



BSI Standards Publication

High-voltage switchgear and controlgear

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

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 It supersedes BS EN 62271-100:2009+A1:2012, which is withdrawn.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.

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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

**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.

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

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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.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: avenue Marnix 17, B - 1000 Brussels

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).

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alternatif
(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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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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European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

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

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.

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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.

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



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European foreword

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 (dop) 2018-04-20
implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2020-07-20
standards conflicting with the
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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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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	-

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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**

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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:

belted cable	3.1.134
current chopping	3.4.121
direct connection to an overhead line	3.7.163
individually screened cable	3.1.135
initiation of (opening or closing) operation	3.7.161
total arcing time	3.7.162

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 $20\text{ °C} \pm 5\text{ °C}$.

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 $\leq 5\%$, 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 ($\pm 0,1$ 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 SF₆ 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;
- $d\alpha = 18^\circ$;
- 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:

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

- 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:

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

- 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:

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

- 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.	$k_{pp} = 1,5, 1,3 \text{ or } 1,2$		$k_{pp} = 1,5$		$k_{pp} = 1,3 \text{ or } 1,2$	
			Δt_1 ms	Δt_{a1} ms	Δt_2 ms	Δt_{a2} ms	Δt_3 ms	Δt_{a3} ms
45	$10,0 < t \leq 27,0$	1,52	13,6	4,1	15,0	10,6	14,4	10,0
	$27,0 < t \leq 47,5$	1,33	12,2	3,8	13,7	9,8	13,1	9,1
	$47,5 < t \leq 68,0$	1,21	11,4	3,7	12,9	9,2	12,3	8,6
60	$10,0 < t \leq 27,0$	1,61	14,2	4,3	15,6	11,1	15,1	10,5
	$27,0 < t \leq 47,5$	1,44	12,9	4,0	14,3	10,2	13,8	9,6
	$47,5 < t \leq 67,5$	1,31	12,1	3,8	13,6	9,7	12,9	9,1
	$67,5 < t \leq 88,0$	1,22	11,4	3,7	13,0	9,3	12,3	8,6
75	$10,0 < t \leq 27,0$	1,67	14,8	4,4	16,1	11,3	15,6	10,8
	$27,0 < t \leq 47,5$	1,51	13,4	4,2	14,9	10,6	14,3	10,0
	$47,5 < t \leq 67,5$	1,39	12,6	3,9	14,1	10,1	13,4	9,4
	$67,5 < t \leq 87,5$	1,30	12,0	3,8	13,5	9,7	12,8	9,0
	$87,5 < t \leq 108,0$	1,23	11,5	3,7	13,1	9,3	12,4	8,7
120	$10,0 < t \leq 27,0$	1,78	15,7	4,8	17,0	11,9	16,6	11,4
	$27,0 < t \leq 47,0$	1,66	14,6	4,4	15,9	11,3	15,3	10,8
	$47,0 < t \leq 67,5$	1,56	13,8	4,3	15,2	10,8	14,6	10,3
	$67,5 < t \leq 87,5$	1,47	13,2	4,1	14,6	10,4	14,0	9,8
	$87,5 < t \leq 108,0$	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.	$k_{pp} = 1,5, 1,3 \text{ or } 1,2$		$k_{pp} = 1,5$		$k_{pp} = 1,3 \text{ or } 1,2$	
			Δt_1 ms	Δt_{a1} ms	Δt_2 ms	Δt_{a2} ms	Δt_3 ms	Δt_{a3} ms
45	$8,5 < t \leq 22,5$	1,58	11,6	3,5	12,8	9,1	12,4	8,6
	$22,5 < t \leq 39,5$	1,40	10,5	3,3	11,8	8,4	11,2	7,9
	$39,5 < t \leq 56,5$	1,27	9,8	3,1	11,1	7,9	10,6	7,4
	$56,5 < t \leq 73,0$	1,19	9,3	3,0	10,7	7,6	10,1	7,1
60	$8,5 < t \leq 22,5$	1,66	12,2	3,7	13,3	9,4	12,9	9,0
	$22,5 < t \leq 39,5$	1,50	11,1	3,4	12,4	8,8	11,8	8,3
	$39,5 < t \leq 56,5$	1,38	10,4	3,3	11,7	8,3	11,2	7,8
	$56,5 < t \leq 73,0$	1,29	9,9	3,1	11,2	8,0	10,6	7,5
	$73,0 < t \leq 90,0$	1,22	9,5	3,1	10,8	7,7	10,2	7,2
75	$8,5 < t \leq 22,5$	1,72	12,6	3,8	13,7	9,6	13,3	9,2
	$22,5 < t \leq 39,5$	1,57	11,6	3,6	12,8	9,1	12,3	8,6
	$39,5 < t \leq 56,0$	1,46	10,9	3,4	12,1	8,6	11,6	8,1
	$56,0 < t \leq 73,0$	1,37	10,3	3,2	11,6	8,3	11,1	7,8
	$73,0 < t \leq 90,0$	1,30	9,9	3,1	11,2	8,0	10,7	7,5
	$90,0 < t \leq 106,5$	1,24	9,6	3,1	10,9	7,8	10,4	7,3
120	$8,5 < t \leq 22,5$	1,81	13,4	4,1	14,4	10,1	14,1	9,7
	$22,5 < t \leq 39,0$	1,71	12,5	3,8	13,6	9,6	13,2	9,2
	$39,0 < t \leq 56,0$	1,62	11,8	3,7	13,0	9,3	12,5	8,8
	$56,0 < t \leq 73,0$	1,54	11,3	3,5	12,5	8,9	12,0	8,5
	$73,0 < t \leq 89,5$	1,47	10,9	3,4	12,1	8,7	11,6	8,1
	$89,5 < t \leq 106,5$	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:

$$t_{\text{arc}} = t_{\text{a}100\text{s}} + T \times \frac{119^\circ}{360^\circ}$$

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 $k_{\text{pp}} = 1,3$

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

$$t_{\text{arc}} = t_{\text{a}100\text{s}} + T \times \frac{162^\circ}{360^\circ}$$

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 $k_{\text{pp}} = 1,3$

k_{pp}	Rated voltage					
	$U_r < 100 \text{ kV}$ 2-parameter-TRV		$U_r \geq 100 \text{ kV}$ 4-parameter-TRV			
	$u_{\text{c,sp}}$	$t_{3,\text{sp}}$	$u_{1,\text{sp}}$	$t_{1,\text{sp}}$	$u_{\text{c,sp}}$	$t_{2,\text{sp}}$
1,3	$k_{\text{af}} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_3 \times u_{\text{c,sp}}/u_{\text{c}}$	$0,75 \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	$t_1 \times u_{1,\text{sp}}/u_1$	$k_{\text{af}} \times \frac{\sqrt{2}}{\sqrt{3}} \times U_r$	a
^a $4 \times t_{1,\text{sp}}$ for rated voltages from 100 kV up to and including 800 kV, $3 \times t_{1,\text{sp}}$ 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 $k_{\text{pp}} = 1,3$;

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 $k_{pp} = 1,5$.

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

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, L₉₀, L₇₅ and L₆₀

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 ($t_{\text{arc min}}$). 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 $t_{\text{arc max}}$ and is determined as follows:

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

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

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

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

where

$t_{\text{arc min}}$ 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 ($t_{\text{arc med}}$) and is determined by

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

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:

$$t_{\text{arc1}} = t_{\text{a100s}} + \Delta t_{\text{a1}} - T \times \frac{d\alpha}{360^\circ}$$

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 $k_{\text{pp}} = 1,5$

This is achieved, when following condition is met:

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

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

This is achieved, when following condition is met:

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

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 $k_{\text{pp}} = 1,5$ or after a major extended loop as second-pole-to-clear for circuit-breakers rated for $k_{\text{pp}} = 1,2$ 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 $+15^\circ$), 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
17,5	T10	1,5	1,7	31,2	15	2	9,8	7	2,08
	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
24	T10	1,5	1,7	36,4	16	2	12,1	8	2,28
	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
27 ^b	T10	1,5	1,7	50	19	3	16,7	9	2,63
	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
36	T10	1,5	1,7	56,2	20	3	17,9	10	2,82
	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
38 ^b	T10	1,5	1,7	75,0	24	4	25,0	12	3,13
	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
52	T10	1,5	1,7	79,1	24	4	26,4	12	3,30
	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
72,5	T10	1,5	1,7	108	29	4	36,1	14	3,72
	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 "L₉₀" (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 L₉₀ 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 L₉₀ 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 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.

6.104.5.5 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.	Ampli- tude 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.	Ampli- tude 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	Test-duty	First-pole-to-clear factor	Amplitude factor	First reference voltage	Time	TRV peak value	Time	Time delay	Voltage	Time	Rate-of-rise
U_r		k_{pp}	k_{af}	u_1	t_1	u_c	t_2 or t_3	t_d	u'	t'	u_1/t_1 u_c/t_3
kV		p.u.	p.u.	kV	μs	kV	μs	μs	kV	μs	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	$0,9 \times 1,7$	-	-	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	$0,9 \times 1,7$	-	-	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	$0,9 \times 1,7$	-	-	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	$0,9 \times 1,7$	-	-	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	Test-duty	First-pole-to-clear factor	Amplitude factor	First reference voltage	Time	TRV peak value	Time	Time delay	Voltage	Time	Rate-of-rise
U_r		k_{pp}	k_{af}	u_1	t_1	u_c	t_2 or t_3	t_d	u'	t'	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}^*		Time t_i µs
	f_i kV/kA 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).