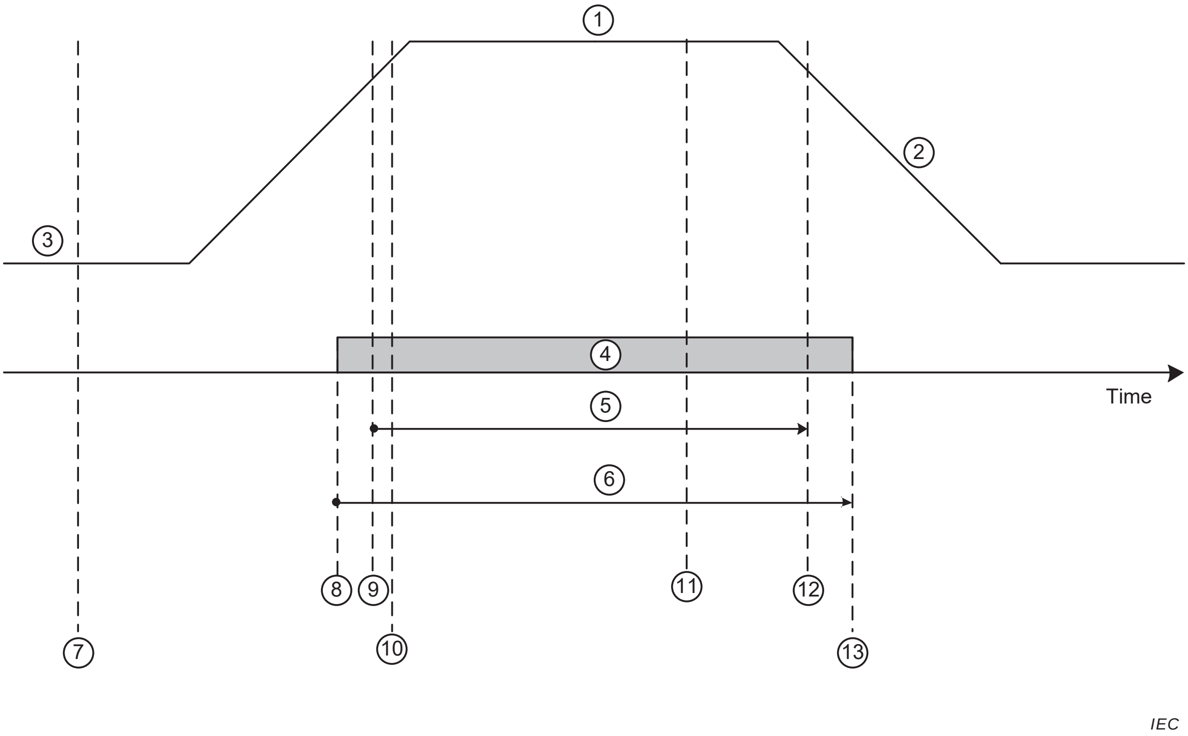


Opening operation **Closing operation**

Key

1	Closed position	10	Instant of initiation of opening operation, 3.7.161
2	Contact travel	11	Instant of final arc extinction in all poles
3	Open position	12	Make time, 3.7.137
4	Current flow	13	Pre-arcing time, 3.7.138
5	Opening time, 3.7.133	14	Closing time, 3.7.136
6	Total acing time, 3.7.162	15	Instant of initiation of closing operation, 3.7.161
7	Break time, 3.7.135	16	Instant of start of current flow in the first pole
8	Instant of separation of arcing contacts in first opening pole	17	Instant of contact touch in all poles
9	Instant of separation of arcing contacts in all poles		

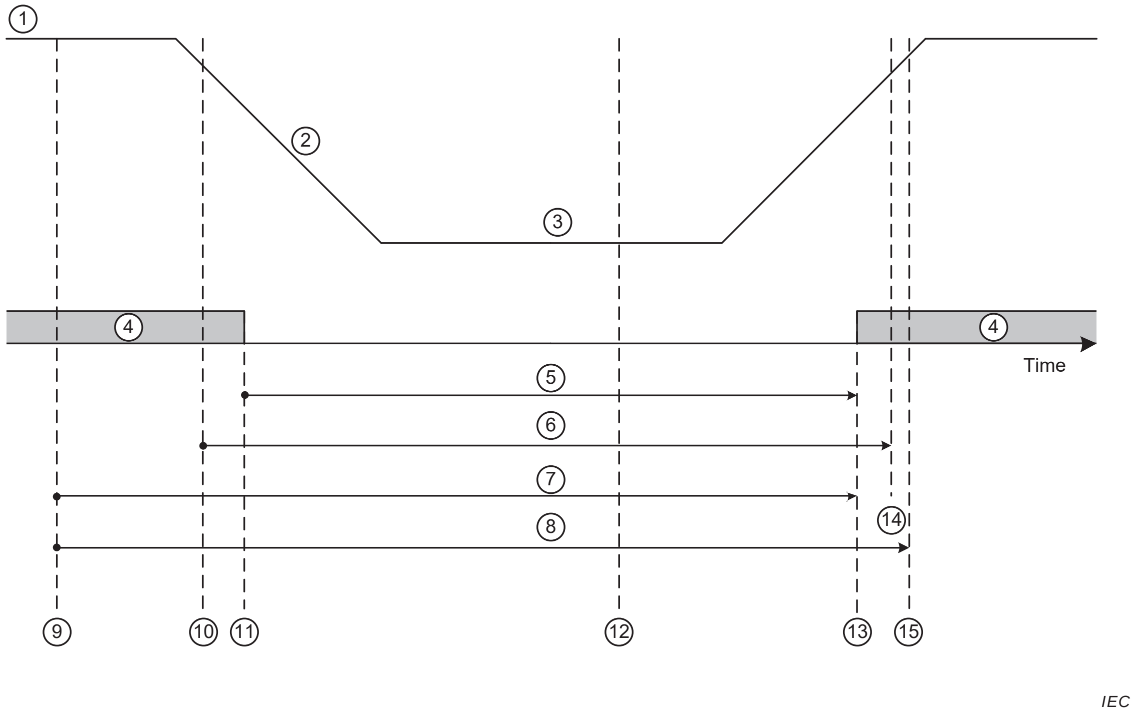
Figure 2 – Circuit-breaker without switching resistors – Opening and closing operation



Key

1 Closed position
2 Contact travel
3 Open position
4 Current flow
5 Close-open time, 3.7.143
6 Make-break time, 3.7.144
7 Instant of initiation of closing operation, 3.7.161
8 Instant of start of current flow in the first pole
9 Instant of contact touch in the first closing pole
10 Instant of contact touch in all poles
11 Instant of initiation of opening operation, 3.7.161
12 Instant of separation of arcing contacts in all poles
13 Instant of arc extinction in all poles

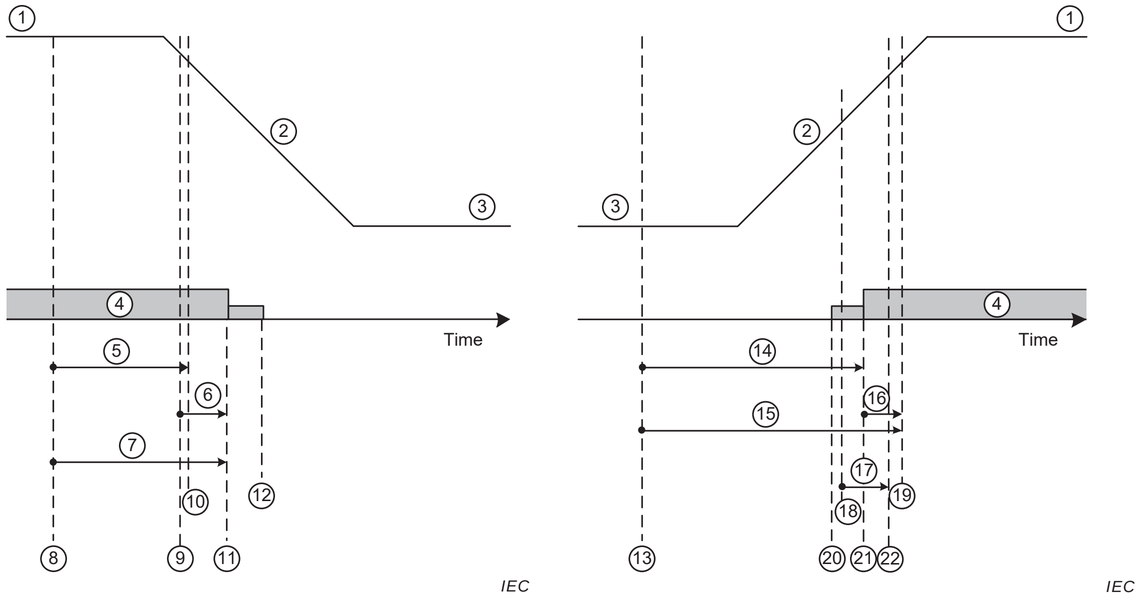
Figure 3 – Circuit-breaker without switching resistors – Close-open cycle



Key

1	Closed position	9	Instant of initiation of opening operation, 3.7.161
2	Contact travel	10	Instant of separation of arcing contacts in all poles
3	Open position	11	Instant of final arc extinction in all poles
4	Current flow	12	Instant of initiation of closing operation, 3.7.161
5	Dead time, 3.7.140	13	Instant of start of current flow in the first closing pole
6	Open-close time, 3.7.139	14	Instant of contact touch in first pole
7	Re-make time, 3.7.142	15	Instant of contact touch in all poles
8	Reclosing time, 3.7.141		

Figure 4 – Circuit-breaker without switching resistors – Reclosing (auto-reclosing)

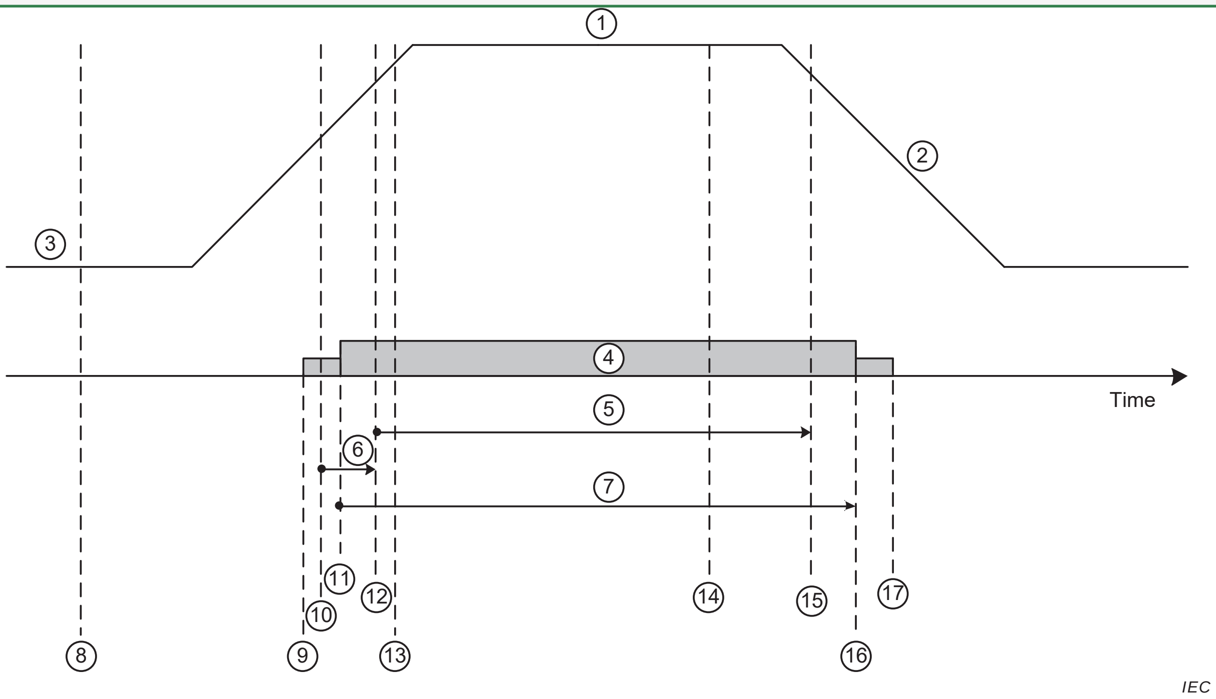


Opening operation **Closing operation**

Key

1 Closed position
2 Contact travel
3 Open position
4 Current flow
5 Opening time, 3.7.133
6 Total arcing time, 3.7.162
7 Break time, 3.7.135
8 Instant of initiation of opening operation, 3.7.161
9 Instant of separation of arcing contacts in first opening pole
10 Instant of separation of arcing contacts in all poles
11 Instant of arc extinction in all poles – Full current
12 Instant of arc extinction in all poles – Resistor current
13 Instant of initiation of the closing operation, 3.7.161
14 Make time, 3.7.137
15 Closing time, 3.7.136
16 Pre-arcing time, 3.7.138
17 Pre-insertion time, 3.7.145
18 Instant of contact touch in the closing resistor of any one pole
19 Instant of contact touch in all poles
20 Instant of start of current flow in the first pole – Resistor current
21 Instant of the start of current flow in the first pole – Full current
22 Instant of contact touch in the main breaking unit of the same pole as regarded for the resistor

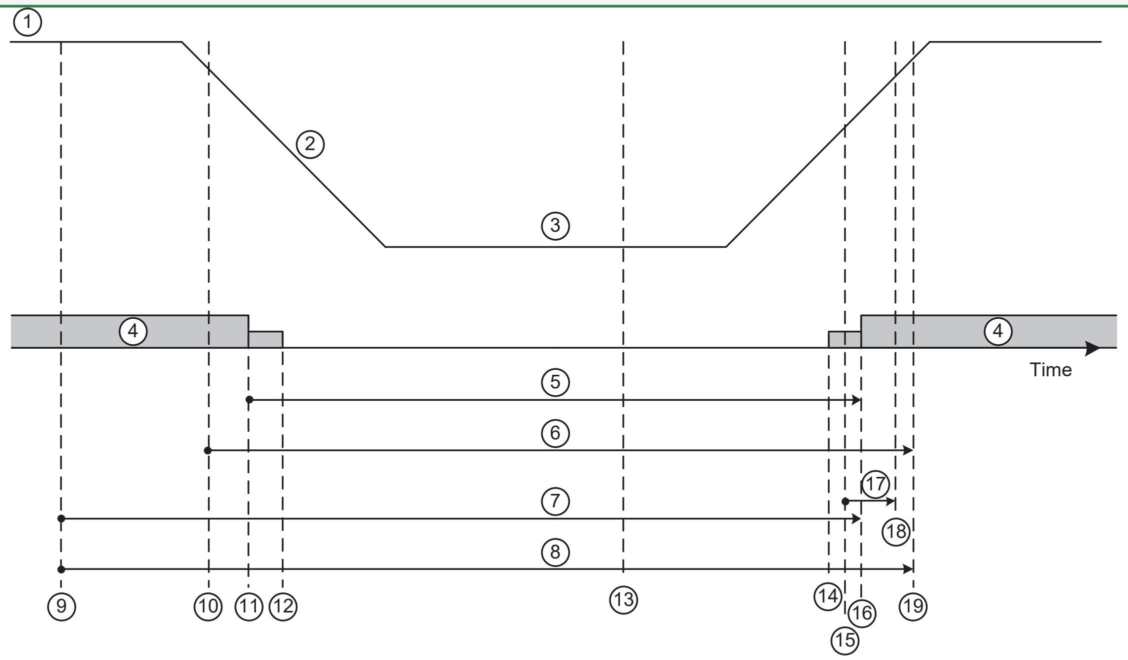
Figure 5 – Circuit-breaker with switching resistors – Opening and closing operations



Key

1	Closed position	10	Instant of contact touch in the closing resistor of any one pole
2	Contact travel	11	Instant of start of current flow in the first pole – Full current
3	Open position	12	Instant of contact touch in the main breaking unit of the same pole as regarded for the resistor
4	Current flow	13	Instant of contact touch in all poles
5	Close-open time, 3.7.143	14	Instant of initiation of opening operation, 3.7.161
6	Pre-insertion time, 3.7.145	15	Instant of separation of arcing contacts in all poles
7	Make-break time, 3.7.144	16	Instant of arc extinction in all poles – Full current
8	Instant of initiation of closing operation, 3.7.161	17	Instant of arc extinction in all poles – Resistor current
9	Instant of start of current flow in the first pole – Resistor current		

Figure 6 – Circuit-breaker with switching resistors – Close-open cycle



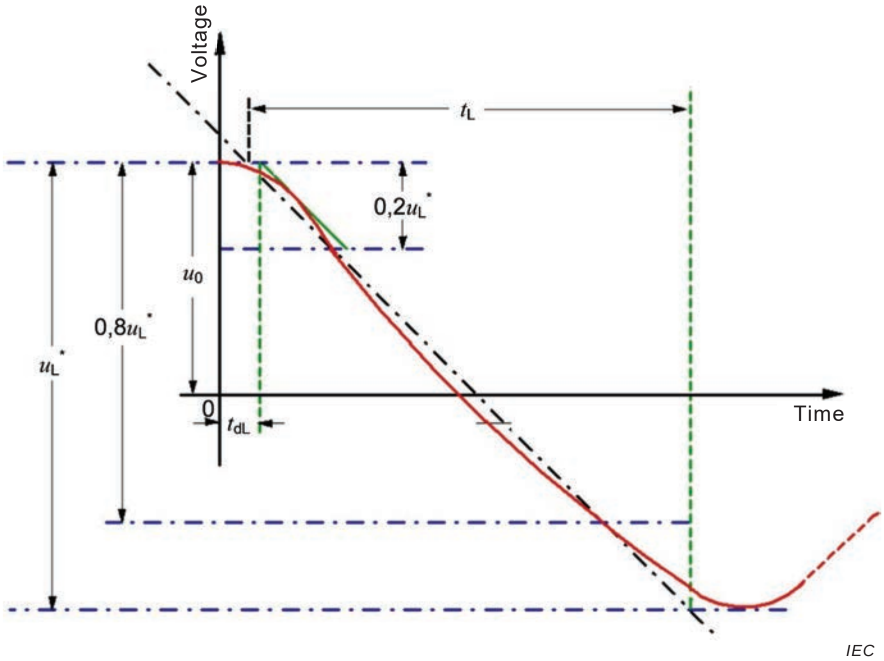
Key

1	Closed position
2	Contact travel
3	Open position
4	Current flow
5	Dead time, 3.7.140
6	Open-close time, 3.7.139
7	Re-make time, 3.7.142
8	Reclosing time, 3.7.141
9	Instant of initiation of opening operation, 3.7.161
10	Instant of separation of arcing contacts in all poles
11	Instant of arc extinction in all poles – Full current
12	Instant of arc extinction in all poles – Resistor current
13	Instant of initiation of closing operation, 3.7.161
14	Resistor current
15	Instant of contact touch in the closing resistor of any one pole
16	Instant of start of current flow in the first pole – Full current
17	Pre-insertion time, 3.7.145
18	Instant of contact touch in the main breaking unit of the same pole as regarded for the resistor
19	Instant of contact touch in all poles

Figure 7 – Circuit-breaker with switching resistors – Reclosing (auto-reclosing)

Figure 16b – Example of line transient voltage with time delay with non-linear rate of rise

Replace Figure 16b, modified by Amendment 1, by the following new figure, without modifying its title:



Delete Figure 19, modified by Amendment 1, as well as Figures 20, 21 and 22.

Add, after the existing Figure 18, the following new figure:

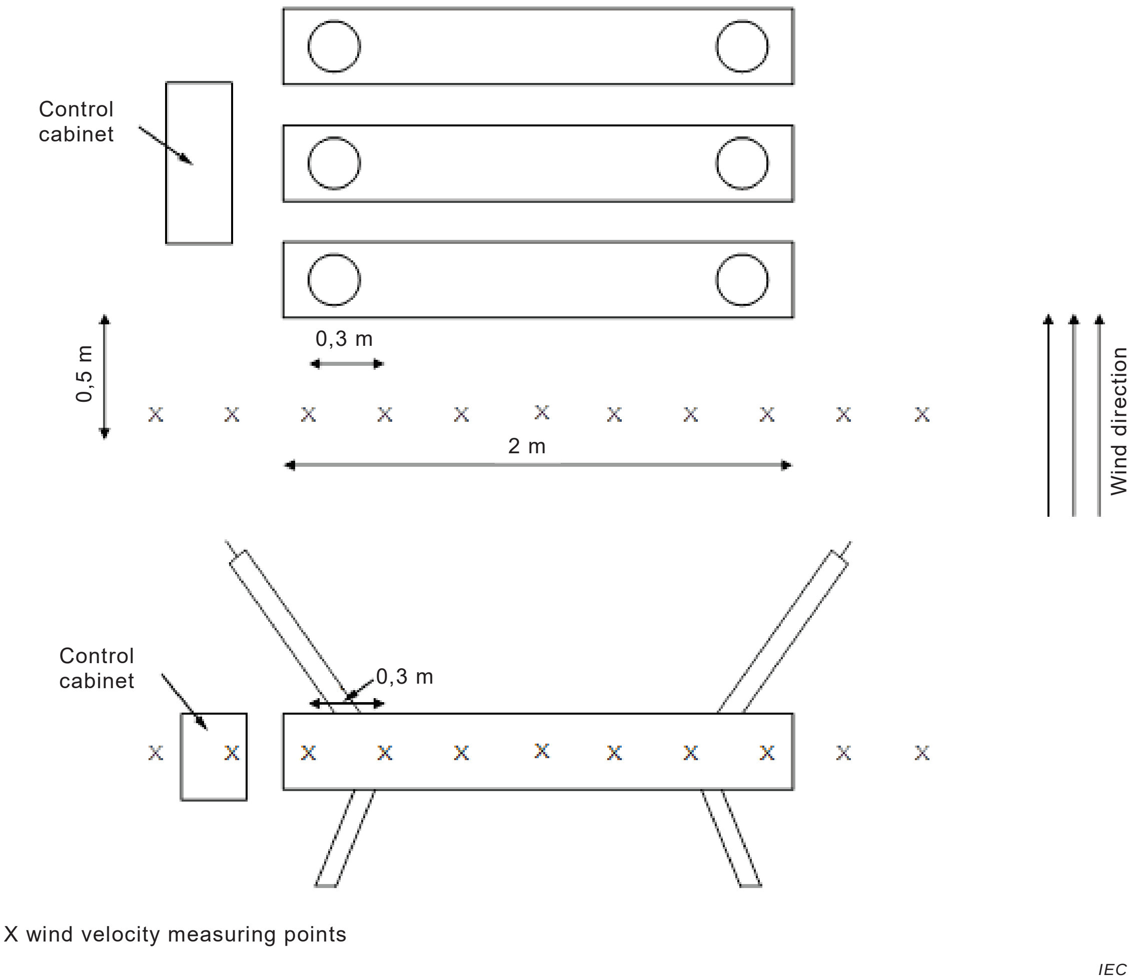


Figure 59 – Example of wind velocity measurement

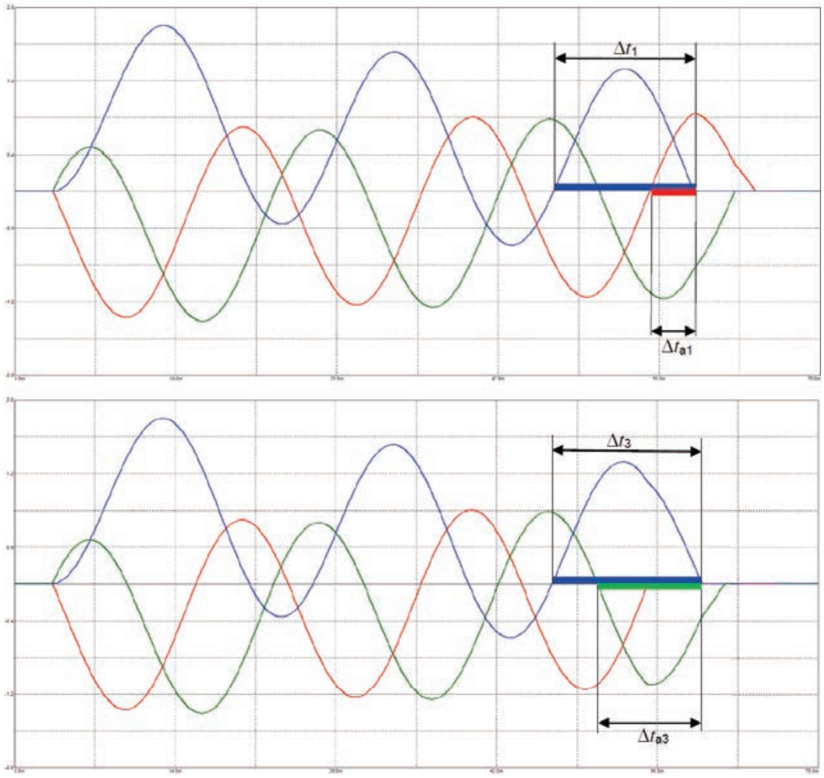
Figure 27b – Alternative circuit not applicable for circuit-breakers where the insulation between phases and/or to earth is critical (e.g. GIS or dead tank circuit-breakers)

Replace the title of this subfigure by "Alternative circuit"*.*

Figure 28b – Alternative circuit, not applicable for circuit-breakers where the insulation between phases and/or to earth is critical (e.g. GIS or dead tank circuit-breakers)

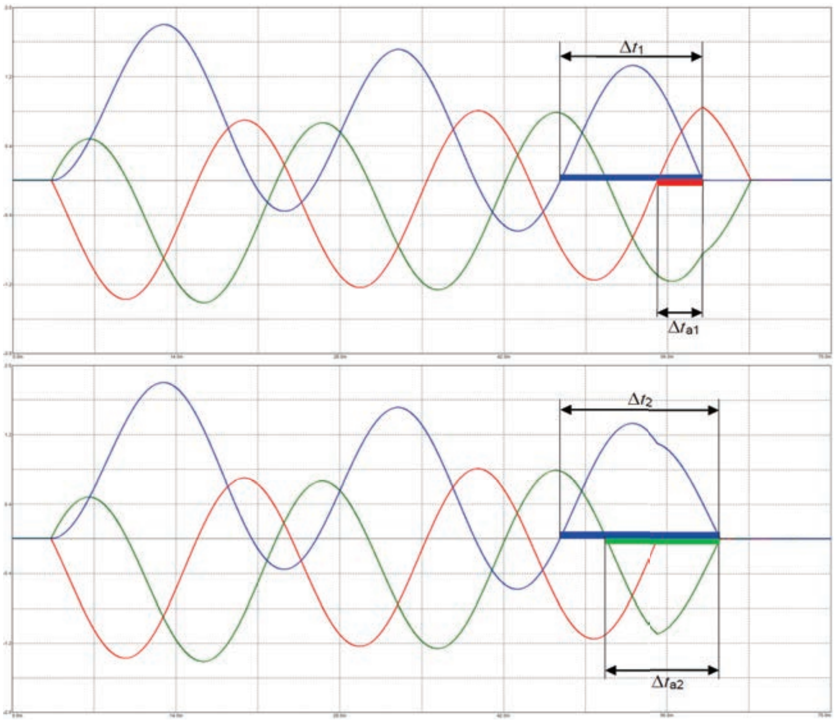
Replace the title of this subfigure by "Alternative circuit"*.*

Add, after the existing Figure 28, the following new figure:



IEC

a) Time parameters for k_{pp} = 1,2 or 1,3



IEC

b) Time parameters for k_{pp} = 1,5

Figure 60 – Graphical representation of the time parameters for the demonstration of arcing times in three-phase tests of test-duty T100a

Replace existing Figures 29 to 39, some of them were modified by Amendment 1, by the following:

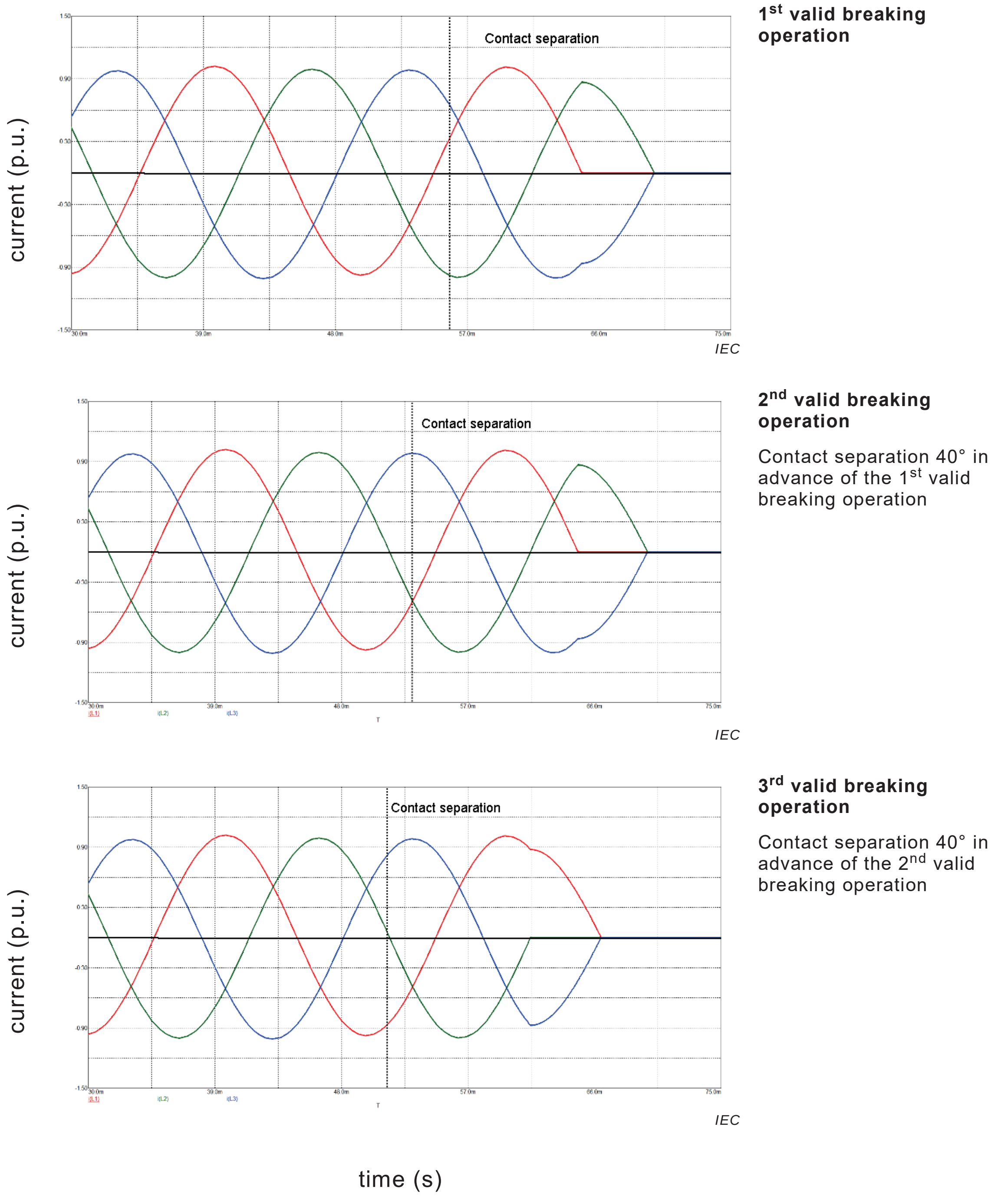
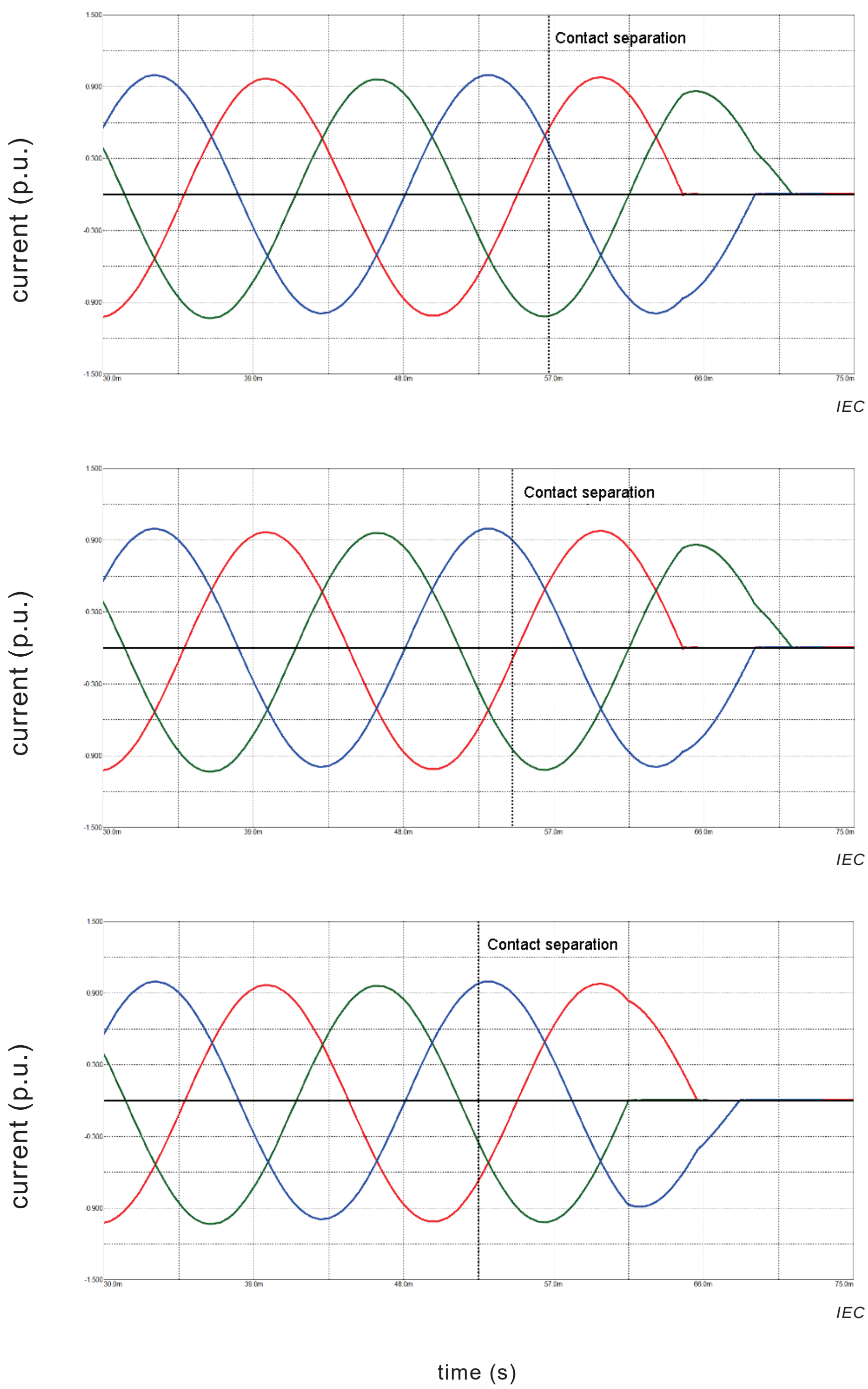


Figure 29 – Graphical representation of an example of the three valid symmetrical breaking operations for k_{pp} = 1,5



1st valid breaking operation

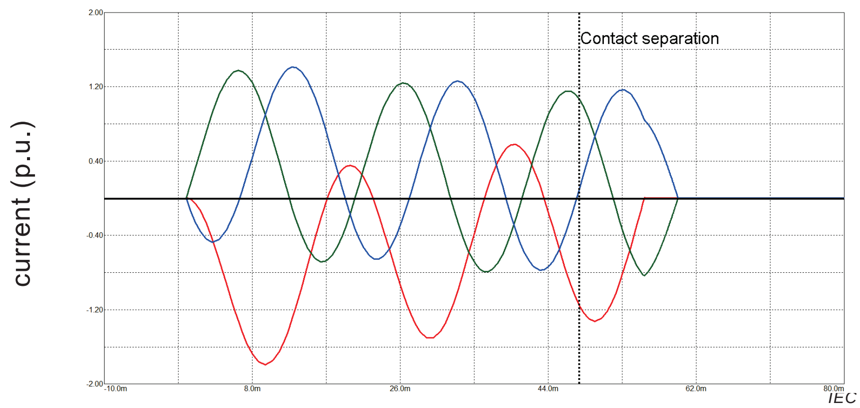
2nd valid breaking operation

Contact separation 40° in advance of the 1st valid breaking operation

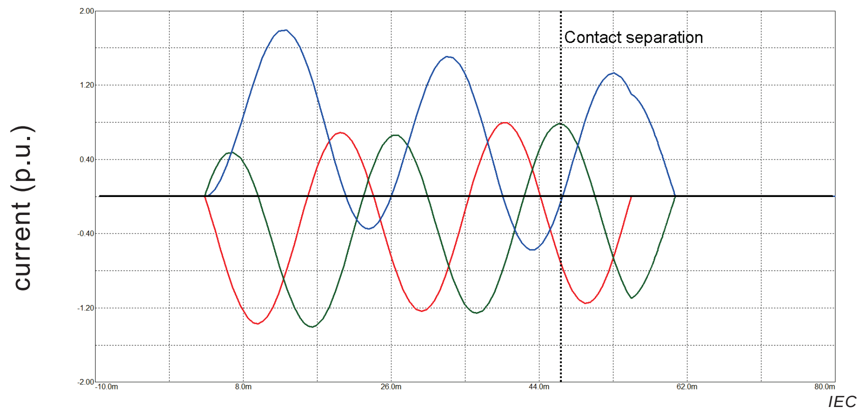
3rd valid breaking operation

Contact separation 40° in advance of the 2nd valid breaking operation

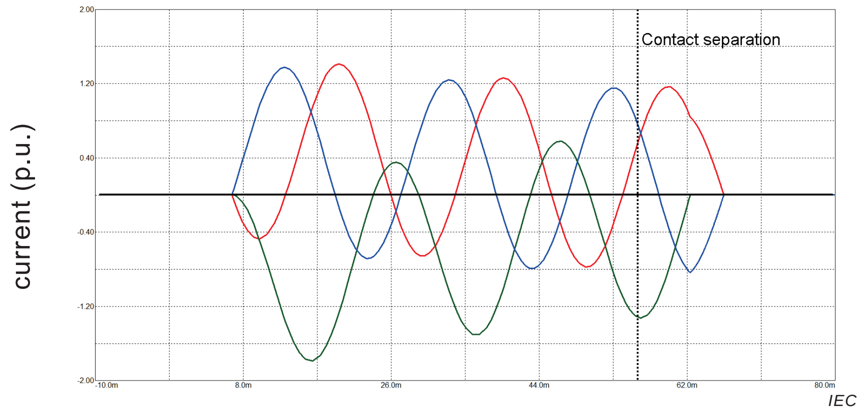
Figure 30 – Graphical representation of the three valid symmetrical breaking operations for k_{pp} = 1,2 or 1,3



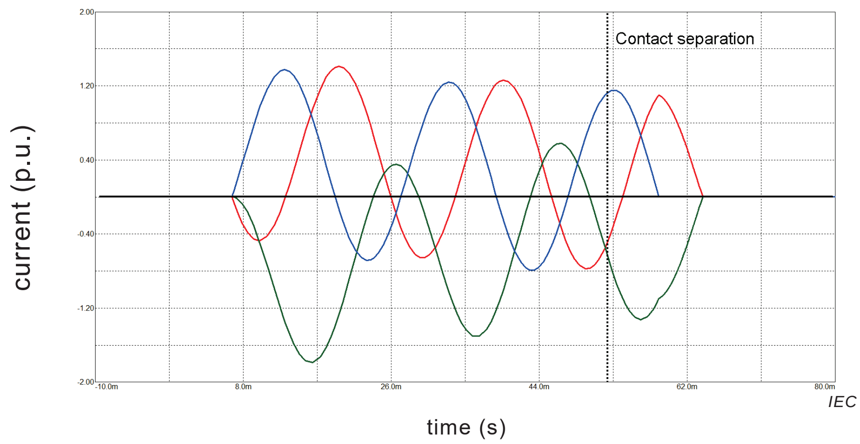
1st valid breaking operation
First-pole-to-clear on a major loop with the required maximum arcing time
(assumption t_{a100s}=5 ms)



2nd valid breaking operation
Current initiation delayed 60° from that of the first breaking operation
Last-pole-to-clear on an extended major loop with the required maximum arcing time

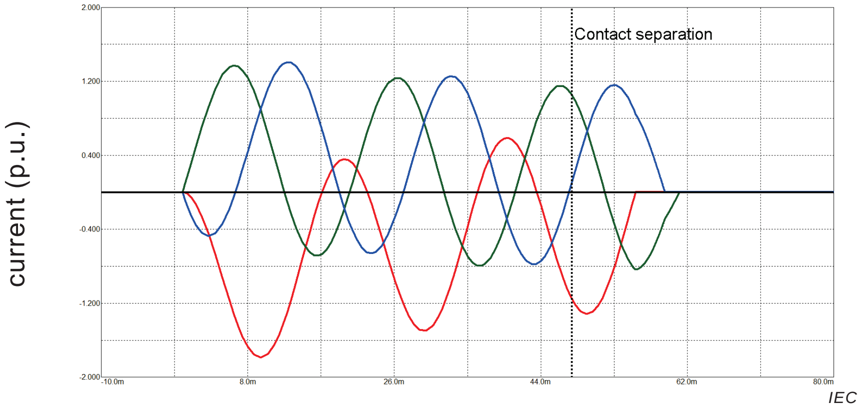


3rd valid breaking operation, option 1
Current initiation delayed 60° from that of the second breaking operation
First-pole-to-clear on a major loop, no requirement regarding arcing time

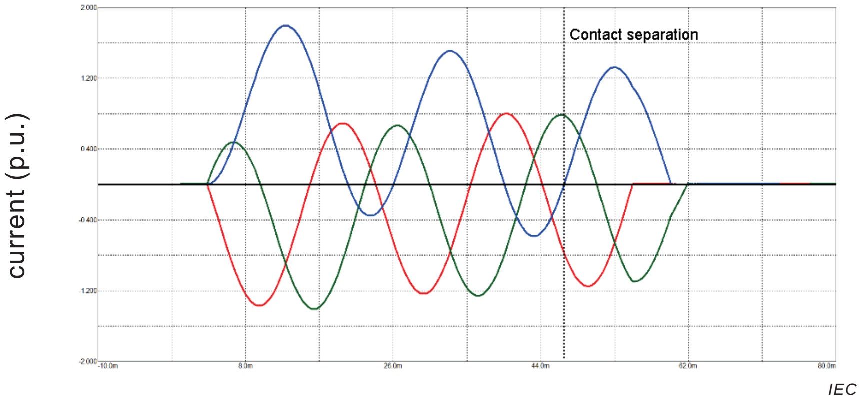


3rd valid breaking operation, option 2
Current initiation delayed 60° from that of the second breaking operation
Last-pole-to-clear on an extended major loop, no requirement regarding arcing time

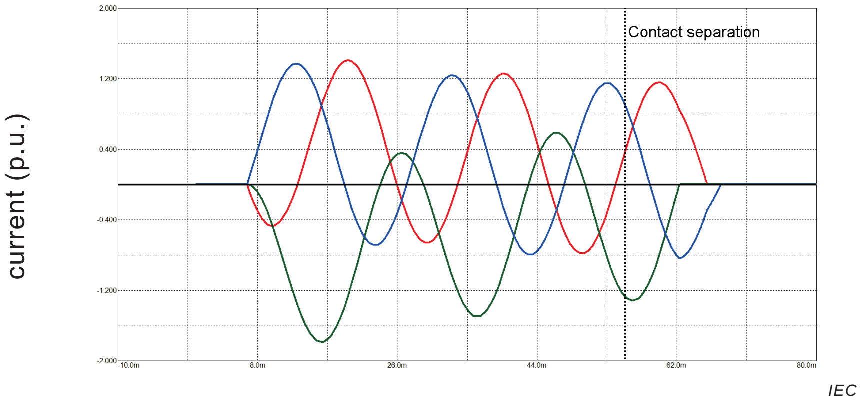
Figure 31 – Graphical representation of an example of the three valid asymmetrical breaking operations for k_{pp} = 1,5



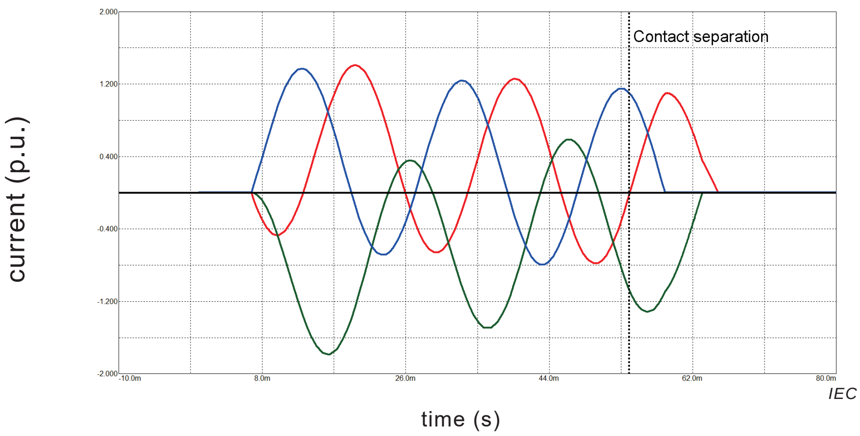
1st valid breaking operation
first-pole-to-clear on a major loop with the required maximum arcing time (assumption t_{a100s}= 5 ms)



2nd valid breaking operation
Current initiation delayed 60° from that of the first breaking operation
Second-pole-to-clear on an extended major loop with the required maximum arcing time

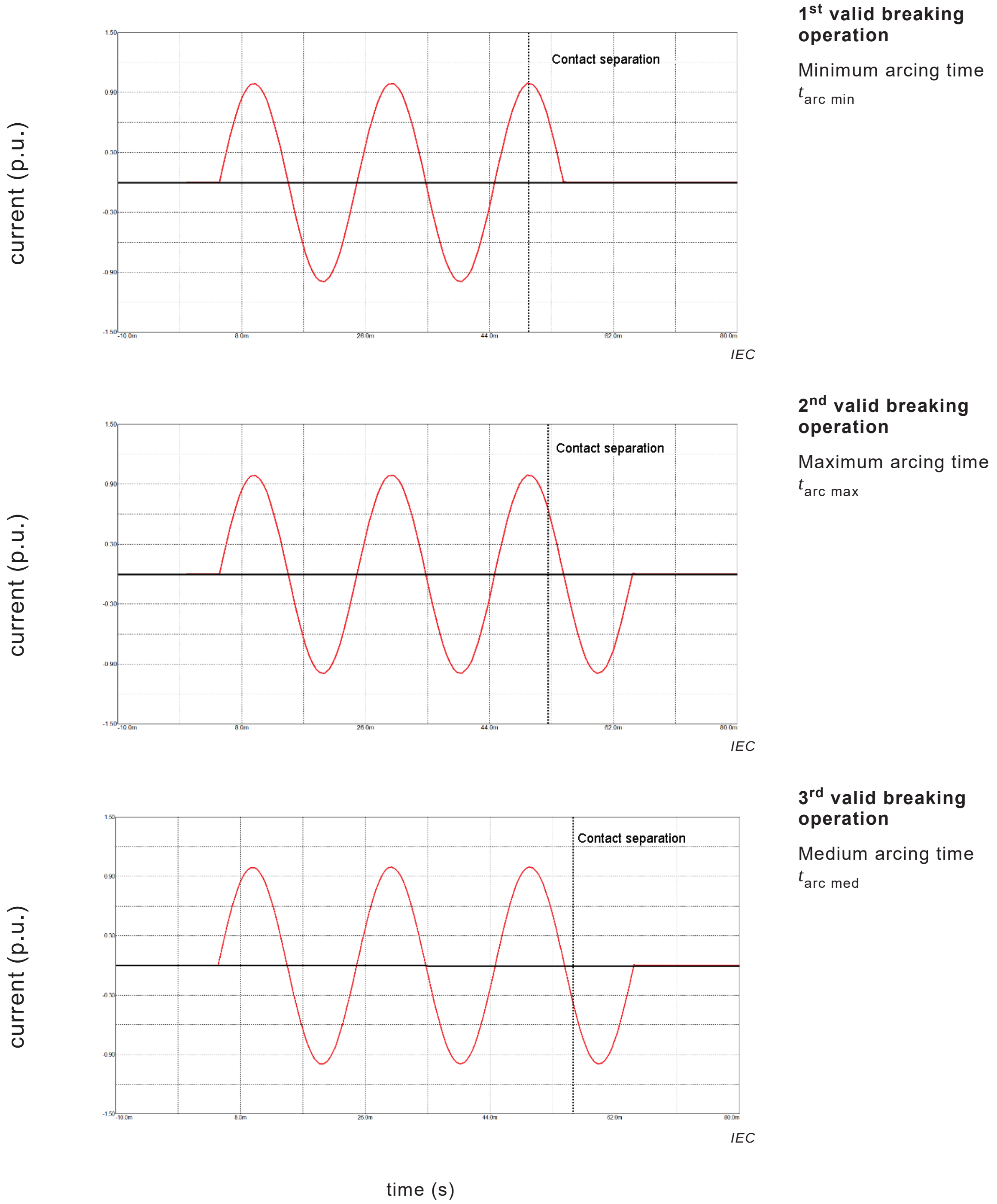


3rd valid breaking operation, option 1
Current initiation delayed 60° from that of the second breaking operation
First-pole-to-clear on a major loop, no requirement regarding arcing time



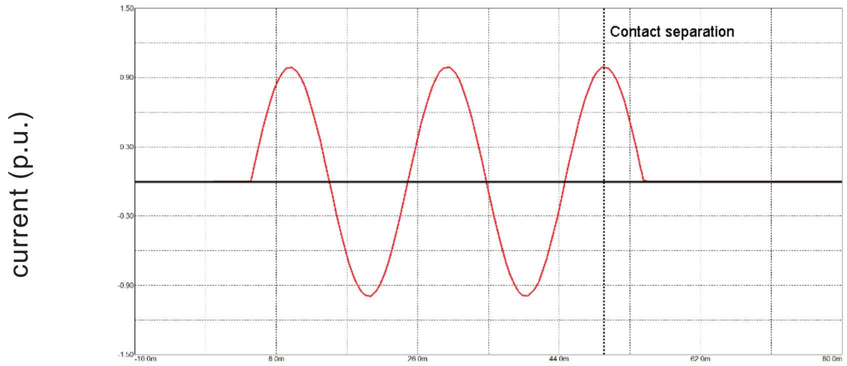
3rd valid breaking operation, option 2
Current initiation delayed 60° from that of the second breaking operation
Second-pole-to-clear on an extended major loop, no requirement regarding arcing time

Figure 32 – Graphical representation of an example of the three valid asymmetrical breaking operations for k_{pp} = 1,2 or 1,3



NOTE The polarity of the current can be reversed.

Figure 33 – Graphical representation of the three valid symmetrical breaking operations for single-phase tests in substitution of three-phase conditions for k_{pp} = 1,5

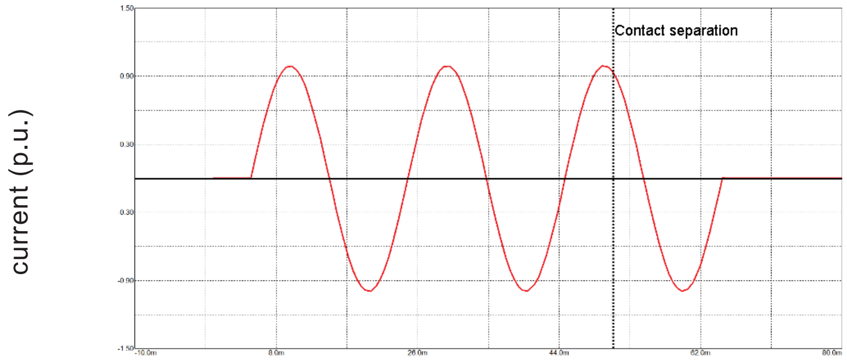


IEC

1st valid breaking operation

Minimum arcing time

$t_{arc\ min}$

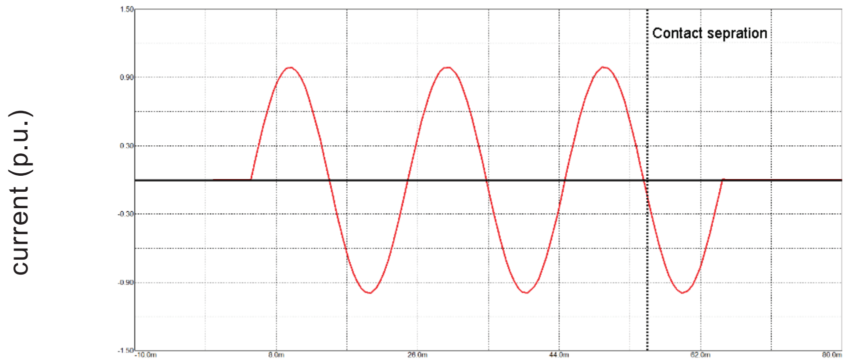


IEC

2nd valid breaking operation

Maximum arcing time

$t_{arc\ max}$



IEC

3rd valid breaking operation

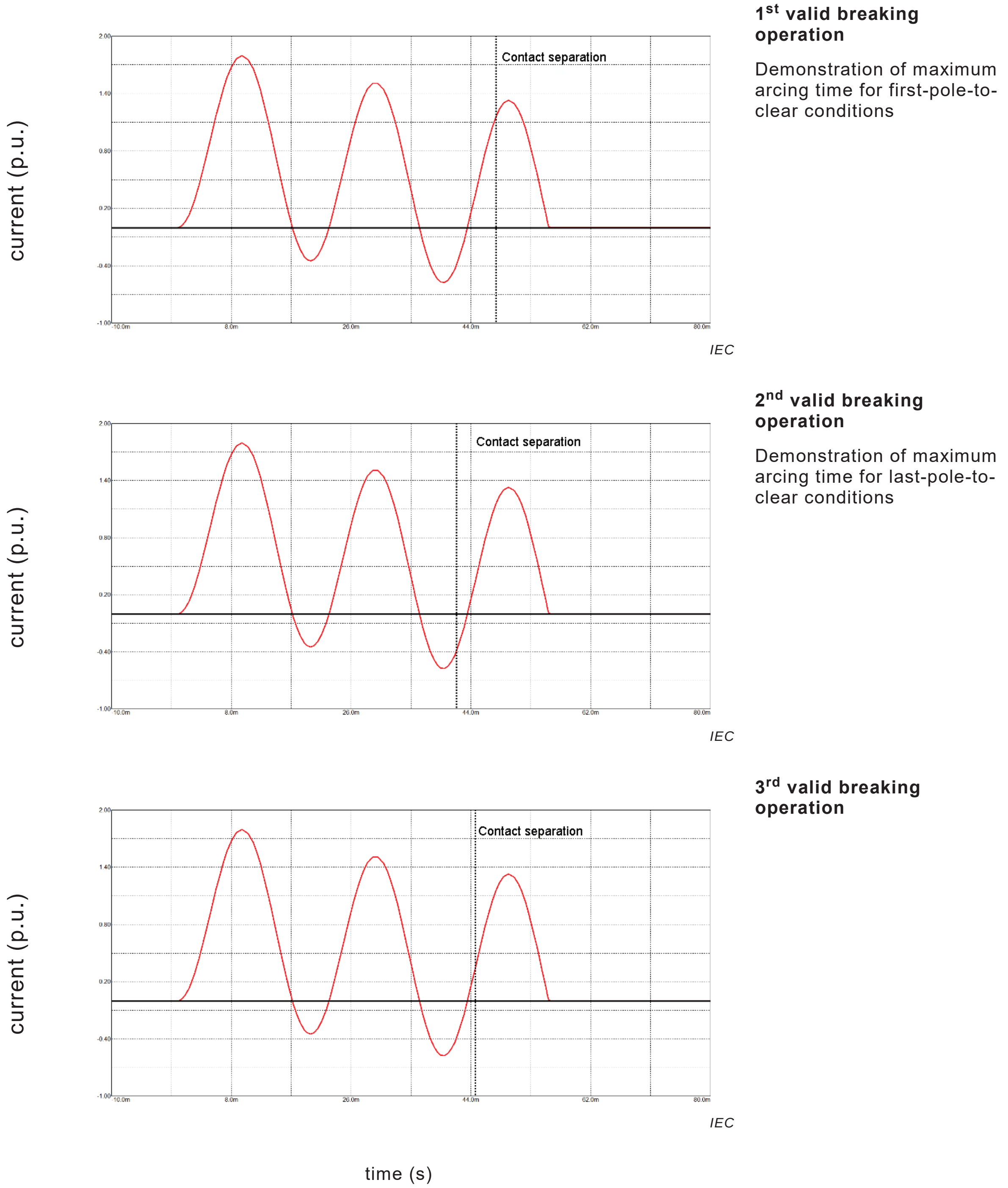
Medium arcing time

$t_{arc\ med}$

time (s)

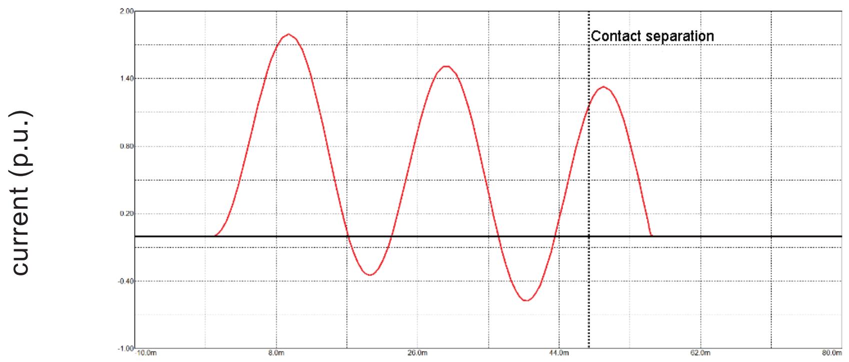
NOTE The polarity of the current can be reversed.

Figure 34 – Graphical representation of an example of the three valid symmetrical breaking operations for single-phase tests in substitution of three-phase conditions for k_{pp} = 1,2 or 1,3



NOTE The polarity of the current can be reversed.

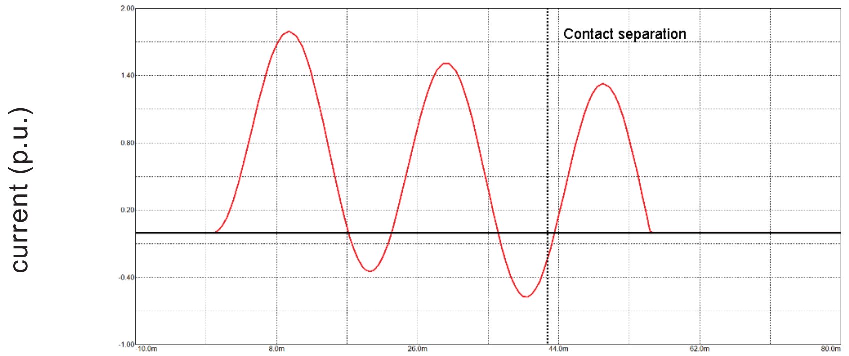
Figure 35 – Graphical representation of an example of the three valid asymmetrical breaking operations for single-phase tests in substitution of three-phase conditions for k_{pp} = 1,5



IEC

1st valid breaking operation

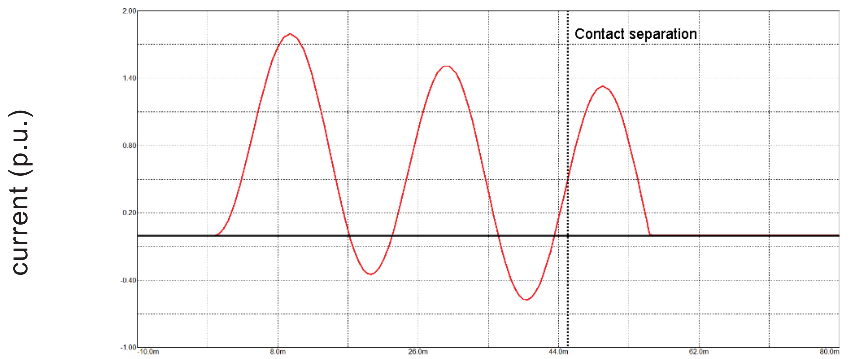
Demonstration of maximum arcing time for first-pole-to-clear conditions



IEC

2nd valid breaking operation

Demonstration of maximum arcing time for second-pole-to-clear conditions



IEC

3rd valid breaking operation

time (s)

NOTE The polarity of the current can be reversed.

Figure 36 – Graphical representation of an example of the three valid asymmetrical breaking operations for single-phase tests in substitution of three-phase for k_{pp} = 1,2 and 1,3

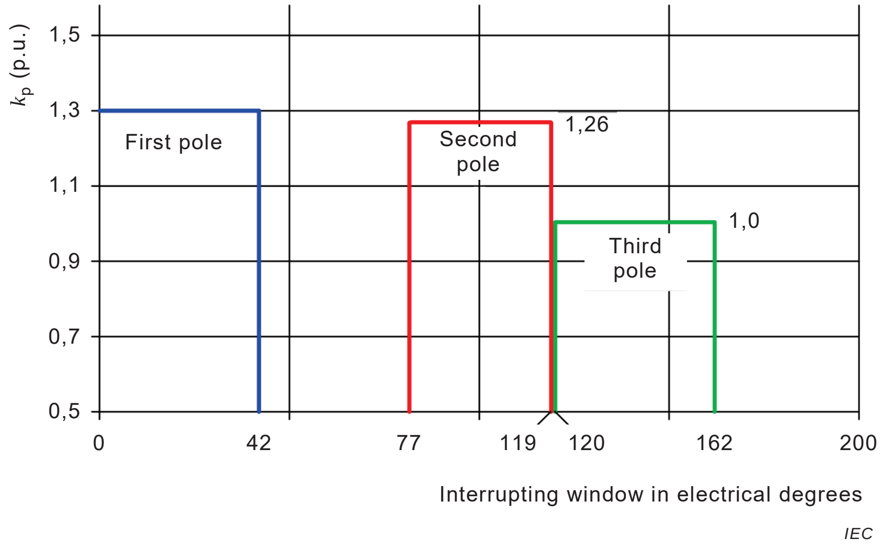


Figure 37 – Graphical representation of the interrupting window and the voltage factor k_p, determining the TRV of the individual pole, for systems with a first-pole-to-clear factor of 1,3

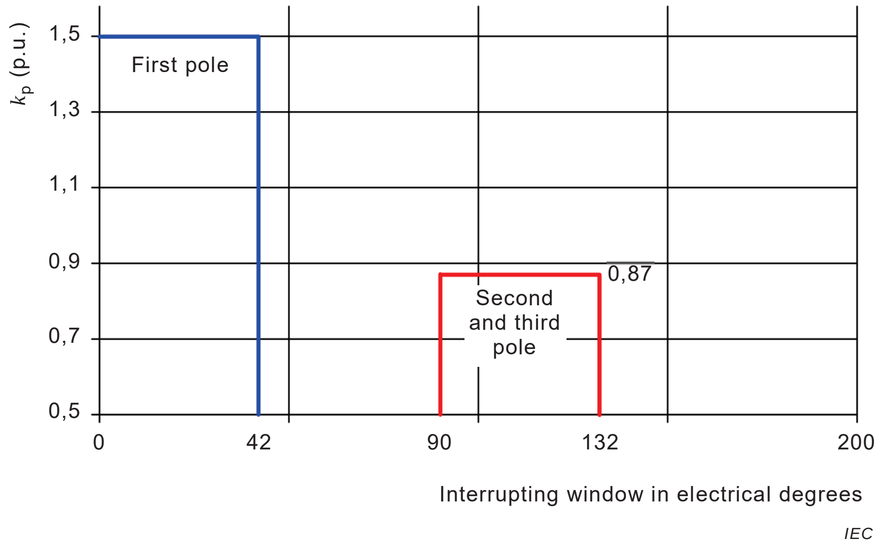
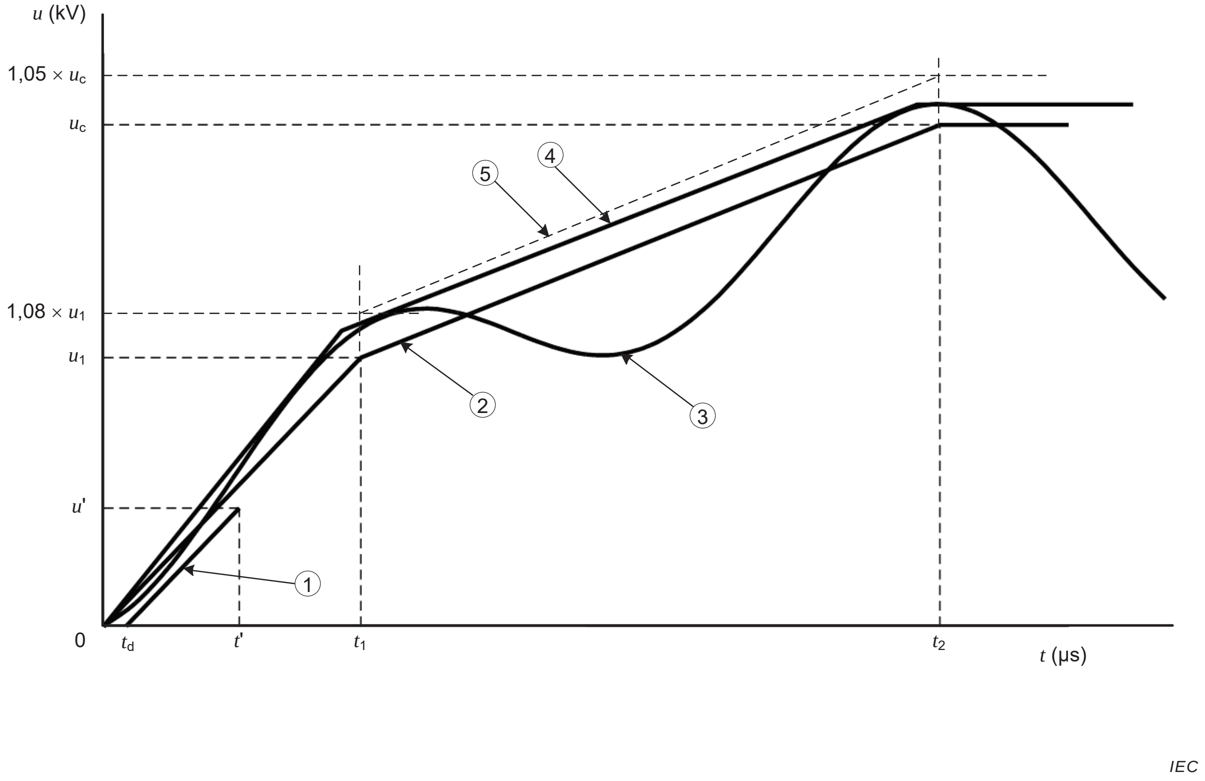


Figure 38 – Graphical representation of the interrupting window and the voltage factor k_p, determining the TRV of the individual pole, for systems with a first-pole-to-clear factor of 1,5



Key

1 Delay line of the specified TRV

2 Reference line of the specified TRV

3 Prospective test TRV

4 Envelope of the prospective test TRV

5 Upper limit of the envelope of the prospective test TRV

Figure 39 – Example of prospective test TRV with four-parameter envelope which satisfies the conditions to be met during type test – Case of specified TRV with four-parameter reference line

Delete Figures 41 and 42.

Figure 46 – Basic circuit arrangement for short-line fault testing and prospective TRV circuit-type a) according to 6.109.3: source side and line side with time delay

Replace the existing last subfigure of this figure by the following new figure:

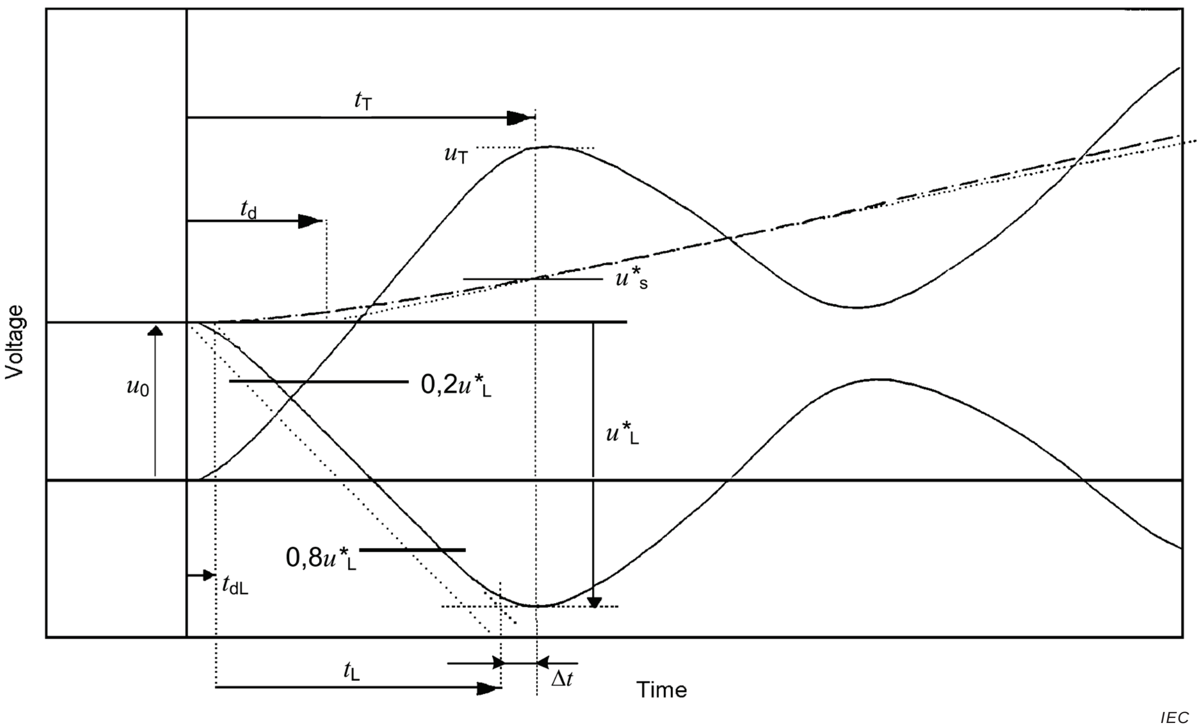


Figure 47 – Basic circuit arrangement for short-line fault testing – circuit type b1) according to 6.109.3: source side with ITRV and line side with time delay

Replace the existing last subfigure of this figure by the following new figure:

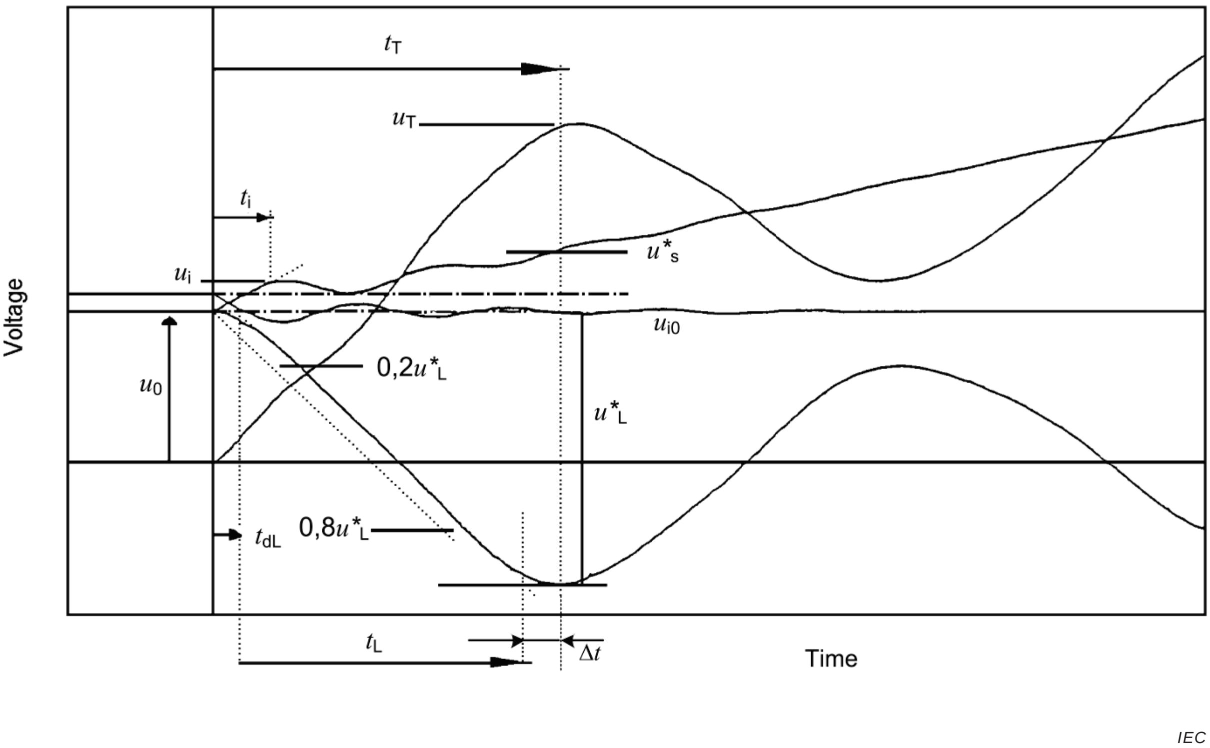
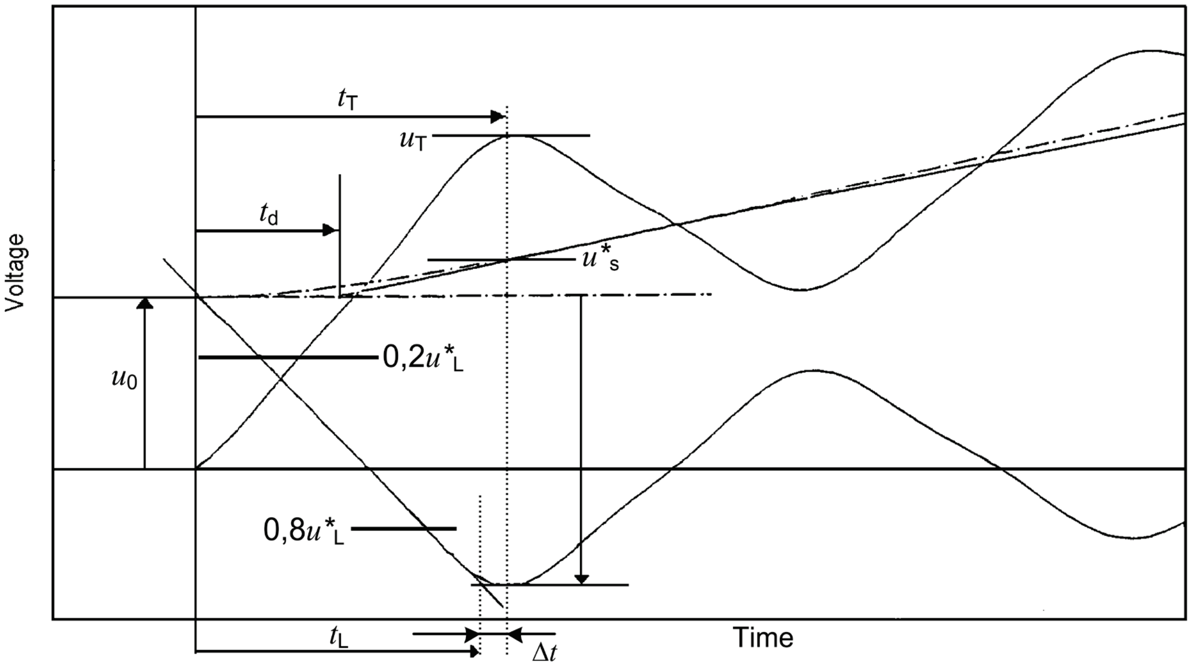


Figure 48 – Basic circuit arrangement for short-line fault testing – circuit type b2) according to 6.109.3: source side with time delay and line side without time delay

Replace the existing last subfigure of this figure by the following new figure:



A.2 Transient voltage on line side

Add, at the beginning of the clause, the following two new paragraphs:

Only separate measurement of the line side prospective TRV can be used to assess that the circuit fulfils the requirements given in this standard.

The prospective TRV of the line side circuit shall be measured separately from that of the source side. The resulting rate-of-rise of the line side TRV, du_L/dt, t_{dL}, u_L* and the surge impedance, Z, shall be within the tolerances given in Annex B.

Replace, in the existing clause, the reference to "4.105" *by* "6.109.3".

A.3.1 Rated voltages of 100 kV and above

Replace Equations (A.17a) and (A.17b), modified by Amendment 1, by the following:

– line with time delay (see Figures 46 and 47): $t_T = t_{dL} + t_L + \Delta t$ (A.17a)

– line with a time delay less than 100 ns (see Figure 48): $t_T = t_L + \Delta t$ (A.17b),

where t_{dL} is considered 0 for calculation purposes

$\Delta t = t_T - (t_{dL} + t_L)$

A.4.1 Source side and line side with time delay (L_{90} and L_{75} for 245 kV, 50 kA, 50 Hz)

Delete, in this table, the entire lines of u_T and t_T values.

A.4.2 Source side with ITRV, line side with time delay (L_{90} for 245 kV, 50 kA, 50 Hz)

Delete, in this table, the entire lines of u_T and t_T values.

A.4.3 Source side with time delay, line side without time delay (L_{90} for 245 kV, 50 kA, 50 Hz) – Calculation carried out using a simplified method

Delete, in this table modified by Amendment 1, the entire lines of u_T and t_T values.

Figure A.1 – Typical graph of line and source side TRV parameters – Line side and source side with time delay

Replace the existing figure and title by the following:

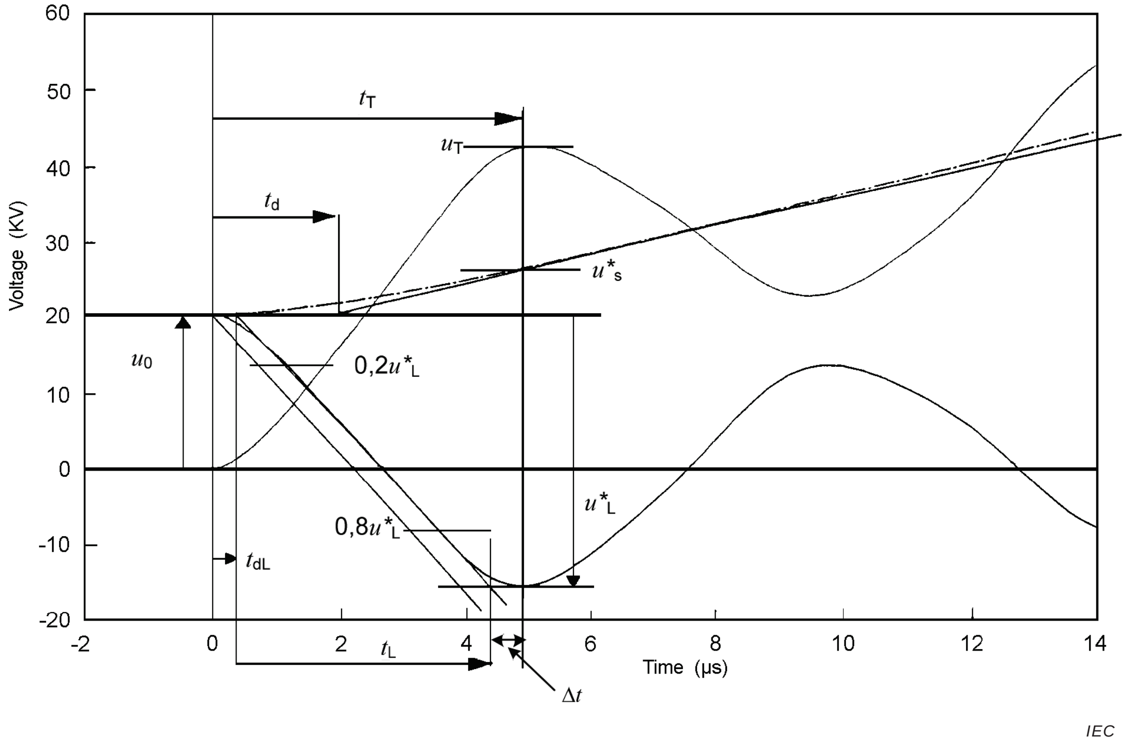


Figure A.1 – Typical graph of line and source side TRV parameters – Line side and source side with time delay

Figure A.2 – Typical graph of line and source side TRV parameters – Line side and source side with time delay, source side with ITRV

Replace the existing figure and title by the following:

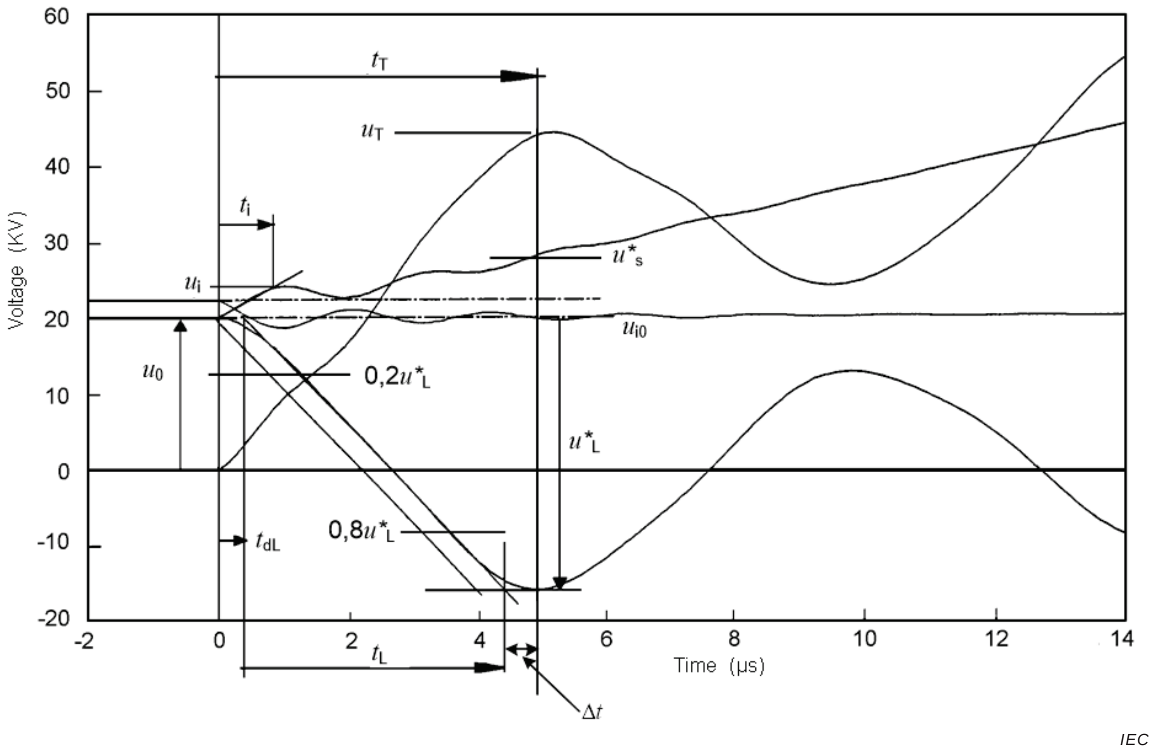


Figure A.2 – Typical graph of line and source side TRV parameters – Line side and source side with time delay, source side with ITRV

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

Add, after row 6.101.3, the following new row:

6.101.3.1	Low and high temperature tests; General	Perpendicular wind speed, if applicable	Specified average test value	±10 %	
			Limits for any individual measurement from the specified average test value	±50 %	

Delete the following row:

6.101.6	Guide for static terminal load test	Forces	As specified in 6.101.6	$^{+10}_{\ 0}$ %	

Replace the existing row for 6.102 by the following:

6.102.10.2.2	Demonstration of arcing times Test duty T100a, three-phase test	t_{arc1}:	maximum arcing time in T100a for the first-pole-to-clear	t_{arc1}	> (t_{arc1}-1 ms)	
		t_{arc2}:	maximum arcing time in T100a for the last-pole-to-clear for k_{pp}= 1,5	t_{arc2}	> (t_{arc2}-1 ms)	
		t_{arc3}:	maximum arcing time in T100a for the second-pole-to-clear for k_{pp}= 1,3 or 1,2	t_{arc3}	> (t_{arc3}-1 ms)	
6.102.10.2.3	Demonstration of arcing times Tests for covering the conditions for effectively and non-effectively earthed neutral systems	t_{arc}:	demonstration of the performance of the second-pole-to-clear under symmetrical fault conditions and demonstration the performance of the third-pole-to-clear under symmetrical fault conditions	t_{arc}	> (t_{arc}-1 ms)	
		t_{arc}:	maximum possible arcing time calculated for a three-phase condition considering the minimum arcing time value found during T100s test-duty performed for k_{pp} = 1,5.	t_{arc}	> (t_{arc}-1 ms)	
6.102.10.3.2	Demonstration of arcing times Test-duties T10, T30, T60, T100s and T100s(b), OP1 and OP2, L_{90}, L_{75} and L_{60}, single-phase test	$t_{arc\ max}$	maximum arcing	$t_{arc\ max}$	> ($t_{arc\ max}$-1 ms)	
		$t_{arc\ med}$	medium arcing time	$t_{arc\ med}$	> ($t_{arc\ med}$-1 ms)	
6.102.10.3.3	Demonstration of arcing times Test duty T100a, single-phase test	t_{arc1}:	maximum arcing time in T100a for the first-pole-to-clear	t_{arc1}	> (t_{arc1}-1 ms)	
		t_{arc2}:	maximum arcing time in T100a for the last-pole-to-clear for k_{pp}= 1,5	t_{arc2}	> (t_{arc2}-1 ms)	
		t_{arc3}:	maximum arcing time in T100a for the second-pole-to-clear for k_{pp}= 1,3 or 1,2	t_{arc3}	> (t_{arc3}-1 ms)	

Replace the existing rows under 6.104.3 and 6.104.4 by the following:

6.104.3	Short-circuit breaking current	AC component of any phase / average	1	± 10 %	
		AC component of the prospective current at final arc extinction in last-pole-to-clear	Specified breaking current for the relevant test-duty	≥ 90 %	
6.104.4	DC component of short-circuit breaking current	DC component in T10, T30, T60, T100s	--	≤ 20 %	
		Peak short-circuit current $\hat{I}$ during the last loop prior to interruption for T100a	See Tables 39 and 40	±10 %	
		Duration of the short-circuit current loop Δt prior to interruption for T100a	See Tables 39 and 40	± 10%	

Replace the existing row for 6.104.5 by the following:

6.104.5	TRV for terminal fault tests	Peak value of TRV: – for circuit-breakers ≤ 72,5 kV – for circuit-breakers > 72,5 kV	See Tables 24 and 25 See Tables 24, 25, 26 and 27	$^{+10}_{0}$ % $^{+5}_{0}$ %	
		Rate of rise of TRV: – for circuit-breakers ≤ 72,5 kV – for circuit-breakers > 72,5 kV	See Tables 24 and 25 See Tables 24, 25, 26 and 27	$^{+15}_{0}$ % 1) $^{+8}_{0}$ % 2)	
		Time delay t_d	See Tables 24, 25, 26 and 27	± 20 %	

2) See Figure 39.

Replace the existing row for 6.106 by the following:

6.106	Basic short-circuit test-duty	Breaking current in T10	10 % of rated short-circuit breaking current	± 20 %	
		Breaking current in T30	30 % of rated short-circuit breaking current	± 20 %	
		Breaking current in T60	60 % of rated short-circuit breaking current	± 10 %	
		Breaking current in T100s	100 % of rated short-circuit breaking current	$^{+5}_{0}$ %	
		Breaking current in T100a	100 % of rated short-circuit breaking current	±10%	
		Making current in T100s	Rated short-circuit making current	$^{+10}_{0}$ %	
		Peak short-circuit current in T100a	Rated peak withstand current	≤ 110 %	

Replace the row for 6.108, modified by Amendment 1, by the following:

6.108	Single-phase and double earth fault tests	Breaking current	See Figure 45	$^{+5}_{0}$ %	
		DC component of breaking current	≤ 20 %		
		Peak value of TRV: – for circuit-breakers ≤ 52 kV – for circuit-breakers > 52 kV	See 6.108.2 and Tables 24, 25, 26 and 27	 $^{+10}_{0}$ % $^{+5}_{0}$ %	
		Rate-of-rise of TRV – for circuit-breakers ≤ 52 kV – for circuit-breakers > 52 kV	See 6.108.2 and Tables 24, 25, 26 and 27	 $^{+15}_{0}$ % $^{+8}_{0}$ % [3)]	
[3)] See Figure 39					

Replace the row for 6.110, modified by Amendment 1, by the following:

6.110	Out-of-phase making and breaking tests	Power factor	--	≤ 0,15	
		DC component of breaking current	≤ 20 %		
		Applied voltage and power frequency recovery voltage	As specified in 6.110.2	± 5 %	
		Peak value of TRV:			
		– for circuit-breakers ≤ 52 kV	See Tables 1 and 2	$^{+10}_{\ 0}$ %	
		– for circuit-breakers > 52 kV	See Tables 1, 2, 3, 4 and 26	$^{+5}_{\ 0}$ %	
		Rate of rise of TRV:			
		– for circuit-breakers ≤ 52 kV	See Tables 1 and 2	$^{+15}_{\ 0}$ %	
		– for circuit-breakers > 52 kV	See Tables 1, 2, 3, 4 and 26	$^{+8}_{\ 0}$ % [4)]	
		Instant of making in OP2	At crest of applied voltage in one pole	± 15°	
		Breaking current for OP1	30 % of rated out-of-phase breaking current	± 20 % of specified value	
		Breaking current for OP2	100 % of rated out-of-phase breaking current	$^{+10}_{\ 0}$ %	

4) See Figure 39

Annex E – Method of drawing the envelope of the prospective transient recovery voltage of a circuit and determining the representative parameters

Replace the existing title of this annex by the following:

Annex E – Method of determination of the prospective TRV

E.1 Introduction

Replace the existing title and text by the following:

E.1 General

A TRV wave may assume different forms, both oscillatory and non-oscillatory.

The TRV related to the rated short-circuit breaking current in accordance with 4.101, is the reference voltage which constitutes the limit of the prospective TRV of circuits which the circuit-breaker shall be capable of withstanding under fault conditions.

The waveform of the TRVs varies according to the arrangement of actual circuits. Two representations of TRV waves are defined, depending on the rated voltage and level of short-circuit current.

a) A two-parameter representation is used for circuit-breakers with rated voltages less than 100 kV and for circuit-breakers with rated voltages higher than 100 kV when the short-circuit current is equal to or lower than 30 % of rated breaking current and for out of phase test for rated voltages higher than 800 kV.

   The two-parameter reference line is shown in Figure 11.

   u_c = reference voltage (TRV peak value), in kV;

   t_3 = time in µs.

   The rate of rise of recovery voltage (RRRV) is u_c/t_3.

b) A four-parameter representation is used for circuit-breakers with rated voltages equal to or higher than 100 kV when the short-circuit current is higher than 30 % of rated breaking current and for out of phase condition equal to or higher than 100 kV and lower than or equal to 800 kV.

   The four-parameter reference line is shown on Figure 10.

   u_1 = first reference voltage, in kV;

   t_1 = time to reach u_1, in µs;

   u_c = second reference voltage (TRV peak value), in kV;

   t_2 = time to reach u_c, in µs.

The RRRV is u_1/t_1.The influence of local capacitance on the source side of the circuit-breaker produces a slower rate of rise of the voltage during the first few microseconds of the TRV. This is taken into account by introducing a time delay.

The TRV wave may be defined by means of an envelope made up of three consecutive line segments; when the wave approaches that of a damped oscillation at one single frequency, the envelope resolves itself into two consecutive line segments. In all cases, the envelope should reflect as closely as possible the actual shape of the TRV. The method described here enables this aim to be achieved in the majority of practical cases with sufficient approximation.

NOTE In some cases the chosen circuit could lead to overstressing the circuit-breaker after the first TRV peak.

F.1 Introduction

Replace the title by:

F.1 General

Replace, in the last paragraph, the reference to "4.105" to "6.109".

Delete the existing Annex H.

Delete the existing Annex I.

Delete the existing Annex J.

Delete the existing Annex K.

Delete the existing Annex L.

Annex M – Requirements for breaking of transformer-limited faults by circuit-breakers with rated voltage higher than 1 kV

Replace, in the title modified by Amendment 1, "normative" to "informative".

Table M.1 – Standard values of prospective transient recovery voltage for T30, for circuit-breakers intended to be connected to a transformer with a connection of small capacitance – Rated voltage higher than 1 kV and less than 100 kV – Representation by two parameters

Replace the title of this table by the following:

Table M.1 – Required values of prospective TRV for T30, for circuit-breakers intended to be connected to a transformer with a connection of small capacitance – Rated voltage higher than 1 kV and less than 100 kV for non-effectively earthed neutral systems

Add, after the existing Table M.1, the new table as follows:

Table M.3 – Required values of prospective TRV for T30, for circuit-breakers intended to be connected to a transformer with a connection of small capacitance – Rated voltage higher than 1 kV and less than 100 kV for effectively earthed neutral systems

Rated voltage U_r kV	Test-duty	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV[a] u_c/t_3 kV/µs
3,6	T30	1,3	1,6	6,1	4,0	1	2,0	2	1,58
4,76[b]	T30	1,3	1,6	8,1	4,5	1	2,7	2	1,86
7,2	T30	1,3	1,6	12,2	5,0	1	4,1	2	2,56
8,25[b]	T30	1,3	1,6	14,0	5,0	1	4,7	2	2,70
12	T30	1,3	1,6	20,4	5,5	1	6,8	3	3,62
15[b]	T30	1,3	1,6	25,5	6,0	1	8,5	3	4,20
17,5	T30	1,3	1,6	29,7	6,5	1	9,9	3	4,53
24	T30	1,3	1,6	40,8	8,0	1	13,6	4	4,95
25,8[b]	T30	1,3	1,6	43,8	8,0	1	14,6	4	5,37
36	T30	1,3	1,6	61,1	10,0	2	20,4	5	6,17
38[b]	T30	1,3	1,6	64,5	10,0	2	21,5	5	6,43
48,3[b]	T30	1,3	1,6	82,0	12,0	2	27,3	6	6,79
52	T30	1,3	1,6	88,3	12,0	2	29,4	6	7,29
72,5[b]	T30	1,3	1,6	123	15,5	2	41,0	7	7,89

[a] RRRV = rate of rise of recovery voltage.

[b] Used in some countries.

Table M.2 – Standard values of prospective transient recovery voltage for circuit-breakers with rated voltages higher than 800 kV intended to be connected to a transformer with a connection of low capacitance

Replace the title of this table, modified by Amendment 1, by the following:

Table M.2 – Required values of prospective TRV for circuit-breakers with rated voltages higher than 800 kV intended to be connected to a transformer with a connection of low capacitance

M.4 Circuit-breakers with rated voltage higher than 800 kV

Delete, in the second and third paragraphs modified by Amendment 1, the word "rated".

Annex N – Use of mechanical characteristics and related requirements

Replace Annex N by the following:

Annex N
(normative)

Use of mechanical characteristics and related requirements

At the beginning of the type tests, the mechanical characteristics of the circuit-breaker shall be established, for example, by recording no-load travel curves and by defining additional characteristic parameters, such as, if applicable, momentary speed at a certain stroke, closing and opening times, damping time, etc. The tolerances applicable to these additional parameters shall also be defined and declared by the manufacturer. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the circuit-breaker.

The mechanical characteristics shall be used to confirm that the different test objects used during the mechanical, making, breaking and switching type tests behave mechanically in a similar way. All test objects used for mechanical, making, breaking and switching type tests shall have their respective no-load contact travel curves within the following described envelopes. Care should be exercised in the interpretation of the curves when, due to variable measuring methods at different laboratories, a direct comparison between the envelopes cannot be made.

The reference mechanical characteristics are also used to confirm that production units behave mechanically in a similar way as the test objects used during type tests.

The type and location of the sensor used for the record of the mechanical characteristics shall be stated in the test report. The mechanical characteristic curve which can be measured at any part of the power kinematic chain may be recorded continuously or discretely. In case of discrete measurement, at least 20 discrete values should be given for the complete stroke.

The no-load contact travel curves shall be used for determining the limits of the allowable deviations over or under this reference curve. From this reference curve, two envelope curves shall be drawn from the instant of contact separation to the end of the contact travel for the opening operation and from the beginning of the contact travel to the instant of contact touch for the closing operation. The distance of the two envelopes from the original course shall be ± 5 % of the total stroke as shown in Figure 23b. In case of circuit-breakers with a total stroke of 40 mm or less the distance of the two envelopes from the original course shall be ±2 mm. It is recognised that for some designs of circuit-breakers, these methods may be unsuitable, as for example for vacuum circuit-breakers or for some circuit-breakers rated less than 52 kV. In such cases the manufacturer shall define an appropriate method to verify the proper operation of the circuit-breaker.

If mechanical characteristics other than no-load contact travel curves are used, the manufacturer shall define the alternative method and the tolerances used.

The series of Figures 23a to 23d are for illustrative purposes and only illustrate the opening operation. They are idealised, and do not show the variation in profile caused by the friction effect of the contacts or the end of travel damping. In particular, it is important to note that the effects of damping are not shown in these diagrams. The oscillations produced at the end of travel are dependent upon the efficiency of the damping of the drive system. The shape of these oscillations may be a deliberate function of the design and may slightly vary from one specimen to another. Therefore, it is important that any variations in the curve at the end of the stroke, which are outside the tolerance margin given by the envelope, are fully explained and understood before they are rejected or accepted as showing equivalence with the reference curves. In general, all curves should fall within the envelopes for acceptance.

The travel characteristics of all production units shall lie within the 10 % total allowable tolerance around the reference travel characteristic. The reference travel characteristic may lie at any point within the defined tolerance band but the parameters of the 10 % tolerance band, once defined, shall remain unchanged. Figures 23c and 23d show the two extremes of the allowable cases which are –0 %, +10 % and –10 %, +0 % respectively.

Annex O – Guidance for short-circuit and switching test procedures for metal-enclosed and dead tank circuit-breakers

Replace the existing annex by the following:

Annex O
(normative)

Requirements for short-circuit and switching test procedures for metal-enclosed and dead tank circuit-breakers

O.1 General

This annex contains requirements for test circuits and procedures for type testing relevant to short-circuit making and breaking and switching performance of metal-enclosed and dead tank circuit-breakers. Other methods are not excluded, provided that they supply the correct stresses to the circuit-breaker.

The various test cases are evaluated and test circuits are given, or special precautions required to use test circuits developed for open-air equipment. The tests described can be made in principle in both direct and synthetic circuits. For synthetic test circuits, see IEC 62271-101.

Circuit-breakers in metal enclosures have to fulfil their duties under conditions which are different from those prevailing in insulating enclosures.

The main features with certain consequences on making and breaking tests are:

a) The switching units are integrated parts of a given substation design. Thus, the surrounding components of a substation have to be considered when defining the test conditions;
b) Several breaking units of one pole, or even all three poles, can be placed within a common enclosure. Various components of switching units of the substation as well as other live and earthed parts are in immediate vicinity. This will cause high dielectric stress on the insulating medium and may lead to strong interactions between parts of switching units and the surroundings. It also results in a relatively high capacitance and low inductance of tested and surrounding parts.

   The implications of such interactions have to be considered in determining the test requirements;
c) In metal-enclosed equipment, the insulating surfaces are exposed to a relatively high dielectric stress and this may make them sensitive to deposit.

O.2 Reduced number of units for testing purposes

Due to limitations of test facility it may not be possible to perform the tests on a complete circuit-breaker. In these cases alternative procedures can be used if the following instructions are taken into account.

Depending on the alternatives, the following interactions between the tested object and the omitted parts should be analysed:

– between circuit-breaker units and surrounding parts of the substation;
– between poles or between poles and the enclosure;

– between different units or between units and the enclosure.

Two different stresses can be considered, which usually can be treated separately:

– stress of the interrupting gap;
– stress of insulation between phases, or between phases and the enclosure.

O.3 Tests for single pole in one enclosure

O.3.1 General

The conditions of 6.102 shall be fulfilled.

O.3.2 Terminal fault tests

O.3.2.1 General

For short-circuit-currents in excess of 60 % of the short-circuit breaking current the test circuits shall comply with Figures 25a, 26a, 27a, 28a.

Test circuits given in Figures 25b, 26b, 27b and 28b do not stress metal-enclosed and dead tank circuit-breakers in earthed fault conditions correctly but are acceptable for short-circuit currents equal to or less than 60 % of the rated short-circuit breaking current.

O.3.2.2 Unit testing

Subclause 6.102.4.2 is applicable with the following additional requirements:

During T100s and T100a the full-pole TRV and recovery voltage between the relevant live parts and the enclosures shall be applied.

O.3.3 Capacitive current switching tests

O.3.3.1 General

The testing procedure shall be in agreement with 6.111.

Table O.1 gives the source-side and load-side voltages and the recovery voltages during three-phase capacitive current switching in actual service conditions and shall be used for three phase tests.

Table O.2 gives the corresponding values of the source-side, load-side, and recovery voltages during single-phase capacitive current switching tests.

Table O.1 – Three-phase capacitive current switching in service conditions: voltages on the source-side, load-side, and recovery voltages

Voltage at circuit-breaker terminal	Values of the voltages for effectively earthed neutral systems			Values of the voltages for non-effectively earthed neutral systems
	Unearthed capacitors	Earthed capacitor banks and screened cables	Lines	In all cases
U_{CE}	$U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$
$U_{C/E}$	$1{,}5 \times U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$	$1{,}2 \times U_r\sqrt{2}/\sqrt{3}$	$1{,}5 \times U_r\sqrt{2}/\sqrt{3}$
$U_{CC'}$	$2{,}5 \times U_r\sqrt{2}/\sqrt{3}$	$2 \times U_r\sqrt{2}/\sqrt{3}$	$2{,}2 \times U_r\sqrt{2}/\sqrt{3}$	$2{,}5 \times U_r\sqrt{2}/\sqrt{3}$

Pole C is assumed to be the first-pole-to-clear.

C: source side

C': load side

C/C': across the open contacts

U_r = rated voltage

U_{CE} = voltage between source-side terminal and earth

$U_{C'E}$ = voltage between load-side terminal and earth

$U_{C/C'}$ = voltage across the open contacts

NOTE 1 The designation of the poles is illustrated in Figure O.1.

NOTE 2 The values given do not consider the voltage drop at the supply side after interruption.

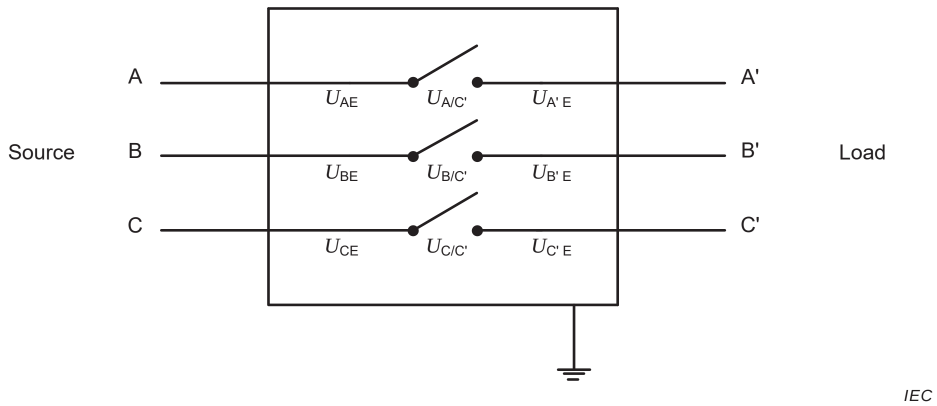


Figure O.1 – Test configuration considered in Tables O.1, O.2 and O.3

Table O.2 – Corresponding capacitive current-switching tests in accordance with 6.111.7 for single-phase laboratory tests. Values of voltages on the source-side, load-side, and recovery voltages

Voltage at circuit-breaker terminal	Values of the voltages for effectively earthed neutral systems			Values of the voltages for non-effectively earthed neutral systems
	Unearthed capacitors	Earthed capacitor banks and screened cables	Lines	In all cases
U_{CE}	$1{,}3 \times U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$	$1{,}2 \times U_r\sqrt{2}/\sqrt{3}$	$1{,}3 \times U_r\sqrt{2}/\sqrt{3}$
$U_{C'E}$	$1{,}5 \times U_r\sqrt{2}/\sqrt{3}$	$U_r\sqrt{2}/\sqrt{3}$	$1{,}2 \times U_r\sqrt{2}/\sqrt{3}$	$1{,}5 \times U_r\sqrt{2}/\sqrt{3}$
$U_{CC'}$	$2{,}8 \times U_r\sqrt{2}/\sqrt{3}$	$2 \times U_r\sqrt{2}/\sqrt{3}$	$2{,}4 \times U_r\sqrt{2}/\sqrt{3}$	$2{,}8 \times U_r\sqrt{2}/\sqrt{3}$

Pole C is assumed to be the first-pole-to-clear.

C: source side

C': load side

C/C': across the open contacts

U_r = rated voltage

U_{CE} = voltage between source-side terminal and earth

$U_{C'E}$ = voltage between load-side terminal and earth

$U_{CC'}$ = voltage across the open contacts

NOTE 1 The designation of the poles is illustrated in Figure O.1.

NOTE 2 The values given do not consider the voltage drop at the supply side after interruption.

O.3.3.2 Single-pole testing of three-pole circuit-breakers

In some test circuits, both voltages are combined at one terminal of the circuit-breaker, the other terminal being earthed.

This condition is more severe for the insulation to earth and may affect the severity of the test across the circuit-breaker.

For single-phase tests performed to prove three-phase switching of capacitor banks with unearthed neutral or switching in non-effectively earthed neutral systems, the dielectric withstand can be demonstrated by one of the following test methods:

a) Switching tests with an intermediate earth point in the source-side or in the load-side resulting in a voltage between the live parts on the source side and the enclosure of $1{,}5 \times U_r\sqrt{2}/\sqrt{3}$ and a recovery voltage of $2{,}8 \times U_r\sqrt{2}/\sqrt{3}$;

b) Subject to agreement of the manufacturer, tests can be performed with a supply circuit having an earthed neutral and a supply voltage of $1{,}5 \times U_r\sqrt{2}/\sqrt{3}$.

If for single-phase tests, according to 6.111.7, the dielectric stress between the live part and the enclosure is not correctly reproduced, additional dielectric tests shall be performed applying the load side dielectric stresses to the enclosure according to Table O.2. The load side voltage shall be applied, with both polarities, on each terminal of the circuit-breaker and maintained for 0,3 s.

In addition to the conditions of Tables O.1 and O.2, the following paragraphs give information concerning switching of capacitive currents in the presence of earth faults (see Annex S).

With the neutral of the supply effectively earthed and in presence of single- or two-phase earth faults, the voltages in the healthy phases can reach up to $1{,}4 \times U_r\sqrt{2}/\sqrt{3}$ .The precise value depends on the zero sequence impedances. In that case, the values of the voltages on source-side and load-side terminals to earth which shall be achieved are:

– $U_{C/E} = U_{C'/E} = 1{,}4 \times U_r\sqrt{2}/\sqrt{3}$

– $U_{C/C'} = 2{,}8 \times U_r\sqrt{2}/\sqrt{3}$ (recovery voltage)

With the neutral of the supply not effectively earthed and in presence of single- or two-phase earth faults, the voltages in the healthy phases can reach up to $1{,}7 \times U_r\sqrt{2}/\sqrt{3}$.

In that case, the values of the voltages on source-side and load-side terminals to earth which shall be achieved are:

– $U_{C/E} = U_{C'/E} = 1{,}7 \times U_r\sqrt{2}/\sqrt{3}$

– $U_{C/C'} = 3{,}4 \times U_r\sqrt{2}/\sqrt{3}$ (recovery voltage)

O.3.3.3 Unit testing

Unit testing is only acceptable if the voltage to earth at one terminal is equal to the load side voltage to earth during full-pole testing. This condition can be met by:

– energizing the enclosure of the circuit-breaker, insulated from earth, with a proper voltage, or

– in the case of two series connected breaking units per pole, performing half-pole testing with both voltages (a.c. and d.c.) superimposed at one terminal and the other terminal of that half-pole being earthed.

O.4 Tests for three poles in one enclosure

O.4.1 Terminal fault tests

For short-circuit-currents in excess of 60 % of the short-circuit breaking current the test circuits shall comply with Figures 25a or 26a.Test circuits given in Figures 25b, 26b, 27a, 27b, 28a and 28b do not stress metal-enclosed and dead tank circuit-breakers in earthed fault conditions correctly but are acceptable for short-circuit testing equal to or less than 60 % of the rated short-circuit breaking current.

O.4.2 Capacitive current switching tests

In case of single-phase testing, the dielectric stresses between the insulation to earth and between poles are not reproduced correctly and additional dielectric test are necessary. If not otherwise verified, the stresses stated in Table O.3 shall be verified by applying them at both polarities and for a duration of at least 0,3 s in case of d.c. voltages and for a duration of at least 0,3 s in case of a.c. voltages. In case of d.c. voltages on two terminals these voltages shall have opposite polarity. For voltage distribution of the a.c. and d.c. voltages, see Table O.1. All terminals not being part of the testing shall be earthed.

Depending on configuration of the circuit-breaker, some tests are redundant and do not need to be performed.

Table O.3 – Capacitive current switching in actual service conditions: maximum typical voltage values

Voltage between terminal	Effectively earthed neutral systems			Non-effectively earthed neutral systems
	Unearthed capacitor banks p.u.	Earthed capacitor banks p.u.	Lines p.u.	p.u.
A-earth	1,0	1,0	1,0	1,5
A'-earth	1,5	1,0	1,2	1,0
A-A'	2,5	2,0	2,2	2,5
A'-B'	≤1,73	≤1,73	≤1,73	≤1,73
A'-C'	2,37	2,0	2,1	2,37
B'-C'	≤1,73	2,0	1,9	≤1,73
A-B'	1,87	2,0	2,0	1,87
A-C'	1,87	2,0	1,9	1,87
B-A'	2,5	2,0	2,2	2,5
B-C'	1,87	2,0	1,9	1,87
C-A'	2,5	2,0	2,2	2,5
C-B'	1,87	2,0	2,0	1,87
A-A' First-pole-to-clear A = Source side A' = Load side				

NOTE 1 The indicated values for non-effectively earthed neutral systems apply if the source-side zero sequence capacitance is negligible compared to that of the load side.

NOTE 2 1 p.u. = $U_r \sqrt{2} / \sqrt{3}$

NOTE 3 Poles B and C clear at the first current zeros after the clearance of pole A.

NOTE 4 The voltage value for A-B, A-C and B-C are in all cases equal to $U_r \sqrt{2}$.

NOTE 5 The voltages B-earth, B'-earth, B-B' and C-earth, C'-earth and C-C' are not incorporated in the table, because their values are lower than those for pole A.

Delete the existing Annex P.

Delete the existing Annex Q.

Annex R – Requirements for circuit-breakers with opening resistors

Replace, in the entire annex modified by Amendment 1, "L_V" by "L_S" (3 occurrences).

Add, after Annex R, modified by Amendment 1, the following new Annex S:

Annex S
(normative)

Verification of capacitive current switching in presence of single or two-phase earth faults

S.1 General

In case of single or two-phase earth faults higher voltages across open circuit-breaker and to earth will appear on the healthy phases. Those values are not covered with type tests according 6.111.

This annex is applicable in case switching of capacitive currents in the presence of single or two-phase earth faults is required by a user. A test procedure based on class C1 is considered to be sufficient because of the low probability of occurrence.

If during tests according to 6.111.9, the requirements regarding test voltage, test current and number of tests of this annex are fulfilled no further testing is required for verification of capacitive current switching in presence of single or two-phase earth faults.

Only a limited number of single-phase laboratory tests as per Clause S.4 shall be made with a test voltage as given in Clause S.2 and a capacitive current as given in Clause S.3. A preconditioning test is not required.

6.111.1 to 6.111.3, 6.111.5 and 6.111.6 apply to tests according to this annex.

S.2 Test voltage

The test voltage measured at the circuit-breaker location immediately prior to opening shall be not less than the product of $U_r/\sqrt{3}$ and the following capacitive voltage factor k_c:

– **1,4** for tests corresponding to breaking in the presence of single or two-phase earth faults in effectively earthed neutral systems;

– **1,7** for tests corresponding to breaking in non-effectively earthed neutral systems in the presence of single or two-phase earth faults.

For unit tests, the test voltage shall be chosen to correspond to the most stressed unit of the pole of the circuit-breaker.

The power frequency test voltage and the d.c. voltage resulting from the trapped charge on the capacitive circuit shall be maintained for a period of at least 0,3 s after breaking.

For testing of metal-enclosed circuit-breakers refer also to Annex O.

S.3 Test current

For capacitive current switching in the presence of earth faults, the test current shall be:

– 1,25 times the rated capacitive breaking current in effectively earthed neutral systems;

– 1,7 times the rated capacitive breaking current in non-effectively earthed neutral systems.

S.4 Test-duty

Subclauses 6.111.9.1 and 6.111.9.2 are applicable but restricted to test-duty 2. For line-charging, cable-charging and single capacitor bank current switching the making operations can be carried out as no-load operations. For back-to-back capacitor bank current switching the making operations may be carried out separately at phase-to-earth voltage.

– 6 CO, distributed on one polarity (step: 30°);
– 3 CO at minimum arcing time on one polarity;
– 6 CO, distributed on the other polarity (step: 30°);
– 3 CO at minimum arcing time on the other polarity;
– additional tests to achieve 24 CO.

If the behaviour of the circuit-breaker prevents accurate control, the total number of tests is limited to 36.

S.5 Criteria to pass the tests

The circuit-breaker has successfully passed the tests based on the following criteria:

a) One restrike is permitted to occur without additional testing. If two restrikes occurred then the test-duty shall be repeated on the same apparatus without any maintenance. If no more additional restrike happens during this repetition of tests, the circuit-breaker shall have successfully passed the tests;

b) External flashover and phase-to-ground flashover shall not take place.

The behaviour during test and the condition after test shall comply with 6.102.8 and 6.102.9.4.

Bibliography

Replace the existing reference [4] modified by Amendment 1 by the following:

[4] IEC TR 62271-306:2012, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

Replace the existing reference [6] by the following:

[6] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

Add, after the existing reference [12], the following reference:

[13] CIGRE Technical Brochure 163:2000, *Guide for SF_6 gas mixtures*

Add the following document to the documents listed as "Other documents providing additional information"

IEC 60050-461:2008, *International Electrotechnical vocabulary – Part 461: Electric cables*

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

IEC 62271-100:2008/AMD2:2017
Edition 2.0 2017-06

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 100: Alternating-current circuit-breakers

IEC 62271-100:2008/AMD2:2017
Édition 2.0 2017-06

APPAREILLAGE A HAUTE TENSION –

Partie 100: Disjoncteurs à courant alternatif

CORRIGENDUM 1

6.104.5.4 Test-duty T30

Add, after item a) as modified by Amendment 2, the following new text:

In case that small values of time *t*3 cannot be met, the shortest time that can be met shall be used. The values used shall be stated in the test report.

6.104.5.4 Séquence d'essais T30

Ajouter, après le point a) modifié par l'Amendement 2, le nouveau texte suivant:

Si de petites valeurs du temps *t*3 ne peuvent pas être satisfaites, la durée la plus courte pouvant être satisfaite doit être utilisée. Les valeurs utilisées doivent être consignées dans le rapport d’essai.

IEC 62271-100:2008/AMD1:2012/COR1:2018-01(en-fr)

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