

INTERNATIONAL STANDARD



**High-voltage switchgear and controlgear –
Part 109: Alternating-current series capacitor by-pass switches**

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IECNORM.COM : Click to view the full PDF IEC 62211-109:2019 PLV

INTERNATIONAL STANDARD



**High-voltage switchgear and controlgear –
Part 109: Alternating-current series capacitor by-pass switches**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.130.10

ISBN 978-2-8322-6816-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD	9
~~General~~	~~12~~
1 Scope	12
2 Normative references	12
3 Terms and definitions	13
3.1 General terms and definitions	13
3.2 Assemblies	16
3.3 Parts of assemblies	16
3.4 Switching devices	16
3.5 Parts of by-pass switches	19
3.6 Operational characteristics of by-pass switches	22
3.7 Characteristic quantities	25
3.8 Terms and definitions related to series capacitor banks	33
3.9 Index of definitions	36
4 Normal and special service conditions	40
5 Ratings	40
5.1 General	40
5.2 Rated voltage (U_r)	41
5.2.1 General	41
5.2.2 Range I for rated voltage of 245 kV and below	41
5.2.3 Range II for rated voltage above 245 kV	41
5.3 Rated insulation level (U_p , U_d , U_s)	42
5.3.101 Rated insulation level to earth (U_{pe} , U_{de} , U_{se})	42
5.3.102 Rated insulation level across the by-pass switch (U_{pp} , U_{dp} , U_{sp})	42
5.4 Rated frequency (f_r)	42
5.5 Rated ~~normal~~ continuous current (I_r) ~~and temperature rise~~	42
5.6 Rated short-time withstand current (I_k)	42
5.7 Rated peak withstand current (I_p)	42
5.8 Rated duration of short-circuit (t_k)	42
5.9 Rated supply voltage of ~~closing and opening devices and of~~ auxiliary and control circuits (U_a)	43
5.10 Rated supply frequency of ~~closing and opening devices and~~ auxiliary and control circuits	43
5.11 Rated pressures of compressed gas supply for ~~insulation, operation and/or by-passing and insertion~~ controlled pressure systems	43
5.101 Rated operating sequence	43
5.102 Rated by-pass making current (I_{BP})	43
5.103 Rated by-pass insertion current (I_{INS})	44
5.104 Rated reinsertion voltage (U_{INS})	44
5.105 Number of mechanical operations	45
6 Design and construction	45
6.1 Requirements for liquids in by-pass switches	45
6.2 Requirements for gases in by-pass switches	45
6.3 Earthing of by-pass switches	45
6.4 Auxiliary and control equipment and circuits	45
6.4.1 General	45

6.4.2	Protection against electrical shock	45
6.4.3	Components installed in enclosures	45
6.5	Dependent power operation	46
6.6	Stored energy operation	46
6.7	Independent ~~manual~~ unlatched operation (independent manual or power operation)	47
6.8	Manually operated actuators	47
6.9	Operation of releases	47
6.9.1	General	47
6.9.2	Shunt closing releases	47
6.9.3	Shunt opening releases	47
6.9.4	Capacitor operation of shunt releases	47
6.9.5	Under-voltage release	47
6.9.101	Multiple releases	47
6.9.102	Operation limits of releases	47
6.9.103	Power consumption of releases	47
6.10	Pressure/level indication	48
6.11	Nameplates	48
6.12	~~Interlocking~~ Locking devices	50
6.13	Position indication	50
6.14	Degrees of protection provided by enclosures	50
6.15	Creepage distances for outdoor insulators	50
6.16	Gas and vacuum tightness	50
6.17	~~Liquid tightness~~ Tightness for liquid systems	50
6.18	Fire hazard (flammability)	50
6.19	Electromagnetic compatibility	50
6.20	X-ray emission	50
6.21	Corrosion	50
6.22	Filling levels for insulation, by-passing, insertion and/or operation	51
6.101	Requirements for simultaneity within a pole	51
6.102	General requirement for operation	51
6.103	Pressure limits of fluids for operation	51
6.104	Vent outlets	51
6.105	~~Rated~~ Time quantities	52
6.106	Static mechanical loads	52
7	Type tests	53
7.1	General	53
7.1.1	~~Grouping of tests~~ Basics	53
7.1.2	Information for identification of ~~specimens~~ test objects	54
7.1.3	Information to be included in type test reports	54
7.1.101	Invalid tests	54
7.1.102	Type tests to repeat for by-pass switches with alternative operating mechanisms	55
7.2	Dielectric tests	55
7.2.1	General	55
7.2.2	Ambient air conditions during tests	55
7.2.3	Wet test procedure	55
7.2.4	~~Condition of by-pass switch during dielectric tests~~ Arrangement of the equipment	55

7.2.5	Criteria to pass the test	55
7.2.6	Application of test voltage and test conditions	56
7.2.7	Tests of by-pass switches of $U_{re} \leq 245$ kV or $U_{rp} \leq 245$ kV	56
7.2.8	Tests of by-pass switches of $U_{re} > 245$ kV or $U_{rp} > 245$ kV	57
7.2.9	Artificial pollution tests for outdoor insulators	57
7.2.10	Partial discharge tests	57
7.2.11	Dielectric tests on auxiliary and control circuits	57
7.2.12	Voltage test as condition check	57
7.3	Radio interference voltage (RIV) tests	59
7.4	Resistance measurement of the resistance of the main circuit	59
	~~Temperature rise tests~~	~~59~~
	~~Conditions of the by pass switch to be tested~~	~~59~~
	~~Arrangement of the equipment~~	~~59~~
	~~Measurement of the temperature and the temperature rise~~	~~59~~
	~~Ambient air temperature~~	~~59~~
	~~Temperature rise tests of the auxiliary and control equipment~~	~~59~~
	~~Interpretation of the temperature rise tests~~	~~59~~
7.5	Continuous current tests	60
7.5.1	Conditions of the test object	60
7.5.2	Arrangement of the equipment	61
7.5.3	Test current and duration	61
7.5.4	Temperature measurement during test	61
7.5.5	Resistance of the main circuit	61
7.5.6	Criteria to pass test	61
7.6	Short-time withstand current and peak withstand current tests	61
7.6.1	General	61
7.6.2	Arrangement of the by-pass switch and of the test circuit	61
7.6.3	Test current and duration	61
7.6.4	Condition of the by-pass switch after test	61
7.7	Verification of the protection	61
7.7.1	Verification of the IP coding	61
7.7.2	~~Mechanical impact test (Verification of the IK coding)~~	~~61~~
7.8	Tightness tests	61
7.9	Electromagnetic compatibility tests (EMC)	62
7.9.1	Emission tests	62
7.9.2	Immunity tests on auxiliary and control circuits	62
7.9.3	Additional EMC tests on auxiliary and control circuits	62
7.10	Additional tests on auxiliary and control circuits	62
7.10.1	General	62
7.10.2	Functional tests	63
7.10.3	Verification of the operational characteristics of auxiliary contacts	63
7.10.4	Environmental tests	63
7.10.5	Dielectric test	63
7.11	X-Radiation ~~procedure~~ test for vacuum interrupters	63
7.101	Mechanical and environmental tests	63
7.101.1	Miscellaneous provisions for mechanical and environmental tests	63
7.101.2	Mechanical operation test at ambient air temperature	66
7.101.3	Low and high temperature tests	68
7.101.4	Humidity test	74

7.101.5	Test to prove the operation under severe ice conditions	74
	~~Static terminal load test~~	
7.102	Miscellaneous provisions for by-pass making and insertion tests	78
7.102.1	General	78
7.102.2	Number of test specimens	78
7.102.3	Arrangement of by-pass switch for tests	78
7.102.4	General considerations concerning testing methods	80
7.102.5	Synthetic tests	83
7.102.6	No-load operations before tests	83
7.102.7	Alternative operating mechanisms	83
7.102.8	Behaviour of by-pass switch during tests	84
7.102.9	Condition of by-pass switch after tests	84
7.103	By-pass making current test-duty and insertion current test-duty, sequence of tests	86
7.103.1	General	86
7.103.2	By-pass making current test-duty	86
7.103.3	Insertion current test-duty	89
7.103.4	Criteria to pass the test duties	98
8	Routine tests	98
8.1	General	98
8.2	Dielectric test on the main circuit	98
8.3	~~Dielectric~~ Tests on auxiliary and control circuits	100
8.3.1	Inspection of auxiliary and control circuits, and verification of conformity to circuit diagrams and wiring diagrams	100
8.3.2	Functional tests	100
8.3.3	Verification of protection against electrical shock	100
8.3.4	Dielectric tests	100
8.4	Measurement of the resistance of the main circuit	100
8.5	Tightness test	100
8.5.1	General	100
8.5.2	Controlled pressure systems for gas	100
8.5.3	Closed pressure systems for gas	101
8.5.4	Sealed pressure systems	101
8.5.5	Liquid tightness tests	101
8.6	Design and visual checks	101
8.101	Mechanical operating tests	101
9	Guide to the selection of by-pass switches ~~for service~~ (informative)	103
10	Information to be given with enquiries, tenders and orders (informative)	103
10.1	General	103
10.2	Information ~~to be given~~ with enquiries and orders	103
10.3	Information ~~to be given~~ with tenders	104
11	~~Rules for~~ Transport, storage, installation, ~~operation~~ operating instructions and maintenance	106
11.1	General	106
11.2	Conditions during transport, storage and installation	106
11.3	Installation	106
11.4	~~Operation~~ Operating instruction	106
11.5	Maintenance	106
11.101	Guide for commissioning tests	107

11.101.1	General	107
11.101.2	Commissioning checks and test programme	107
11.101.3	Resistors and capacitors (if applicable)	112
12	Safety.....	113
12.1	General.....	113
12.2	Precautions by manufacturers.....	113
12.3	Precautions by users	113
13	Influence of the product on environment.....	113
Annex A	(normative) Tolerances on test quantities during type tests.....	114
Annex B	(normative) Records and reports of type tests.....	118
B.1	Information and results to be recorded	118
B.2	Information to be included in type test reports.....	118
B.2.1	General	118
B.2.2	Apparatus tested	118
B.2.3	Rated characteristics of by-pass switch, including its operating devices and auxiliary equipment.....	118
B.2.4	Test conditions (for each series of tests; if applicable).....	118
B.2.5	Short-time withstand current and peak withstand current test	119
B.2.6	No-load operation	119
B.2.7	By-pass making current test-duty.....	119
B.2.8	Insertion current test-duty	119
B.2.9	Oscillographic and other records	120
Annex C	(informative) ~~List of symbols and abbreviations used~~ (Void).....	121
Annex D	(informative) Examples of by-pass switch ratings.....	123
Annex E	(~~informative~~ normative) By-pass switches used as the primary by-passing devices	131
Annex F	(informative) Explanatory note regarding ~~transient~~ recovery voltage during reinsertion	133
Annex G	(normative) Use of mechanical characteristics and related requirements	143
Bibliography		147
~~Figure – Static terminal load forces.....~~		
~~Figure – Directions for static terminal load tests.....~~		
Figure 1	– Different layouts for series capacitor banks	18
Figure 2	– By-pass switch – Opening and closing operations	26
Figure 3	– By-pass switch – Close-open cycle	27
Figure 4	– By-pass switch – Open-close cycle	28
Figure 5	– Example of wind velocity measurement.....	70
Figure 6	– Test sequences for low and high temperature tests	71
Figure 7	– Equivalent testing set-up for unit testing of by-pass switches with more than one separate by-pass units	81
Figure 8	– Typical test circuit for the by-pass making current test-duty	87
Figure 9	– Oscillogram obtained from the typical test circuit for the by-pass making current test-duty	88
Figure 10	– Typical LC test circuit for the insertion current test-duty	91
Figure 11	– Oscillogram obtained from the typical LC test circuit for the insertion current test-duty	92

Figure 12 – Typical test circuit for the insertion current test-duty (mainly for high rated insertion current)	93
Figure 13 – Oscillogram obtained from the typical test circuit shown in Figure 12 for the insertion current test-duty	94
Figure 14 – Typical direct test circuit for the insertion current test-duty	95
Figure 15 – Oscillogram obtained from the typical direct test circuit for the insertion current test-duty	96
Figure 16 – Reference mechanical travel characteristics (idealized curve)	102
Figure E.1 – Typical component layout for by-pass switches used as the primary by-passing device	131
Figure F.1 – Typical example of the ~~transient~~ reinsertion voltage across a by-switch for a low compensation factor scheme ($k = 0,2$) and for a power swing of 1,8 p.u.	140
Figure F.2 – Typical example of the ~~transient~~ reinsertion voltage across a by-switch for a high compensation factor scheme ($k = 0,5$) and for a power swing of 1,8 p.u.	140
Figure F.3 – Comparison of the calculated ~~transient~~ reinsertion voltage examples and possible testing envelopes for 50 Hz systems	141
Figure F.4 – Comparison of the calculated ~~transient~~ reinsertion voltage examples and possible testing envelopes for 60 Hz systems	141
Figure G.1 – Reference mechanical travel characteristics (idealized curve)	145
Figure G.2 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes centered over the reference curve ($\pm 5\%$), contact separation in this example at time $t = 20$ ms	145
Figure G.3 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced upward from the reference curve ($\begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \%$), contact separation in this example at time $t = 20$ ms	146
Figure G.4 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced downward from the reference curve ($\begin{smallmatrix} 0 \\ -10 \end{smallmatrix} \%$), contact separation in this example at time $t = 20$ ms	146
~~Table – Examples of static horizontal and vertical forces for static terminal load test~~	~~.....~~
~~Table – Summary of type tests related to mechanical characteristics~~	~~.....~~
Table 1 – Number of mechanical operations	45
Table 2 – Nameplate information	49
Table 3 – Examples of static horizontal and vertical forces for static terminal load	53
Table 4 – Type tests	54
Table 5 – Invalid tests	55
Table 6 – Number of operating sequences	67
Table 7 – Limits of supply voltage for closing and opening releases	79
Table 8 – Test procedures for by-pass making current tests	89
Table 9 – Application of voltage for dielectric test on the main circuit	98
Table 10 – Test voltage for partial discharge test	100
Table A.1 – Tolerances on test quantities for type tests (1 of 3)	115
Table D.1 – Typical ratings for a series capacitor bank by-pass switch – Cases 1 to 6	124
Table D.2 – Typical series capacitor bank by-pass switch ratings – Cases 7 to 12	126
Table D.3 – Typical series capacitor bank by-pass switch ratings – Cases 13 to 18	128

Table F.1 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing nor emergency overload, $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	134
Table F.2 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	134
Table F.3 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	135
Table F.4 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	135
Table F.5 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	135
Table F.6 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	136
Table F.7 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	136
Table F.8 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz.....	136
Table F.9 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing nor emergency overload, $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	137
Table F.10 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	137
Table F.11 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	137
Table F.12 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	138
Table F.13 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	138
Table F.14 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	138
Table F.15 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	139
Table F.16 – Typical examples of ~~transient~~ reinsertion recovery voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz.....	139

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 109: Alternating-current series capacitor
by-pass switches**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

International Standard IEC 62271-109 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This third edition cancels and replaces the second edition published in 2008 and Amendment 1:2013. This edition constitutes a technical revision.

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

- a) the document has been restructured according to edition 2.0 of IEC 62271-1;
- b) the rated voltage assignation across the by-pass switch has been aligned to the rule defined in IEC 60143-1;
- c) clarification has been given regarding rated continuous current of compensated and uncompensated line;
- d) some clarifications have been given following a loss of "suitable precautions";
- e) as per Amendment 2 of IEC 62271-100, the section "Rated time quantities" has been moved to Clause 6 under "Time quantities";
- f) as per Amendment 2 of IEC 62271-100, the section "Test for static mechanical loads" have been moved to Clause 6 under "Static mechanical loads";
- g) additional rules have been introduced for vacuum interrupters during impulse tests;
- h) additional clarifications have been given regarding the number of reduced impulses during impulse tests;
- i) a wider tolerance on the current damping during by-pass making current test-duty has been introduced.

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

FDIS	Report on voting
17A/1208/FDIS	17A/1215/RVD

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

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

A list of all parts of the IEC 62271 series can be found, under the general title *High-voltage switchgear and controlgear*, on the IEC website.

This standard is to be read in conjunction with IEC 62271-100:2008 with its Amendment 1:2012 and Amendment 2:2017, and IEC 62271-1:2017, 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 IEC 62271-1:2017. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

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

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

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

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 109: Alternating-current series capacitor by-pass switches

~~1~~ General

~~1.1~~ Scope

This part of IEC 62271 is applicable to AC series capacitor by-pass switches designed for outdoor installation and for operation at frequencies of 50 Hz and 60 Hz on systems having voltages above 52 kV.

It is only applicable to by-pass switches for use in three-phase systems.

This document is also applicable to the operating devices of by-pass switches and to their auxiliary equipment.

~~1.2~~ Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-436:1990, *International Electrotechnical Vocabulary – Chapter 436: Power capacitors*

IEC 60050-441:1984, *International Electrotechnical Vocabulary – Chapter 441: Switchgear, controlgear and fuses*

~~IEC 60050-604:1987, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*~~

IEC 60050-614:2016, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60060 (all parts), *High-voltage test techniques*

IEC 60137:2017, *Insulated bushings for alternating voltages above 1000 V*

IEC 60143-1:2004 2015, *Series capacitors for power systems – Part 1: General*

IEC 60143-2:1994 2012, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*

~~IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*~~

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

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF₆) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use*

~~IEC 60529, Degrees of protection provided by enclosures (IP Code)~~

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

IEC 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF₆) and its mixtures*

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

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*

IEC 62271-102:2004 2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

~~IEC 62271-303, High-voltage switchgear and controlgear – Part 303: Use and handling of sulphur hexafluoride (SF₆)~~

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60050-151, IEC 60050-436, IEC 60050-441, ~~IEC 60050-604~~ IEC 60050-614, IEC 60143-1, IEC 60143-2 and IEC 62271-1 apply. Some of them are recalled here for ease of reference.

Additional terms and definitions are classified so as to be aligned with the classification used in IEC 60050-441.

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

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

3.1 General terms and definitions

3.1.101

switchgear and controlgear

a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:2000, 441-11-01]

3.1.102

outdoor switchgear and controlgear

switchgear and controlgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

short-circuit current

overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:2000, 441-11-07]

3.1.104

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

Note 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.1.105

temperature rise

<of a part of a by-pass switch>

difference between the temperature of the part under consideration and the ambient air temperature

[SOURCE: IEC 60050-151:2001, 151-16-26, modified – "A reference" has been replaced by "the ambient air".]

3.1.106

overvoltage

<in an electric power system>

~~any voltage between one phase and earth or between phases having a peak value or values exceeding the corresponding peak of the highest voltage for equipment~~

~~[IEV 604-03-09, modified]~~

voltage:

- between one line conductor and earth or across a longitudinal insulation having a peak value exceeding the corresponding peak of the highest voltage of the system divided by $\sqrt{3}$

or;

- between phase conductors having a peak value exceeding the amplitude of the highest voltage of the system

[SOURCE: IEC 60050-614:2016, 614-03-10]

3.1.107

unit test

test carried out on a by-passing or insertion unit or group of units at the by-pass making current or the insertion current, specified for the test on the complete pole of a by-pass switch and at the appropriate fraction of the applied voltage, or the recovery voltage, specified for the test on the complete pole of the by-pass switch

3.1.108**external insulation**

distances in atmospheric air, and along the surfaces in contact with ~~open~~ atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other ~~external~~ environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin.

~~[IEV 604-03-02, modified]~~

[SOURCE: IEC 60050-614:2016, 614-03-02]

3.1.109**internal insulation**

internal distances of the solid, liquid or gaseous ~~parts of the~~ insulation of equipment, which are protected from the effects of atmospheric and other external conditions

~~[IEV 604-03-03]~~

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.1.110**self-restoring insulation**

insulation which completely recovers its insulating properties within a short time interval after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

~~[IEV 604-03-04]~~

3.1.111**non-self-restoring insulation**

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-05]

~~[IEV 604-03-05]~~

3.1.112**disruptive discharge**

phenomenon associated with the failure of insulation under electric stress, ~~in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero~~ which includes a collapse of voltage and the passage of current

Note 1 to entry: This term applies to ~~discharges~~ electric breakdown in solid, liquid and gaseous dielectrics and ~~to~~ combinations of these.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss may be temporary ~~(self-restoring insulation)~~ only.

Note 3 to entry: The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term "flashover" is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

[SOURCE: IEC 60050-614:2016, 614-03-16, modified – Note 3 to entry added.]

3.1.113

restrike performance

expected probability of restrike during insertion current test-duty as demonstrated by specified type test

Note 1 to entry: Specific numeric probabilities cannot be applied throughout a by-pass switch service life.

3.1.114

re-ignition

<of an AC mechanical switching device>

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency

[SOURCE: IEC 60050-441:2000, 441-17-45]

3.1.115

restrike

<of an AC mechanical switching device>

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of a quarter cycle of power frequency or longer

[SOURCE: IEC 60050-441:2000, 441-17-46]

3.1.116

non-sustained disruptive discharge

NSDD

disruptive discharge associated with current interruption which does not result in the resumption of power frequency current or, in the case of insertion does not result in a current in the series capacitor bank

Note 1 to entry: Oscillations following NSDDs are associated with the parasitic capacitance and inductance local to or of the by-pass switch itself. NSDDs may also involve the stray capacitance to ground of nearby equipment.

Note 2 to entry: This note applies to the French language only.

3.2 Assemblies

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices

3.4.101

switching device

device designed to make or break the current in one or more electric circuits

[SOURCE: IEC 60050-441:2000, 441-14-01]

3.4.102

mechanical switching device

switching device designed to close and open one or more electric circuits by means of separable contacts

Note 1 to entry: Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g. air, SF₆, oil.

[SOURCE: IEC 60050-441:2000, 441-14-02]

3.4.103

by-pass switch

three-phase switching device used in parallel with a series capacitor and its overvoltage protector to shunt line current of a specified level for a specified time, or continuously

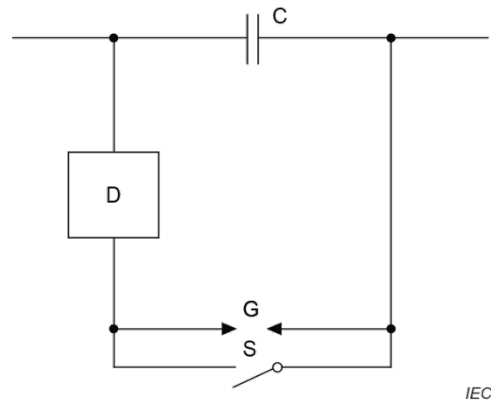
Note 1 to entry: By-pass switches ~~may~~ can be three-pole or single-pole operated

Note 2 to entry: Besides by-passing the capacitor, this device normally has the capability to insert the capacitor into a circuit that carries a specified level of current.

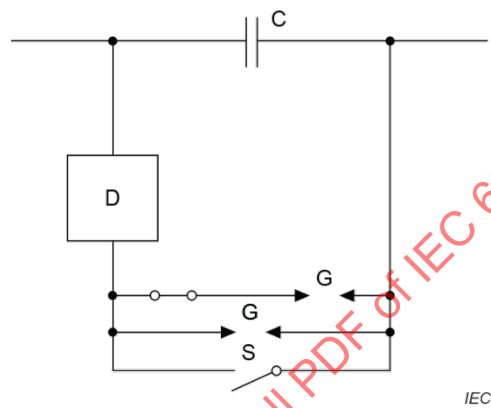
Note 3 to entry: By-pass switches are normally used in conjunction with a fast by-passing device, for example, spark-gap (for special applications without the use of a fast by-passing device, see Annex E).

Note 4 to entry: Examples of series capacitor layouts using a fast by-passing device in parallel with the by-pass switch (see IEC 60143-1) are ~~shown below~~ given in Figure 1.

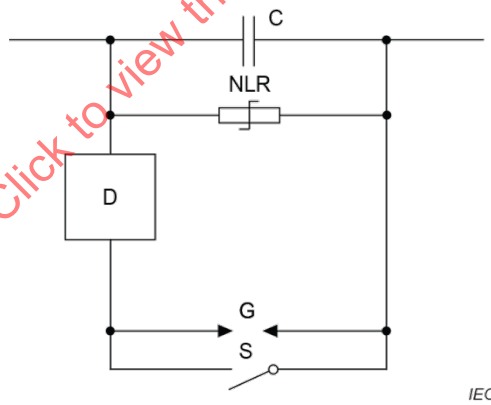
IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV



Single gap



Dual gap



Non-linear resistor with by-pass gap

Key

C	series capacitor
D	damping circuit
G	spark-gap
S	by-pass switch
NLR	non-linear resistor

Figure 1 – Different layouts for series capacitor banks

3.4.104**by-pass switch class M1**

by-pass switch with normal mechanical endurance ~~(mechanically type tested for 2 000 operating sequences) not falling into the category of class M2 as defined in 3.4.105~~ as demonstrated by specific type tests

3.4.105**by-pass switch class M2**

frequently operated by-pass switch for special service requirements and designed so as to require only limited maintenance as demonstrated by specific type tests ~~(by-pass switch with extended mechanical endurance, mechanically type tested for 10 000 operating sequences)~~

Note 1 to entry: This type of by-pass switch is normally used on multi-segmented capacitors where the control of the capacitor impedance is a frequent duty.

3.5 Parts of by-pass switches**3.5.101****pole of a switching device**

the portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102**main circuit**

<of a switching device>

all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103**control circuit**

<of a switching device>

all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.104**auxiliary circuit**

<of a switching device>

all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:2000, 441-15-04]

3.5.105
contact

<of a mechanical switching device>

conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.106
contact
contact piece

one of the conductive parts forming a contact

[SOURCE: IEC 60050-441:2000, 441-15-06]

3.5.107
main contact

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.108
arcing contact

contact on which the arc is intended to be established

Note 1 to entry: An arcing contact may serve as a main contact; it may be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from injury.

[SOURCE: IEC 60050-441:2000, 441-15-08]

3.5.109
control contact

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.110
auxiliary contact

contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:2000, 441-15-10]

3.5.111
auxiliary switch

<of a mechanical switching device>

switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:2000, 441-15-11]

3.5.112
“a” contact
make contact

control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.113

**“b” contact;
break contact**

control or auxiliary contact which is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.114

sliding contact

contact in which relative movement of the contact pieces is substantially in a direction parallel to the contact surface

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

3.5.115

rolling contact

contact in which one contact piece rolls on the other

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

3.5.116

release

<of a mechanical switching device>

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

[SOURCE: IEC 60050-441:2000, 441-15-17]

3.5.117

arc control device

device, surrounding the arcing contacts of a mechanical switching device, designed to confine the arc and to assist in its extinction

[SOURCE: IEC 60050-441:2000, 441-15-18]

3.5.118

position indicating device

part of a mechanical switching device which indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.119

connection ~~(bolted or equivalent)~~

two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.5.120

terminal

component provided for the connection of a device to external conductors

~~[IEV 151-12-12, modified]~~

3.5.121

by-pass unit insertion unit

part of a by-pass switch which in itself acts as a by-pass switch and which, in series with one or more identical and simultaneously operated by-pass or insertion units, forms the complete by-pass switch

Note 1 to entry: By-pass units and insertion units are normally combined but may be separated. Each unit may have several contacts.

Note 2 to entry: The means controlling the voltage distribution between units may differ from unit to unit.

3.5.122

module

<of a by-pass switch> assembly which generally comprises by-pass or insertion units, post-insulators (for live tank by-pass switches), bushings (for dead tank by-pass switches) and mechanical parts and which is mechanically and electrically connected to other identical assemblies to form a pole of a by-pass switch

3.5.123

enclosure

part of switchgear and controlgear providing a specified degree of protection ~~(see IEC 60529)~~ of equipment against external influences and a specified degree of protection against an approach to or contact with live parts and against contact with moving parts

[SOURCE: IEC 60050-441:2000, 441-13-01, modified — "a part of an assembly" has been changed for "part of switchgear and controlgear"]

3.5.124

operating mechanism

part of the by-pass switch that actuates, through the power kinematic chain, the main circuit contacts of the by-pass switch

3.5.125

power kinematic chain

mechanical connecting system from and including the operating mechanism up to and including the moving contacts

Note 1 to entry: See also ~~A-3-5-111~~ Figure 1 of IEC 62271-102:2018.

3.5.126

alternative operating mechanism

mechanism obtained when a change in the power kinematic chain of the original operating mechanism or the use of an entirely different operating mechanism leads to the same mechanical characteristics

Note 1 to entry: Mechanical characteristics are defined in 7.101.1.1. The use of mechanical characteristics and related requirements are described in Annex G.

Note 2 to entry: An alternative operating mechanism can implement an operating principle different from the original one (for example the alternative mechanism can be spring-operated and the original hydraulic).

Note 3 to entry: A change in the secondary equipment does not lead to an alternative operating mechanism.

3.6 Operational characteristics of by-pass switches

3.6.101

operation

<of a mechanical switching device>

transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this may be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

operating cycle

<of a mechanical switching device>

succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

operating sequence

<of a mechanical switching device>

succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:2000, 441-16-03]

3.6.104

closing operation

<of a mechanical switching device>

operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.105

opening operation

<of a mechanical switching device>

operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.106

auto-reopening

operating sequence of a by-pass switch whereby, following its closing, it opens automatically after a predetermined time

3.6.107

positive opening operation

<of a mechanical switching device>

opening operation which, in accordance with specified requirements, ensures that all the main contacts are in the open position when the actuator is in the position corresponding to the open position of the device

[SOURCE: IEC 60050-441:2000, 441-16-11]

3.6.108

positively driven operation

operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts

[SOURCE: IEC 60050-441:2000, 441-16-12]

3.6.109**dependent power operation**

<of a mechanical switching device>

operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.110**stored energy operation**

operation by means of energy stored in the mechanism itself prior to the switching operation and sufficient to complete the specified operating sequence under predetermined conditions

3.6.111**independent manual operation**

<of a mechanical switching device>

stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

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

3.6.112**closed position**

<of a mechanical switching device>

position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-22]

3.6.113**open position**

<of a mechanical switching device>

position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.114**shunt release**

release energized by a source of voltage

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

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

3.6.115**anti-pumping device**

device that prevents the reopening after an open-close operation as long as the device initiating opening is maintained in the position for opening

3.6.116**interlocking device**

device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.6.117**by-pass switch with lock-out preventing opening**

by-pass switch in which none of the moving contacts can insert the capacitor if the opening command is initiated while the conditions that cause the closing operation remain established

3.7 Characteristic quantities

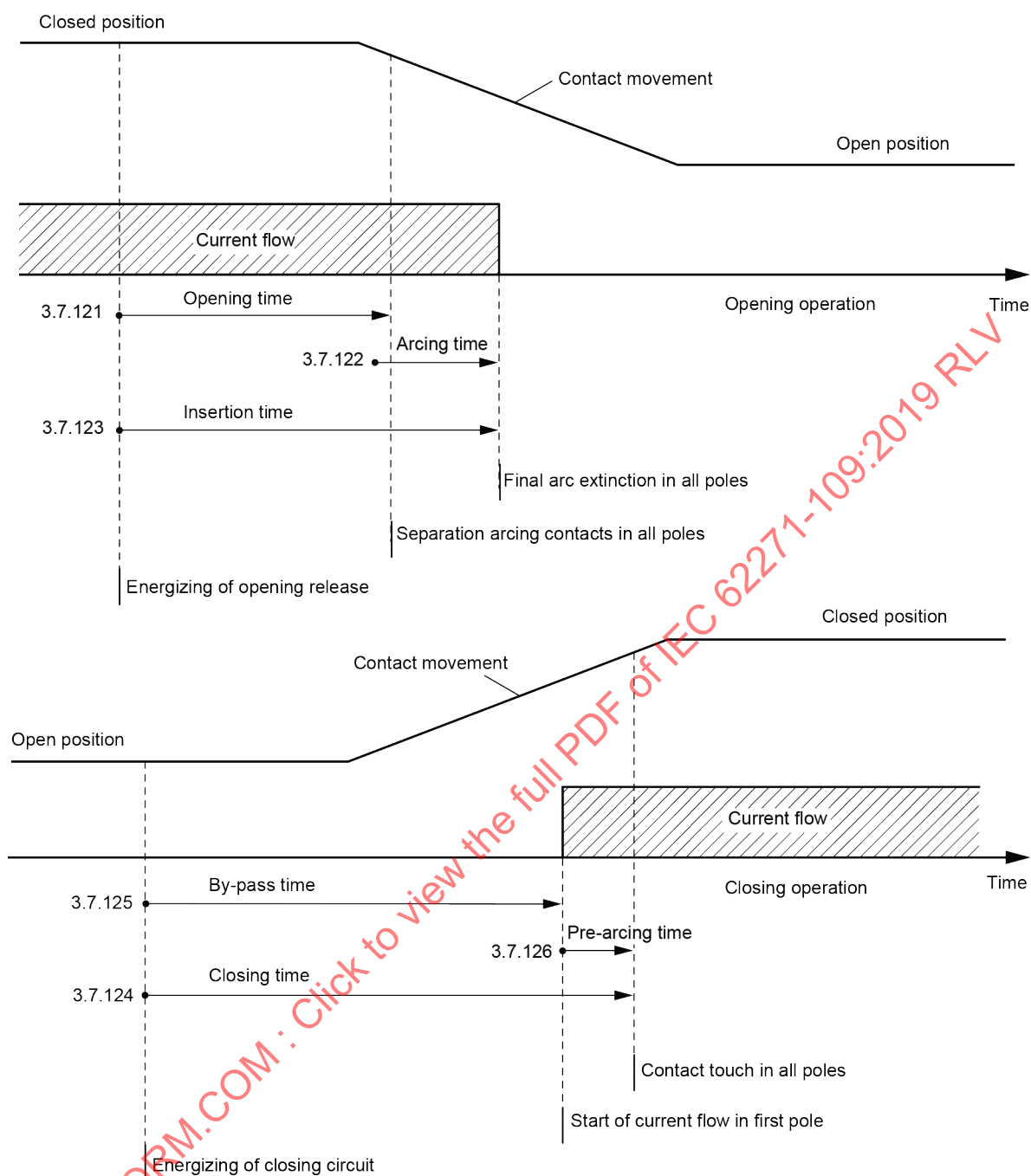
Figures 2 to 4 illustrate some definitions of this subclause.

Time quantities (see definitions 3.7.120 to 3.7.130) are expressed in milliseconds or in cycles. When expressed in cycles, the power frequency shall be stated in brackets.

Concerning Figures 2 to 4:

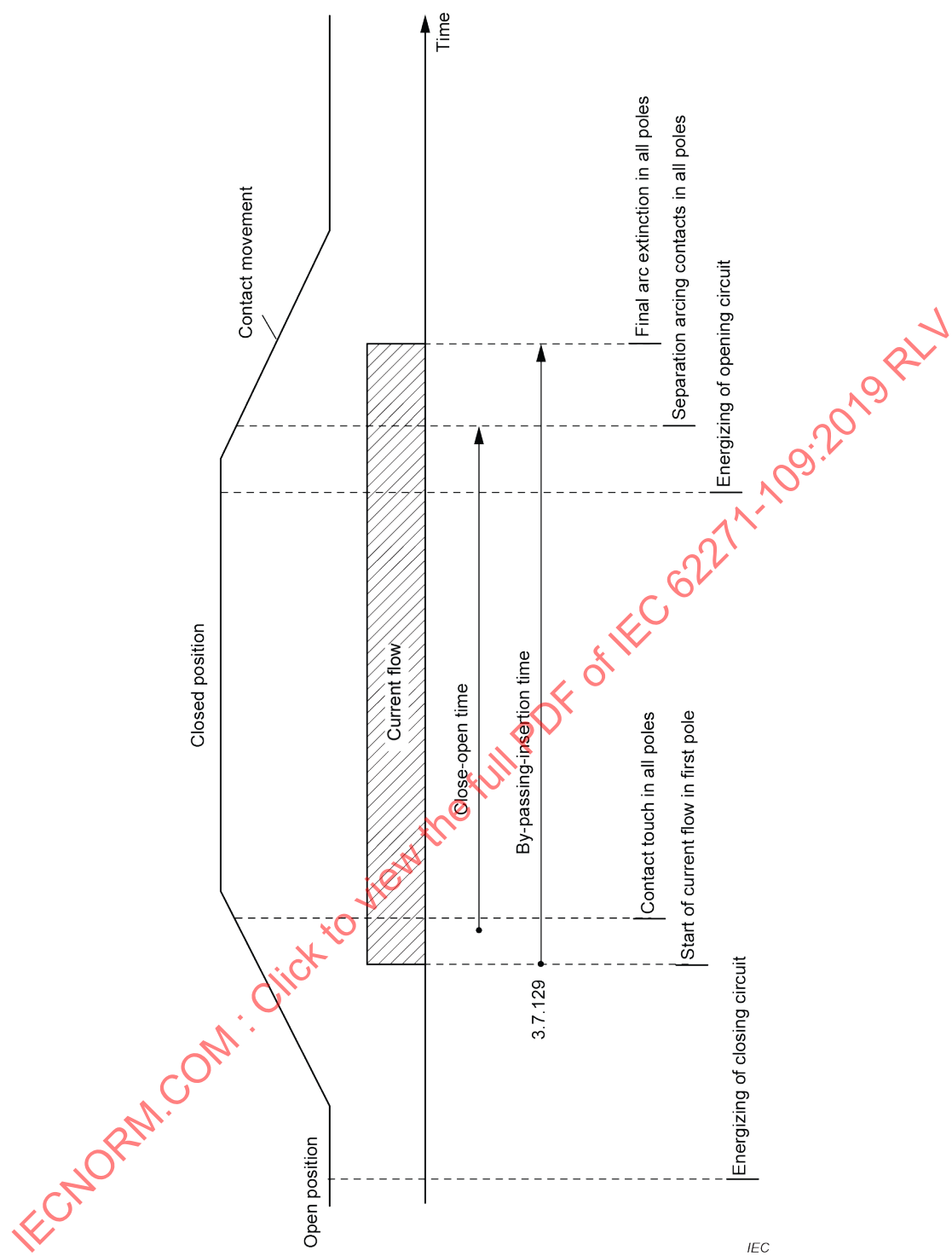
- NOTE** • In practice, there will be a time spread between the travel of the contacts of the three poles. For clarity, the travel of the contacts in the figures is indicated by a single line for all three poles.
- NOTE** • In practice, there will be a time spread between both the start and end of current flow in the three poles. For clarity, both the start and end of current flow in the figures are indicated by a single line for all three poles.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV



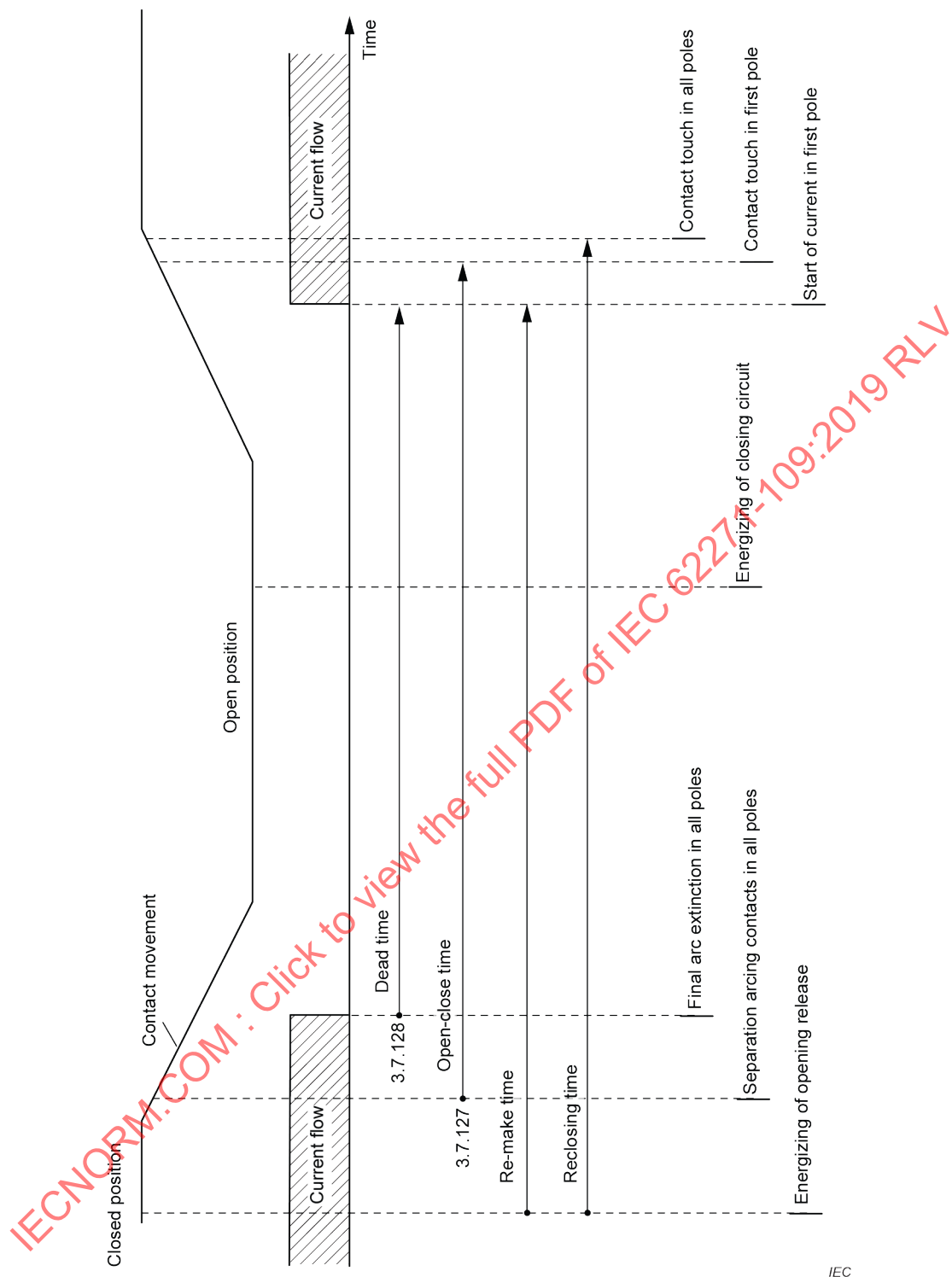
IEC

Figure 2 – By-pass switch – Opening and closing operations



IEC

Figure 3 – By-pass switch – Close-open cycle



IEC

Figure 4 – By-pass switch – Open-close cycle

3.7.101

rated value

quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

Note 1 to entry: Examples of rated value usually stated for fuses: voltage, current, breaking capacity.

3.7.102**prospective current**

<of a circuit and with respect to a switching device or a fuse>

current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is to be specified in the relevant publications.

[SOURCE: IEC 60050-441:2000, 441-17-01]

3.7.103**prospective peak current**

peak value of the first current loop of the prospective current during the transient period following initiation

Note 1 to entry: The definition assumes that the current is made by an ideal by-pass switch, i.e. with the instantaneous and simultaneous transition of its impedance across the terminals of each pole from infinity to zero. The peak value may differ from one pole to another; it depends on the instantaneous voltage across the capacitor prior to by-passing.

3.7.104**peak current**

peak value of the first current loop during the transient period following initiation

3.7.105**transient by-pass current**

superposition of capacitor bank discharge current and power-frequency current

3.7.106**peak value of transient by-pass making current**

peak value of the ~~transient~~ by-pass current in a pole of a by-pass switch during the transient period following the initiation of current during a by-passing operation

Note 1 to entry: The value is the maximum instantaneous value of the sum of the capacitor bank discharge current component and the power-frequency current component. In case of system faults, the power-frequency fault current ~~shall be~~ is equal to the maximum varistor coordinating current or for schemes without varistor, the actual maximum power-frequency fault current at the particular location.

Note 2 to entry: The peak value may differ from one pole to another and from one operation to another as it depends on the instantaneous capacitor voltage prior to by-passing.

Note 3 to entry: Where, for a three-phase circuit, a single value of peak value of ~~transient~~ by-pass making current is referred to, this is, unless otherwise stated, the highest value in any phase.

Note 4 to entry: The maximum power-frequency fault current at a particular location or the maximum varistor coordinating current is generally much lower than the rated peak withstand current of the by-pass switch.

3.7.107**insertion current****by-pass insertion current**

steady state root-mean-square current that flows through the by-pass switch immediately prior to opening

3.7.108**insertion capacity**

value of prospective current that a by-pass switch is capable of inserting at the stated voltage under prescribed conditions of use and behaviour

3.7.109**by-passing capacity**

value of prospective current that a by-pass switch is capable of by-passing at a stated voltage under prescribed conditions of use and behaviour

3.7.110**short-circuit making capacity**

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

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

3.7.111**short-time withstand current**

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

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

3.7.112**peak withstand current**

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.113**applied voltage**

<of a switching device>

voltage which exists across the terminals of a pole of a switching device just before the making of the current

[SOURCE: IEC 60050-441:2000, 441-17-24]

3.7.114**recovery voltage**

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

Note 1 to entry: This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency or the steady-state recovery voltage alone exists.

[SOURCE: IEC 60050-441:2000, 441-17-25]

3.7.115**power-frequency recovery voltage**

recovery voltage after the transient voltage phenomena have subsided

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

3.7.116**peak arc voltage**

<of a mechanical switching device>

maximum instantaneous value of voltage which under prescribed conditions appears across the terminals of a pole of a switching device during the arcing time

[SOURCE: IEC 60050-441:2000, 441-17-30]

3.7.117**clearance**

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.118

clearance between poles

clearance between any conductive parts of adjacent poles

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.119

clearance to earth

clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.120

clearance between open contacts

total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

[SOURCE: IEC 60050-441:2000, 441-17-34]

3.7.121

opening time

opening time of a by-pass switch defined according to the tripping method as stated below and with any time delay device forming an integral part of the by-pass switch adjusted to its minimum setting

Note 1 to entry: For a by-pass switch tripped by any form of auxiliary power, the opening time is the interval of time between the instant of energising the opening release, the by-pass switch being in the closed position, and the instant when the arcing contacts have separated in all poles.

Note 2 to entry: For by-pass switches with more than one insertion unit per pole, the instant when the arcing contacts have separated in all poles is determined as the instant of contact separation in the first unit of the last pole.

Note 3 to entry: The opening time includes the operating time of any auxiliary equipment necessary to open the by-pass switch and forming an integral part of the by-pass switch.

3.7.122

arcing time

<of a ~~multipole switching device~~ pole>

interval of time between the instant of the first initiation of an arc in a pole and the instant of final arc extinction in ~~all poles~~ that pole

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

3.7.123

insertion time

interval of time between the beginning of the opening time of a by-pass switch and the end of the arcing time

3.7.124

closing time

interval of time between energizing the closing circuit, the by-pass switch being in the open position, and the instant when the contacts touch in all poles

Note 1 to entry: The closing time includes the operating time of any auxiliary equipment necessary to close the by-pass switch and forming an integral part of the by-pass switch.

3.7.125

by-pass time

interval of time between energising the closing circuit, the by-pass switch being in the open position, and the instant when the current begins to flow in the first pole

Note 1 to entry: The by-pass time includes the operating time of any auxiliary equipment necessary to close the by-pass switch and forming an integral part of the by-pass switch.

Note 2 to entry: The by-pass time may vary, e.g. due to the variation of the pre-arcing time.

3.7.126

pre-arcing time

interval of time between the initiation of current flow in the first pole during a by-passing operation and the instant when the contacts touch in all poles for three-phase conditions or the instant when the contacts touch in the arcing pole for single-phase conditions

Note 1 to entry: The pre-arcing time depends on the instantaneous value of the applied voltage during a specific by-passing operation and therefore may vary considerably.

3.7.127

open-close time

interval of time between the instant when the arcing contacts have separated in all poles and the instant when the contacts touch in the first pole during a by-passing operation

Note 1 to entry: Unless otherwise stated, it is assumed that the closing release incorporated in the by-pass switch is energized at the instant when the contacts have separated in all poles during opening. This represents the minimum open-close time.

3.7.128

dead time

<during auto-reclosing>

interval of time between final arc extinction in all poles in the insertion operation and the first re-establishment of current in any pole in the subsequent by-passing operation

Note 1 to entry: The dead time ~~may~~ can vary, for example owing to the variation of the pre-arcing time.

3.7.129

by-passing-insertion time

interval of time between the initiation of current flow in the first pole during a by-passing operation and the end of the arcing time during the subsequent insertion operation

Note 1 to entry: The by-pass insertion time may vary due to the variation of the pre-arcing and arcing times.

Note 2 to entry: The by-pass insertion time should be compatible with system requirements.

3.7.130

minimum trip duration

minimum time the auxiliary power is applied to the opening release to ensure complete opening of the by-pass switch

3.7.131

minimum close duration

minimum time the auxiliary power is applied to the closing device to ensure complete closing of the by-pass switch

3.7.132

insulation level

for a by-pass switch, a characteristic defined by values indicating the insulation withstand voltages to earth and/or across the by-pass units

3.7.133**power-frequency withstand voltage**

RMS value of sinusoidal power-frequency voltage that the by-pass switch can withstand during tests made under specified conditions and for a specified ~~time~~ duration

~~[IEV 604-03-40, modified]~~

[SOURCE: IEC 60050-614:2016, 614-03-22, modified, words "insulation of the given equipment" has been replaced by "by-pass switch"]

3.7.134**impulse withstand voltage**

peak value of the standard impulse voltage wave which the insulation of the by-pass switch withstands under specified test conditions

Note 1 to entry: Depending on the shape of the wave, the term may be qualified as "switching impulse withstand voltage" or "lightning impulse withstand voltage".

3.7.135**minimum functional pressure p_{mm} for operation**

pressure (in Pa), for operation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of a by-pass switch are maintained and at which a replenishment of the ~~operating~~ energy storage device becomes necessary

Note 1 to entry: This pressure is often designated as interlocking pressure (refer to 3.6.5.6 of IEC 62271-1:2017).

3.7.136**minimum functional pressure p_{me} for by-passing, insertion and insulation**

pressure (in Pa), for by-passing, insertion and for insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of a by-pass switch are maintained and at which a replenishment of the by-passing, insertion and/or insulating fluid becomes necessary

Note 1 to entry: See also 3.6.5.5 of IEC 62271-1:2017.

Note 2 to entry: For by-pass switches with a sealed pressure system (also termed sealed-for-life), the minimum functional pressure for by-passing and insertion is the one at which the rated characteristics of the by-pass switch are maintained taking into account the pressure drop at the end of the expected operating life.

3.7.137**initiation of closing operation**

instant of receipt of a command for a closing operation at the control circuit

3.7.138**initiation of opening operation**

instant of receipt of a command for an opening operation at the control circuit

3.8 Terms and definitions related to series capacitor banks**3.8.1****capacitor**

term used when it is not necessary to distinguish between the different meanings of the words "capacitor unit" and the assembly of capacitors associated with a segment

3.8.2**overvoltage protector**

<of a series capacitor>

quick fast-acting device ~~that limits~~ intended to limit the voltage across the capacitor to a permissible value when that value would otherwise be exceeded as a result of a circuit fault or other abnormal power system conditions

[SOURCE: IEC 60050-436:1990, 436-03-14, modified – words added: "when that value would otherwise be exceeded as a result of a circuit fault or other abnormal power system conditions"]

3.8.3**rated capacitance** C_N

<of a capacitor>

capacitance value for which the capacitor has been designed

~~[IEV 436-01-12, modified]~~

3.8.4**rated current of a capacitor** I_N

RMS value of the alternating current for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-13, ~~modified~~]

3.8.5**rated reactance** X_N

<of a capacitor>

reactance of each phase of the series capacitor at rated frequency and 20 °C dielectric temperature

3.8.6**rated voltage** U_N

<of a capacitor>

RMS value of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$

[SOURCE: IEC 60050-436:1990, 436-01-15, modified – words "of the alternating voltage for which the capacitor has been designed." Have been replaced by " of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$ "]

3.8.7**limiting voltage** U_{LIM} maximum peak of the power-frequency voltage occurring between capacitor unit terminals immediately before or during operation of the overvoltage protector, divided by $\sqrt{2}$ **3.8.8****series capacitor bank ~~(or bank)~~**

three-phase assembly of capacitors with associated protection and insulated support structure

Note 1 to entry: The bank may include one or more modules.

3.8.9**segment**

<of a series capacitor>

where each phase of a bank is divided into one or more series connected parts, of which each part contains its own assembly of capacitor units, overvoltage protector, protective functions and bypass switch, each such complete part is called segment

Note 1 to entry: Segments are not normally separated by isolating disconnectors. More than one segment can be on the same insulated platform.

3.8.10**bank protection**

general term for all protective equipment for a capacitor bank, or part thereof

3.8.11**by-pass current**

steady-state RMS current flowing through the by-pass switch in parallel with the capacitor

3.8.12**by-pass fault current**

current flowing through the by-passed series capacitor bank caused by a fault on the line

3.8.13**by-pass gap (protective gap)**

gap, or system of gaps, to protect either the capacitor (type K) against overvoltage or the non-linear resistor (type M) against overload by carrying the load or fault current around the protected parts for a specified time (see Figure 2 of IEC 60143-2:2012)

3.8.14**by-pass interlocking device**

device that requires all three poles of the by-pass switch to be in the same open or closed position

3.8.15**current-limiting damping equipment**

reactor or a reactor with a parallel connected resistor to limit the current magnitude and frequency and to provide a sufficient damping of the discharge of the capacitors upon operation of the by-pass gap or the by-pass switch

3.8.16**insertion**

opening of the series capacitor by-pass switch to insert the series capacitor in series with the transmission line

3.8.17**insertion current**

RMS current that flows through the series capacitor after the by-pass switch has opened. This current may be at the specified continuous or overload current magnitudes

3.8.18**insertion voltage**

peak voltage appearing across the series capacitor upon transfer of the by-pass current with the opening of the by-pass switch

3.8.19**main gap**

that part of the protective spark-gap intended to carry the fault current during a specified time, comprising two or more heavy-duty electrodes

3.8.20

module

<capacitor switching step>

three-phase function unit consisting of one capacitor segment (possibly several) per phase with provision for interlocked operation of the single-phase by-pass switches

3.8.21

non-linear resistor

varistor

device to act as overvoltage protection of the capacitor consisting of resistors with a non-linear voltage-dependent resistance (normally metal-oxide varistors)

3.8.22

protective level

U_{PL}

magnitude of the maximum peak of the power-frequency voltage appearing across the overvoltage protector during a power system fault ($U_{PL} = U_{LIM} \times \sqrt{2}$)

Note 1 to entry: The protective level may be expressed in terms of the actual peak voltage across a segment or in terms of per unit of the peak of the rated voltage across the capacitor.

3.8.23

reinsertion

restoration of load current to the series capacitor from the by-pass path

3.8.24

reinsertion current

transient current, power-frequency current, or both, flowing through the series capacitor during the opening of the by-pass path

3.8.25

reinsertion voltage

~~transient recovery voltage, power frequency voltage, or both,~~ appearing across the series capacitor during the opening of the by-pass path

3.8.26

temporary overvoltage

temporary power-frequency voltage higher than the continuous rated voltage of the series capacitor

3.8.27

varistor coordinating current

magnitude of the maximum varistor current associated with the protective level

3.8.28

capacitor bank discharge current

$I_{DISCHARGE}$

current which flows during the discharging of the capacitor bank

Note 1 to entry: The maximum peak value of the capacitor discharge current occurs when the capacitor bank is charged to the protective level U_{PL} .

3.9 Index of definitions

A

"a" contact, make contact	3.5.112
Alternative operating mechanism	3.5.126
Ambient air temperature	3.1.104

Anti-pumping device	3.6.115
Applied voltage <of a switching device>	3.7.113
Arcing contact	3.5.108
Arcing time <of a ~~multiple switching device~~ pole>	3.7.122
Arc control device	3.5.117
Auto-reopening	3.6.106
Assemblies	3.2
Auxiliary circuit <of a switching device>	3.5.104
Auxiliary contact	3.5.110
Auxiliary switch <of a mechanical switching device>	3.5.111

B

"b" contact, break contact	3.5.113
Bank protection	3.8.10
Break contact	3.5.113
By-pass current	3.8.11
By-pass fault current	3.8.12
By-pass gap (protective gap)	3.8.13
By-pass insertion current	3.7.107
By-passing-insertion time	3.7.129
By-pass interlocking device	3.8.14
By-pass making current	3.7.106
By-pass (or insertion) unit	3.5.121
By-pass switch	3.4.103
By-pass switch class M1	3.4.104
By-pass switch class M2	3.4.105
By-pass switch with lock-out preventing opening	3.6.117
By-pass time	3.7.125
By-passing capacity	3.7.109

C

Capacitor	3.8.1
Capacitor bank discharge current ($I_{DISCHARGE}$)	3.8.28
Clearance	3.7.117
Clearance between open contacts	3.7.120
Clearance between poles	3.7.118
Clearance to earth	3.7.119
Closed position <of a mechanical switching device>	3.6.112
Closing operation <of a mechanical switching device>	3.6.104
Closing time	3.7.124
Connection ~~(bolted or the equivalent)~~	3.5.119
Contact <of a mechanical switching device>	3.5.105
Contact piece	3.5.106
Control circuit <of a switching device>	3.5.103

Control contact	3.5.109
Current-limiting damping equipment	3.8.15

D

Dead time <during auto-reclosing>	3.7.128
Dependent power operation <of a mechanical switching device>	3.6.109
Disruptive discharge	3.1.112

E

Enclosure	3.5.123
External insulation	3.1.108

I

Impulse withstand voltage	3.7.134
Independent manual operation <of a mechanical switching device>	3.6.111
Initiation of closing operation	3.7.137
Initiation of opening operation	3.7.138
Insertion	3.8.16
Insertion current	3.8.17
Insertion capacity	3.7.108
Insertion time	3.7.123
Insertion voltage	3.8.18
Insulation level	3.7.132
Interlocking device	3.6.116
Internal insulation	3.1.109

L

Limiting voltage (U_{LIM})	3.8.7

M

Main circuit <of a switching device>	3.5.102
Main contact	3.5.107
Main gap	3.8.19
Make contact	3.5.112
Mechanical switching device	3.4.102
Minimum close duration	3.7.131
Minimum functional pressure ρ_{me} for by-passing, insertion and insulation	3.7.136
Minimum functional pressure ρ_{mm} for operation	3.7.135
Minimum trip duration	3.7.130
Module <of a by-pass switch>	3.5.122
Module <capacitor switching step>	3.8.20

N

Non-linear resistor (varistor)	3.8.21
Non-self-restoring insulation	3.1.111

Non-Sustained Disruptive Discharge (NSDD) 3.1.116

O

Open-close time 3.7.127

Opening operation <of a mechanical switching device> 3.6.105

Opening time 3.7.121

Open position <of a mechanical switching device> 3.6.113

Operating cycle <of a mechanical switching device> 3.6.102

Operating mechanism 3.5.124

Operating sequence <of a mechanical switching device> 3.6.103

Operation <of a mechanical switching device> 3.6.101

Outdoor switchgear and controlgear 3.1.102

Overvoltage <in an electric power system> 3.1.106

Overvoltage protector <of a series capacitor> 3.8.2

P

Parts of assemblies 3.3

Peak arc voltage <of a mechanical switching device> 3.7.116

Peak current 3.7.104

~~Peak value of the transient by-pass current 3.7.106~~

Peak withstand current 3.7.112

Pole <of a switching device> 3.5.101

Position indicating device 3.5.118

Positively driven operation 3.6.108

Positive opening operation <of a mechanical switching device> 3.6.107

Power-frequency recovery voltage 3.7.115

Power-frequency withstand voltage 3.7.133

Power kinematic chain 3.5.124

Pre-arcing time 3.7.126

Prospective current <of a circuit and with respect to a switching device or a fuse> 3.7.102

Prospective peak current 3.7.103

Protective level U_{PL} 3.8.22

R

Rated capacitance <of a capacitor> C_N 3.8.3

Rated current <of a capacitor> I_N 3.8.4

Rated reactance <of a capacitor> X_N 3.8.5

Rated voltage <of a capacitor> U_N 3.8.6

Rated value 3.7.101

Recovery voltage 3.7.114

Re-ignition <of an AC mechanical switching device> 3.1.114

Reinsertion 3.8.23

Reinsertion current 3.8.24

Reinsertion voltage 3.8.25

Release <of a mechanical switching device> 3.5.116

Restrike <of an AC mechanical switching device>	3.1.115
Restrike performance	3.1.113
Rolling contact	3.5.115

S

Segment <of a series capacitor>	3.8.9
Self-restoring insulation	3.1.110
Series capacitor bank ~~(or bank)~~	3.8.8
Short-circuit current	3.1.103
Short-circuit making capacity	3.7.110
Short-time withstand current	3.7.111
Shunt release	3.6.114
Sliding contact	3.5.114
Stored energy operation	3.6.110
Switchgear and controlgear	3.1.101
Switching device	3.4.101

T

Temperature rise <of a part of a by-pass switch>	3.1.105
Temporary overvoltage	3.8.26
Terminal	3.5.120
Transient by-pass current	3.7.105

U

Unit test	3.1.107

V

Varistor coordinating current	3.8.27

4 Normal and special service conditions

Clause 4 of IEC 62271-1:2017 is applicable.

5 Ratings

5.1 General

The characteristics of a by-pass switch, including its operating devices and auxiliary equipment, that shall be used to determine the ratings are the following.

Rated characteristics to be given for all by-pass switches

- rated voltage to earth (U_{re}) and across the by-pass ~~unit~~ switch (U_{rp});
- rated insulation level to earth (U_{pe} , U_{de} , U_{se}) and across the by-pass ~~unit~~ switch (U_{pp} , U_{dp} , U_{sp});
- rated frequency (f_r);
- rated ~~normal~~ continuous current (I_r);
- rated short-time withstand current (I_k);

- f) rated peak withstand current (I_p);
- g) rated duration of short-circuit (t_k);
- h) rated supply voltage of ~~closing and opening devices and of~~ auxiliary circuits and control circuits (U_a);
- i) rated supply frequency of closing and opening devices and of auxiliary circuits;
- j) rated pressures of compressed gas supply and/or of hydraulic supply for operation, insertion, by-passing and insulation, as applicable;
- k) rated by-pass making current;
- l) rated by-pass insertion current;
- m) rated reinsertion voltage (peak value);
- n) rated operating sequence;
- ~~o) rated time quantities;~~
- o) rated mechanical endurance class.

The rated characteristics of the by-pass switch are referred to the rated operating sequence.

5.2 Rated voltage (U_r)

5.2.1 General

Subclause 5.2.1 of IEC 62271-1:2017 is applicable with the following addition.

5.2.1.101 Rated voltage to earth (U_{re})

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

Subclauses 5.2.2 and 5.2.3 of IEC 62271-1:2017 are applicable. The rated voltage to earth is the power system phase-to-phase voltage for which the phase-to-ground insulation of the by-pass switch is designed.

5.2.1.102 Rated voltage across the by-pass switch (U_{rp})

~~The voltage applied across the by pass switch shall be determined by multiplying the rated reactance of the series capacitor bank or segment ($X_N=1/\omega C_N$) by its rated current (I_N). The rated voltage (phase to phase) assigned to the by pass switch shall be equal to or higher than the voltage calculated from the applied voltage (multiplied by $\sqrt{3}$) and adjusted to the next higher standardized value given in 4.1 of IEC 62271-1.~~

~~NOTE Long duration overloads (several minutes) may be taken into account when assigning a rated voltage across a by-pass switch.~~

The rated voltage across the by-pass switch shall be derived from its associated power frequency withstand voltage as determined in 5.3.102 and in 6.1.3 of IEC 60143-1:2015.

Tables 1 to 4 of IEC 62271-1:2017 shall be used for associating a rated voltage across the by-pass switch from a power frequency withstand voltage across the by-pass switch

5.2.2 Range I for rated voltage of 245 kV and below

Subclause 5.2.2 of IEC 62271-1:2017 is applicable.

5.2.3 Range II for rated voltage above 245 kV

Subclause 5.2.3 of IEC 62271-1:2017 is applicable.

5.3 Rated insulation level (U_p , U_d , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition.

5.3.101 Rated insulation level to earth (U_{pe} , U_{de} , U_{se})

The standard values of rated withstand voltages to earth are given in Tables 1, 2, 3 and 4 of IEC 62271-1:2017.

5.3.102 Rated insulation level across the by-pass switch (U_{pp} , U_{dp} , U_{sp})

The standard values of rated insulation voltages across the by-pass switch are given in Tables 1, 2, 3 and 4 of IEC 62271-1:2017 for the corresponding rated voltage across the by-pass switch. The rated insulation levels shall be determined in accordance with 6.1.3 of IEC 60143-1:2015.

NOTE The insulation levels for insulators and series capacitor equipment mounted on the supporting platform are in reference to the platform. For installations at altitudes exceeding 1 000 m, higher insulation levels ~~may~~ can be required. The insulation level of the insulators and equipment on the platform should be selected based on the protective level established by the overvoltage protector using the equation below. The equation applies to the insulation across the entire segment using the protective level of that segment. It also applies to the insulation within the segment using the applicable protective level across that part of the segment.

$$U_{ipf} \geq 1,2 U_{PL} \sqrt{1,2}$$

where

U_{ipf} is the power-frequency withstand voltage (RMS);

U_{PL} is the protective level.

5.4 Rated frequency (f_r)

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

The standard values for the rated frequency of high voltage by-pass switches are 50 Hz and 60 Hz.

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

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

The rated continuous current of the by-pass switch (uncompensated line) may be lower than the series capacitor bank (compensated line).

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable.

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

Subclause 5.9 of IEC 62271-1:2017 is generally applicable. The tolerance given in 6.9.3 ~~and in 5.8.4~~ of IEC 62271-1:2017 for shunt opening releases shall be applied to shunt closing releases.

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

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressures of compressed gas supply for ~~insulation, operation and/or by-passing and insertion~~ controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable.

5.101 Rated operating sequence

The rated characteristics of the by-pass switch are referred to the rated operating sequence.

$$C - t - OC - t' - OC$$

Unless otherwise specified:

- $t = 0,3$ s for by-pass switches intended for rapid auto-reopening (by-passing-insertion time);
- $t' = 3$ min.

where

C represents a closing operation;

OC represents an opening operation followed immediately (that is, without any intentional delay) by a closing operation;

t and t' are time intervals between successive operations;

t and t' should always be expressed in minutes or in seconds.

If the by-passing-insertion time is adjustable, the limits of adjustment should be specified.

NOTE Instead of $t = 0,3$ s, other value: $t = 0,2$ s ~~is~~ may also be used for by-pass switches intended for rapid auto-reopening.

NOTE Instead of $t' = 3$ min, other values: $t' = 15$ s and $t' = 1$ min ~~are~~ may also be used for by-pass switches intended for rapid auto-reopening.

NOTE Other operating sequences may be specified depending upon system requirements. ~~One example is C – t – OC – t – OC – t' – OC.~~

5.102 Rated by-pass making current (I_{BP})

The rated by-pass making current is the ~~peak~~ maximum value of the by-pass making current that the by-pass switch shall be capable of making under line fault condition when the capacitor bank is precharged to the limiting voltage of the overvoltage protector (U_{PL}) and with a frequency of the by-pass discharge current corresponding to the actual capacitance of the capacitor bank with its associated inductance of the damping circuit. The effective damping of the by-pass discharge current can be taken into consideration.

This current shall be the sum of the capacitor bank discharge current component and the power-frequency fault current component (see 3.7.106). In general, the power-frequency fault current component should be equal to the maximum varistor coordinating current.

NOTE The rated by-pass making current should be determined by system studies as the maximum sum of the instantaneous capacitor bank ~~peak~~ discharge current and the instantaneous fault current ~~peak~~ component ~~in the interval between current initiation in the by-pass switch and contact touch (pre-arcing time)~~ during the pre-arcing period (see also IEC 60143-2:2012). A value of pre-arcing time of 5 ms is suggested in case no data is available.

The by-pass making performance is covered when the required peak value of the by-pass making current is equal to or lower than the peak current value used in the relevant type test. This rule is considered to be valid only when the frequency f_{BP} of the by-pass making current is equal to or lower than 130 % of the corresponding value used during type tests.

Specific ratings can generally not be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings. Nevertheless, preferred values for the rated by-pass making current and frequency are as follows:

I_{BP} : 63 kA ~~peak~~ – 100 kA ~~peak~~ and 125 kA ~~peak~~

f_{BP} : 500 Hz and 1 000 Hz

5.103 Rated by-pass insertion current (I_{INS})

The rated by-pass insertion current is the RMS value of the power-frequency current that the by-pass switch shall be capable of transferring from the by-pass circuit path to the main series capacitor path under the rated reinsertion voltage. Specific ratings cannot be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings.

NOTE The rated by-pass insertion current should be taken from the R10 series and may be equal to or lower (uncompensated line) than the rated current of the capacitor bank (compensated line).

5.104 Rated reinsertion voltage (U_{INS})

The rated reinsertion voltage is the peak value of the ~~transient~~ recovery voltage that the by-pass switch shall be capable of withstanding, without restrike, during the transfer of the rated by-pass insertion current.

In general, the ~~transient~~ reinsertion voltage shall be equal to U_{PL} to take into account all emergency overload conditions and power swings that could result in ~~transient~~ insertion voltages up to the protective level of the overvoltage protector.

Several ~~transient~~ reinsertion voltage waveshapes can be obtained in service. The reinsertion voltage waveshape should be determined by systems studies. For standardization purposes, and in order to cover the greatest number of practical cases, this document recommends a "1-cos" waveshape having a preferred first time-to-peak of 5,6 ms. Other waveshapes may be required and should be clearly specified to the manufacturer at the time of enquiry.

Specific ratings cannot be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings. Annex F gives more information regarding ~~transient~~ recovery voltage during reinsertion.

NOTE 1 No specific recommended values can be given for the ~~transient~~ reinsertion voltage since this value is depending on the series capacitor design parameters (capacitive impedance, rated normal current of the capacitor

bank, a protective level of the overvoltage protector, overload emergency current and power swing). See Annex F for more information.

NOTE 2 To cover most of the 50 Hz and 60 Hz applications with one single test-duty, the ~~transient~~ recovery voltage has been defined with a time-to-peak of 5,6 ms.

5.105 Number of mechanical operations

A by-pass switch shall be able to perform the number of operations given in Table 1 (as defined in 7.101.2.3 and Table 6 for type tests) taking into account the programme of maintenance specified by the manufacturer.

Table 1 – Number of mechanical operations

Standard by-pass switch (normal mechanical endurance) class M1	2 000 operating sequences
By-pass switch for special service requirements (extended mechanical endurance) class M2	10 000 operating sequences

6 Design and construction

6.1 Requirements for liquids in by-pass switches

Subclause 6.1 of IEC 62271-1:2017 is applicable.

6.2 Requirements for gases in by-pass switches

Subclause 6.2 of IEC 62271-1:2017 is applicable.

6.3 Earthing of by-pass switches

Subclause 6.3 of IEC 62271-1:2017 is applicable.

6.4 Auxiliary and control equipment and circuits

6.4.1 General

Subclause 6.4.1 of IEC 62271-1:2017 is applicable.

6.4.2 Protection against electrical shock

Subclause 6.4.2 of IEC 62271-1:2017 is applicable.

6.4.3 Components installed in enclosures

Subclause 6.4.3 of IEC 62271-1:2017 is applicable with the following ~~additions~~ modification:

- after the loss, of "suitable precautions" for a duration longer than 2 h, the functionality of the by-pass switch shall come back to its original characteristics when the service condition is recovered;
- where shunt opening and closing releases are used, appropriate measures shall be taken in order to avoid damage on the releases when permanent orders for closing or opening are applied. For example, those measures may be the use of series control contacts arranged so that when the by-pass switch is closed, the close release control contact ("b" contact or break contact) is open and the open release control contact ("a" contact or make contact) is closed, and when the by-pass switch is open, the open release control contact is open and the close release control contact is closed;

NOTE

- systems other than contacts are possible and may be used;
- for shunt closing releases, the protective measures for the shunt closing releases (the “b” contact) as mentioned in the first indent above shall open no sooner than the minimum close duration (3.7.131) provided by the by-pass switch and no later than the ~~rated~~ specified closing time;

NOTE

- if the current of the shunt closing release is interrupted by the control contact, the closing command should be positively longer than the ~~rated~~ specified closing time.
- for shunt opening releases, the protecting measures for the shunt opening releases (the “a” contact) as mentioned in the first indent above shall open no sooner than the minimum trip duration (3.7.130) required by the by-pass switch and no later than 20 ms after separation of the main contacts;
- for short open-close time requirements, the protective measures for the shunt closing releases (the “b” contact) as mentioned in the first indent above, shall close no sooner than when the “a” contact has opened;
- where auxiliary switches are used as position indicators, they shall indicate the end position of the by-pass switch at rest, open or closed. The signalling shall be sustained;
- connections shall withstand the stresses imposed by the by-pass switch, especially those due to mechanical forces during operations;
- all auxiliary equipment, including the wiring, shall be adequately protected against rain and humidity;
- where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, interrupting and/or insulating and operating fluids and be able to switch the loads which are stated by the by-pass switch manufacturer;
- special items of auxiliary equipment such as liquid indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts, shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of interrupting and/or insulating and operating fluids;
- the power consumption of heaters at rated voltage shall be within the tolerance of $\pm 10\%$ of the value stated by the manufacturer;
- where anti-pumping devices are part of the by-pass switch control scheme, they shall act on each control circuit, if more than one is installed;
- where a control scheme of pole discrepancy is part of the by-pass switch, the position of the poles shall be supervised, open or closed. The closing of one pole shall initiate closure of the remaining poles. Each by-pass switch shall be similarly interlocked for the opening operation.

6.5 Dependent power operation

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

A by-pass switch arranged for dependent power opening with external energy supply shall also be capable of closing immediately following an opening operation.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable with the following addition to subclause 6.6.1.

A by-pass switch arranged for stored energy operation shall also be capable of closing immediately following an opening operation.

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

Subclause 6.7 of IEC 62271-1:2017 is not applicable for by-pass switches.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is generally not applicable and shall be replaced by the following.

6.9.1 General

Subclause 6.9.1 of IEC 62271-1:2017 is applicable.

6.9.2 Shunt closing releases

A shunt closing release shall operate correctly under all operating conditions of switching device up to its rated by-pass making current, and between 70 % in case of DC – or 85 % in case of AC – and 110 % of the rated supply voltage of the closing device (see 5.9), the frequency in the case of AC being the rated supply frequency of the closing device (see 5.10).

6.9.3 Shunt opening releases

A shunt opening release shall operate correctly between 85 % and 110 % of the rated supply voltage of the opening device (see 5.9), the frequency in the case of AC being the rated supply frequency of the opening device (see 5.10).

6.9.4 Capacitor operation of shunt releases

Subclause 6.9.4 of IEC 62271-1:2017 is applicable.

6.9.5 Under-voltage release

Subclause 6.9.5 of IEC 62271-1:2017 is not applicable to by-pass switches.

6.9.101 Multiple releases

If a by-pass switch is fitted with more than one release for the same function, a defect in one release shall not disturb the function in the others. Releases used for the same function shall be physically separated, i.e. magnetically decoupled.

6.9.102 Operation limits of releases

For shunt-opening releases, the minimum trip duration, and for shunt-closing releases, the minimum command duration at rated supply voltage, shall not be less than 2 ms.

In order to prevent untimely operation due to parasitic voltages that may be present in control circuits, the minimum supply voltage, ~~the minimum supply voltage~~ for operation of shunt releases shall not be less than 20 % of the rated supply voltage.

6.9.103 Power consumption of releases

The power consumption of shunt closing or opening releases of a three-pole by-pass switch shall not exceed 1 200 VA. For certain by-pass switch designs, higher values may be necessary.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable.

6.10.101 Low- and high-pressure interlocking devices

~~Subclause 5.9 of IEC 62271-1 is replaced by the following.~~

All by-pass switches having an energy storage in gas receivers or hydraulic accumulators (see 6.6.2 of IEC 62271-1:2017) and all by-pass switches except sealed pressure devices, using compressed gas for by-passing and insertion (see 5.103) shall be fitted with a low-pressure interlocking device, and can also be fitted with a high-pressure interlocking device, set to operate at, or within, the appropriate limits of pressure stated by the manufacturer.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following additions: the nameplates of a by-pass switch and its operating devices shall be marked in accordance with Table 2.

Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer.

Releases shall bear the appropriate data.

~~The nameplate shall be visible in the position of normal service and installation.~~

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Table 2 – Nameplate information

	Abbreviation	Unit	By-pass switch ^b	Operating device ^b	Condition: Marking only required if
1	2	3	4	5	6
Name of manufacturer			X	X	
Type designation and serial number			X	X	
Rated voltage to earth	U_{re}	kV	X		
Rated voltage across by-pass switch	U_{rp}	kV	X		
Rated lightning impulse withstand voltage to earth	U_{pe}	kV	X		
Rated lightning impulse withstand voltage across by-pass switch	U_{pp}	kV	X		
Rated switching impulse withstand voltage to earth	U_{se}	kV	Y		Rated voltage U_{re} 300 kV and above
Rated switching impulse withstand voltage across by-pass switch	U_{sp}	kV	Y		Rated voltage U_{rp} 300 kV and above
Rated frequency	f_r	Hz	Y X		rating is not applicable at both 50 Hz and 60 Hz
Rated ~~normal~~ continuous current	I_r	A	X		
Rated short-time withstand current	I_k	kA	X		
Rated peak withstand current	I_p	kA	X		
Rated duration of short circuit	t_k	s	Y		different from 1 s
Rated by-pass making current	I_{BP}	kA	X		
Frequency of the rated by-pass making current	f_{BP}	Hz	X		
Rated by-pass insertion current	I_{INS}	A	X		
Rated reinsertion voltage	U_{INS}	kV	X		
Rated Filling pressure for operation ^a	P_{rm}	MPa		(X) Y	If applicable
Rated Filling pressure for insulation, by-passing and insertion ^a	P_{re}	MPa	(X) Y		If applicable
Alarm pressure for operation ^a	P_{am}	MPa		Y	If applicable
Alarm pressure for insulation, by-passing and insertion ^a	P_{ae}	MPa	Y		If applicable
Minimum functional pressure for operation ^a	P_{mm}	MPa		Y	If applicable
Minimum functional pressure for insulation, by-passing and insertion ^a	P_{me}	MPa	Y		If applicable
Rated supply voltage of closing and opening devices	U_{ep}	V		(X)	
Rated supply frequency of closing and opening devices		Hz		(X)	
Rated supply voltage(s) of auxiliary and control circuits. Specify DC/AC (with rated frequency)	U_a	V		(X)	
Rated supply frequency of auxiliary circuits		Hz		(X)	
Type and mass of fluid (liquid or gas) for insulation	M_f	kg	X		
Mass of by-pass switch (including ~~oil for oil by-pass switches~~ any fluid)	M	kg	Y	Y	more than 300 kg
Mass of fluid for by-passing and insertion	m	kg	Y		If gas or oil by-pass switches
Rated operating sequence			X		
Year of manufacture			X		
Temperature class			Y	Y	Different from –25 °C outdoor
Minimum and maximum ambient temperature		°C	Y	Y	If different than –5 °C and 40 °C

	Abbreviation	Unit	By-pass switch ^b	Operating device ^b	Condition: Marking only required if
Classification			Y		different from M1
Relevant standard with date of issue			X	X	
NOTE The abbreviations in column 2 ~~may~~ can be used instead of the terms in column 1. When terms in column 1 are used, the word “rated” need not appear.					
^a Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate ^b X = the marking of these values is mandatory; blanks indicate the value zero; Y = the marking of these values to the conditions in column 6. (X) = the marking of these values is optional;					

6.12 ~~Interlocking~~ Locking devices

Subclause 6.12 of IEC 62271-1:2017 is applicable.

~~See also 5.4.~~

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is applicable.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 is applicable.

6.17 ~~Liquid tightness~~ Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable only to vacuum interrupters used as by-pass switches.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, by-passing, insertion and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable.

6.101 Requirements for simultaneity within a pole

If one pole consists of more than one by-pass unit connected in series, the maximum difference between the instants of contact separation or contact touch within these series connected units shall not exceed one-eighth of a cycle of rated frequency.

NOTE The time spread between poles is normally not considered unless the single-pole operation of the by-pass switch is restricted from system operation.

6.102 General requirement for operation

A by-pass switch, including its operating devices, shall be capable of completing its rated operating sequence (5.101) in accordance with the relevant provisions of 6.5 to 6.9 and 6.103 for the whole range of ambient temperatures within its temperature class as defined in Clause 4 of IEC 62271-1:2017.

This requirement is not applicable to auxiliary manual operating devices; where provided, these shall be used only for maintenance and for an emergency operation on a dead circuit.

By-pass switches provided with heaters shall be designed to permit a closing operation at the minimum ambient temperature defined by the temperature class when the heaters are not operational for a minimum time of 2 h.

6.103 Pressure limits of fluids for operation

The manufacturer shall state the maximum and minimum pressures of the fluid for operation at which the by-pass switch is capable of performing according to its ratings and at which the appropriate low- and high-pressure interlocking devices shall be set (see 6.10.101). The manufacturer shall state the minimum functional pressure for operation, by-passing and insertion (see 3.7.135 and 3.7.136).

The manufacturer may specify pressure limits at which the by-pass switch is capable for each of the following performances.

- a) making its rated by-pass making current, i.e. a "C" operation;
- b) reinserting its rated by-pass insertion current immediately followed by making its rated by-pass making current, i.e. an "OC" operating cycle;
- c) for by-pass switches intended for rapid auto-reinsertion; making its rated by-pass making current followed after a time interval t of the rated operating sequence (5.101) by reinserting its rated by-pass insertion current, immediately followed again by making its rated by-pass making current, i.e. an "C – t – OC" operating sequence.

The by-pass switches shall be provided with energy storage of sufficient capacity for satisfactory performance of the appropriate operations at the corresponding minimum pressures stated.

6.104 Vent outlets

Vent outlets are devices that allow a deliberate release of pressure in a by-pass switch during operation.

NOTE This is applicable to air-blast and oil by-pass switches.

Vent outlets of by-pass switches shall be so situated that a discharge of oil or gas or both will not cause electrical breakdown and is directed away from any location where persons may be present. The necessary safety distance shall be stated by the manufacturer.

The construction shall be such that gas cannot collect at any point where ignition can be caused, during or after the operation, by sparks arising from the normal operation of the by-pass switch or its auxiliary equipment.

6.105 ~~Rated~~ Time quantities

Refer to Figures 2, 3 and 4.

~~Rated~~ Values ~~shall~~ may be assigned to the following time quantities:

- opening time (no-load);
- ~~maximum~~ closing time (no-load);
- ~~maximum open-close time (no-load).~~
- close-open time (no-load);
- open-close time (no-load).

~~Rated~~ Time quantities are based on

- rated supply voltages of closing and opening devices and of auxiliary and control circuits (see 5.9);
- rated supply frequency of closing and opening devices and of auxiliary circuits (see 5.10);
- ~~rated pressures of compressed gas supply for operation, for insulation and/or by-passing and insertion, as applicable (see 4.10);~~
- ~~rated pressure of hydraulic supply for operation,~~
- rated pressure of compressed gas supply for controlled pressure systems (see 5.11);
- rated filling levels for insulation and/or operation (see 5.11);
- an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$.

~~NOTE Usually it is not practical to assign a rated value of by-pass making time or of by-pass insertion time due to the variation of the arcing time and the pre-arcing time.~~

~~NOTE The maximum closing time (no load) and the maximum open-close time (no-load) should also be given for the minimum supply voltages, maximum pressure of compressed gas supply for operation, for insulation and/or by-passing and insertion as applicable (see 4.10) and minimum pressure of hydraulic supply for operation.~~

NOTE It is not practical to assign a value of by-pass time or of by-pass- insertion time owing the variation of the arcing time and the pre-arcing time.

6.106 Static mechanical loads

By-pass switches 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 by-pass switch shall be in accordance with Clause 4 of IEC 62271-1:2017.

Some examples of static forces due to wind, ice and weight on flexible and tubular connected conductors are given as a guidance in Table 3.

The tensile force due to the connected conductors is assumed to act at the outermost end of the by-pass switch terminal.

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

Table 3 – Examples of static horizontal and vertical forces for static terminal load

Rated voltage range to earth U_{re} kV	Rated current range I_r A	Static horizontal force F_{th}		Static vertical force (vertical axis-upward and downward) 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 2 500	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

7 Type tests

7.1 General

7.1.1 ~~Grouping of tests~~ Basics

Subclause 7.1.1 of IEC 62271-1:2017 is generally applicable with the following additions.

The type tests for by-pass switches are listed in Table 4.

~~All type tests shall be carried out using the number of test samples specified in 6.1.1 of IEC 62271-1 and in 6.102.2.~~

For the type tests, the tolerances on test quantities are given in Annex A.

The individual type tests shall, in principle, be performed on a by-pass switch in a new and clean condition. In the case of by-pass switches using SF₆ for insulation, by-passing and insertion and/or operation, the quality of the gas shall at least comply with the acceptance levels of IEC 60480.

The responsibility of the manufacturer is limited to the declared rated values and not to those values achieved during the type tests.

The uncertainty of each measurement by oscillograph or equivalent equipment (for example transient recorder), including associated equipment, of the quantities that determine the ratings (for example by-pass current, applied voltage and ~~transient~~ recovery voltage) shall be within ±5 % (equal to a coverage factor of 2,0).

NOTE For the meaning of coverage factor, refer to ISO ~~Guide to the expression of uncertainty in measurement (1995, see Bibliography)~~ / IEC Guide 98-1:2009.

Table 4 – Type tests

Mandatory type tests	Subclause
Dielectric tests	7.2
Measurement of the resistance of the main circuit	7.4
Temperature-rise tests	7.5
Short-time withstand current and peak withstand current tests	7.6
Tightness tests	7.8
Additional test on auxiliary and control circuits	7.10
Mechanical operation test at ambient air temperature	7.101.2
By-pass making current tests	7.103.2
Insertion current tests	7.103.3
Mandatory type tests, where applicable	Subclause
Radio interference voltage tests	7.3
Verification of the degree of protection	7.7
EMC tests	7.9
X-radiation test procedure for vacuum interrupters	7.11
Extended mechanical endurance tests on by-pass switches for special service conditions	7.101.2.4
Low and high temperature tests	7.101.3
~~Static terminal load tests~~	~~6.101.6~~
Test to prove operation under severe ice conditions ^a	7.101.5
^a ~~Additional test sample is allowed.~~	

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

Subclause 7.1.2 of IEC 62271-1:2017 is applicable.

7.1.3 Information to be included in type test reports

Subclause 7.1.3 of IEC 62271-1:2017 is applicable with the following addition.

Further details relating to records and reports of type tests for by-pass current making and insertion tests are given in Annex B.

7.1.101 Invalid tests

In the case of an invalid test, it may become necessary to perform a greater number of tests than is required by this document. An invalid test is one where one or more of the test parameters demanded by the document is not met. This includes, for example, current, voltage and time factors as well as point-on-wave requirements (if specified) and the additional features in synthetic testing such as correct auxiliary switching device operation and correct injection time.

The deviation from the document could make the test less or more severe. Four different cases are considered in Table 5.

The invalid part of the test duty may be repeated without reconditioning of the by-pass switch. However, in the case of a failure of the by-pass switch during such additional tests, or at the discretion of the manufacturer, the by-pass switch may be reconditioned and the complete test-duties repeated. In those cases, the test report shall include reference to the invalid test.

If any record of an individual operation cannot be produced for technical reasons, this individual operation is not considered invalid, provided that evidence can be given in another manner that the by-pass switch did not fail and the required testing values were fulfilled.

Table 5 – Invalid tests

Test conditions related to document	By-pass switch	
	Passes	Fails
More severe	Test valid, result accepted	Test to be repeated with correct parameters Modification of the design of the by-pass switch not required
Less severe	Test to be repeated with correct parameters Modification of the design of the by-pass switch not required	By-pass switch failed the test. Modification of the design of the by-pass switch required, aiming for improvement of the performance Tests to be re-started on the modified by-pass switch

7.1.102 Type tests to repeat for by-pass switches with alternative operating mechanisms

The following type tests shall be repeated on by-pass switches with alternative operating mechanisms:

- mechanical operation tests at ambient temperature (according to 7.101.2);
- high and low temperature tests (according to 7.101.3);
- by-pass making current test (as defined in 7.102.7);
- short-time withstand current and peak withstand current tests on by-pass switches having main contacts of the butt type (according to 7.6).

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is applicable with the following note:

NOTE In the case of dead tank by-pass switches, when the bushings have been previously tested according to the relevant IEC standard, tests under wet conditions can be omitted.

7.2.4 ~~Condition of by-pass switch during dielectric tests~~ Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable with the following ~~addition~~ modification.

The following test procedure B adapted for switching devices that have self-restoring and non-restoring insulation is the preferred test procedure for by-pass switches. The by-pass switch has passed the impulse tests if the following conditions are fulfilled:

- a) each series has at least 15 tests;
- b) no disruptive discharges on non-self-restoring insulation shall occur. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge;
- c) the number of disruptive discharges shall not exceed two for each complete series.

This procedure leads to a maximum possible number of 25 impulses per series.

Procedure C of IEC 60060-1:2010 may be used when all three poles are tested.

If disruptive discharges occur and evidence cannot be given during testing that the disruptive discharges were on self-restoring insulation, the by-pass switch shall be dismantled and inspected after the completion of the dielectric test series. If damage to non-self-restoring insulation is observed, the by-pass switch has failed the test.

NOTE If the atmospheric correction factor K_t is less than 1,00 but greater than 0,95, it is permissible to follow the criteria stated in 7.2.5 of IEC 62271-1:2017 if the correction factor is not applied during the tests. Then, if one or two disruptive discharges out of 15 impulses occur in the external insulation, the particular test series showing flashover(s) is repeated with the appropriate correction factor so that no external disruptive discharge occurs.

NOTE For by-pass switches of gas insulated switchgear tested with test bushings which are not part of the by-pass switch, flashover across the test bushings should be disregarded.

NOTE The determination of the location of the observed disruptive discharges should be done by the laboratory using sufficient detection means, for example, photographs, video recordings, internal inspection, etc.

7.2.6 Application of test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is applicable with the following modifications:

- The allowance of preliminary impulses for vacuum interrupters is not applicable for by-pass switches;
- The number of reduced impulses before a test or before polarity reversal shall be limited to two impulses between 60 % and 80 % of the rated withstand voltage.

7.2.7 Tests of by-pass switches of $U_{re} \leq 245 \text{ kV}$ or $U_{rp} \leq 245 \text{ kV}$

Subclause 7.2.7 of IEC 62271-1:2017 is applicable. These test series need to be performed only for the part of the insulation which fulfils the above criteria.

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-1:2017 is applicable.

7.2.7.2 Power-frequency voltage tests

Subclause 7.2.7.2 of IEC 62271-1:2017 is applicable with the following note:

NOTE In the case of dead tank by-pass switches, when the bushings have been previously tested according to the relevant IEC standard, tests under wet conditions can be omitted.

7.2.7.3 Lightning impulse voltage test

Subclause 7.2.7.3 of IEC 62271-1:2017 is applicable.

7.2.8 Tests of by-pass switches of $U_{re} > 245 \text{ kV}$ or $U_{rp} > 245 \text{ kV}$

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-1:2017 is applicable. These test series need to be performed only for the part of the insulation which fulfils the above criteria.

7.2.8.2 Power-frequency voltage tests

Subclause 7.2.8.2 of IEC 62271-1:2017 is applicable with the following addition.

The test procedure following the alternative method is more severe than the test procedure following the preferred method.

7.2.8.3 Switching impulse voltage tests

Subclause 7.2.8.3 of IEC 62271-1:2017 is applicable with the following addition.

The dry tests shall be performed using voltage of positive polarity only. With the by-pass switch closed, the test voltage equal to the rated withstand voltage to earth, shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

With the by-pass switch open, the test voltage equal to the rated withstand voltage across the open by-pass switch shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

7.2.8.4 Lightning impulse voltage tests

Subclause 7.2.8.4 of IEC 62271-1:2017 is applicable with the following addition.

With the by-pass switch closed, the test voltage equal to the rated withstand voltage to earth, shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

With the by-pass switch open, the test voltage equal to the rated withstand voltage across the open by-pass switch shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is applicable.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition.

Partial discharge tests are not normally required to be performed on the complete by-pass switch. However, in the case of by-pass switches using components for which a relevant IEC standard exists, and if this relevant standard requires partial discharge measurements (for example, bushings, see IEC 60137), evidence shall be produced by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 ~~does not apply and~~ is not applicable; the tests specified there are replaced ~~by~~ with the following ~~procedure~~:

Where after mechanical or environmental tests (see 7.101.1.4) the insulating properties across open contacts of a by-pass switch cannot be verified by visual inspection with sufficient reliability, a power-frequency withstand voltage test in dry condition in accordance with 7.2.12 of IEC 62271-1:2017 across the open by-pass switch shall be applied as a condition check. For ~~designs such as~~ GIS and dead-tank by-pass switches for which the insulation to earth may be impaired, a power-frequency withstand voltage test in dry condition according to 7.2.12 of IEC 62271-1:2017 to earth with the by-pass switch in closed position shall also be performed as a condition check.

For multi-unit live tank by-pass switches with identical units according to 7.102.4.2.3, the voltage test as a condition check may be performed as a unit test.

For gas enclosed vacuum by-pass switches, the voltage test as a condition check may not be sufficient. For such cases, the vacuum integrity shall be demonstrated.

Where, after by-pass and insertion tests (see 7.102.9), a voltage test is performed as a condition check, the following conditions shall apply.

For by-pass switches with an asymmetrical current path, the connections shall be reversed. The complete tests shall be carried out once for each arrangement of the connections.

These test series need to be performed only for the part of the insulation which fulfils the criteria given below.

- By-pass switches with $U_{re} \leq 72,5 \text{ kV}$ or $U_{rp} \leq 72,5 \text{ kV}$
A 1 min power-frequency voltage test shall be performed. The test voltage shall be 80 % of the value in Table 1 or Table 2, column (2) of IEC 62271-1:2017.
- By-pass switches with $72,5 \text{ kV} < U_{re} \leq 245 \text{ kV}$ or $72,5 \text{ kV} < U_{rp} \leq 245 \text{ kV}$
An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 60 % of the highest relevant value in Table 1 or Table 2, column (4) of IEC 62271-1:2017.
- By-pass switches with $300 \text{ kV} \leq U_{re} \leq 420 \text{ kV}$ or $300 \text{ kV} \leq U_{rp} \leq 420 \text{ kV}$
An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 80 % of the rated switching impulse withstand voltage given in Table 3 or Table 4 of IEC 62271-1:2017. The rated switching impulse withstand voltage shall be taken from column (4). The reference value for the condition check shall be taken from the same column.
- By-pass switches with $550 \text{ kV} \leq U_{re} \leq 800 \text{ kV}$ or $550 \text{ kV} \leq U_{rp} \leq 800 \text{ kV}$
An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 90 % of the rated switching impulse withstand voltage given in Table 3 or Table 4 of IEC 62271-1:2017. The rated switching impulse withstand voltage shall be taken from column (4) of this table. The reference value for the condition check shall be taken from the same column.

Where an impulse voltage test shall be carried out, five impulses of each polarity shall be applied across the switching device and to earth (if required). The by-pass switch shall be considered to have passed the test if no disruptive discharge occurs.

For the impulse voltage test, the synthetic testing equipment of the power laboratory may be applied. The waveshape of the impulse voltage shall be either a standard switching impulse or a waveshape according to the TRV specified for terminal fault T10, as defined in IEC 62271-

100. For the test with the waveshape according to T10, timing tolerances of ${}_{-10}^{+200}$ % on time t_3 are permitted.

NOTE Generally the insulation across the pole and to earth cannot be verified simultaneously since the insulation levels across pole are different from the insulation levels to earth. Additional condition check test ~~may~~ **can** be necessary as outlined above.

NOTE For live tank by-pass switches, the phase-to-earth insulation is generally not influenced by by-pass and insertion operations and the phase-to-earth voltage test as a condition check is generally not required. For dead-tank bypass switches, the phase-earth insulation ~~may~~ **can** be impaired by by-pass and insertion operations and the voltage test as a condition check, if required, should also be performed phase-to-earth.

NOTE If the tests are performed using the TRV impulse with a T10 waveshape, equivalence is maintained to the standard switching impulse if the following rules are applied:

- the damping of the TRV should be such that the second peak of the TRV oscillation is not higher than 80 % of the first one;
- about 2,5 ms after the peak, the actual value of the recovery voltage should be in the range of 50 % of the peak value.

NOTE Comparative tests have shown that there are almost no differences in the behaviour of circuit-breakers, both in new and in worn conditions, when testing is performed with standard switching impulses or with TRV impulses with a waveshape in accordance with terminal fault T10, respectively.

7.3 Radio interference voltage (RIV) tests

Subclause 7.3 of IEC 62271-1:2017 is applicable with the following addition.

Tests may be performed on one pole of the by-pass switch in the closed position only. During the tests, the by-pass switch shall be equipped with all accessories such as grading capacitors, corona rings, HV connectors, etc., which may influence the radio interference voltage performance.

See also 7.9.1.1

NOTE If the by-pass switch forms an integral part of the series capacitor platform and RIV tests have been performed on the platform, the RIV test on the by-pass switch is considered to be covered.

7.4 Resistance measurement ~~of the resistance of the main circuit~~

~~Subclause 6.4 of IEC 62271-1 is applicable.~~

Subclauses 7.4.1 to 7.4.3 of IEC 62271-1:2017 are applicable. Subclause 7.4.4 is replaced by the following.

7.4.4 Resistance measurement of contacts and connections in the main circuit as a condition check

7.4.4.101 Resistance measurement test procedure

When resistance measurements are called for as a condition check after a specific test, the following procedure shall be applied.

The resistance across the by-pass switch contacts shall be measured before the test. The measuring test points shall be the nearest accessible points to and on either side of the contacts. An average value of the resistance shall be calculated based on three measurements. If possible, one no-load open and close operation cycle should be made between each of the measurements. If no-load operations cannot be made, the 3 measurements shall be made without no-load operations of the by-pass switch.

NOTE 1 It is recognized that for some tests, it is not practical (e.g. if gas handling is required in between the measurements) nor possible (e.g. during continuous current test because of the presence of temperature sensors within the by-pass switch chamber(s)) to make any no-load operations between each of the three resistances measurements.

The measurements shall be made with DC at full rated continuous current (-20 % to 0 %) if less than or equal to 50 A or any convenient value of current between (and including) 50 A and the rated continuous current if it is higher than 50 A.

NOTE 2 In some designs, it can be only practical that several connections and/or contacts are measured in series in the main circuit or even the complete poles of a by-pass switch are measured during type testing.

After the completion of the test, the resistance shall be measured again using the identical procedure to that used for the resistance measurements made prior to the tests. Before this resistance measurement, some conditioning of the contacts is acceptable based on the manufacturer's recommendations such as no-load operation cycles or the application of rated continuous current for some time.

The resistance measurements before and after shall be performed at ambient temperature with a maximum difference of 10 K between the measurements. The resistance increase is calculated by the difference between the average value of the measurements before and after the test.

7.4.4.102 By-pass making and insertion tests

For by-pass switches having sealed-for-life interrupters, the resistance condition check of the test sample after completion of by-pass making and insertion tests is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.101 is not greater than 100 %. For other by-pass switch types, visual inspection of the contact system is usually sufficient as stated in 7.102.9.2.

~~6.5 Temperature-rise tests~~

~~6.5.1 Conditions of the by-pass switch to be tested~~

~~Subclause 6.5.1 of IEC 62271-1 is applicable.~~

~~6.5.2 Arrangement of the equipment~~

~~Subclause 6.5.2 of IEC 62271-1 is applicable.~~

~~6.5.3 Measurement of the temperature and the temperature rise~~

~~Subclause 6.5.3 of IEC 62271-1 is applicable.~~

~~6.5.4 Ambient air temperature~~

~~Subclause 6.5.4 of IEC 62271-1 is applicable.~~

~~6.5.5 Temperature-rise tests of the auxiliary and control equipment~~

~~Subclause 6.5.5 of IEC 62271-1 is applicable.~~

~~6.5.6 Interpretation of the temperature-rise tests~~

~~Subclause 6.5.6 of IEC 62271-1 is applicable.~~

7.5 Continuous current tests

7.5.1 Conditions of the test object

Subclause 7.5.1 of IEC 62271-1:2017 is applicable.

7.5.2 Arrangement of the equipment

Subclause 7.5.2 of IEC 62271-1:2017 is applicable.

7.5.3 Test current and duration

Subclause 7.5.3 of IEC 62271-1:2017 is applicable.

7.5.4 Temperature measurement during test

Subclause 7.5.4 of IEC 62271-1:2017 is applicable.

7.5.5 Resistance of the main circuit

Subclause 7.5.5 of IEC 62271-1:2017 is applicable.

7.5.6 Criteria to pass test

Subclause 7.5.6 of IEC 62271-1:2017 is applicable.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the by-pass switch and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is applicable.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

~~**6.6.3 Behaviour of the by-pass switch during test**~~

~~Subclause 6.6.3 of IEC 62271-1 is applicable.~~

7.6.4 Conditions of the by-pass switch after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable.

7.7 Verification of the ~~degree of~~ protection

7.7.1 Verification of the IP coding

Subclause 7.7.1 of IEC 62271-1:2017 is applicable ~~to all parts of by-pass switches that are accessible in normal service.~~

7.7.2 ~~Mechanical impact test (Verification of the IK coding)~~

Subclause 7.7.2 of IEC 62271-1:2017 is applicable.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

~~In the case of a vacuum by-pass switch, the tightness verification of the vacuum insulation shall be carried out by means of a power frequency test according to 6.2.11 or an equivalent test.~~

7.9 Electromagnetic compatibility tests (EMC)

7.9.1 Emission tests

7.9.1.1 Emission tests from the main circuits (radio interference voltage test, RIV)

Subclause 7.9.1.1 of IEC 62271-1:2017 is applicable with the following ~~addition~~ modification:

Tests may be performed on one pole of the by-pass switch in the closed position only. During the tests, the by-pass switch shall be equipped with all accessories such as grading capacitors, corona rings and HV connectors, which may influence the radio interference voltage performance.

NOTE If the by-pass switch forms an integral part of the series capacitor platform and RIV tests have been performed on the platform, the RIV test on the by-pass switch is considered to be covered.

7.9.1.2 Emission tests from the auxiliary and control circuits

Subclause 7.9.1.2 of IEC 62271-1:2017 is applicable.

7.9.2 Immunity tests on auxiliary and control circuits

Subclause 7.9.2 of IEC 62271-1:2017 is applicable.

7.9.3 Additional EMC tests on auxiliary and control circuits

Subclause 7.9.3 of IEC 62271-1:2017 is applicable with the following note:

NOTE This clause is applicable to both, complete electronic boards (e.g. control modules) and devices containing at least one electronic component (e.g. electronic timing relays).

7.9.3.1 General

Subclause 7.9.3.1 of IEC 62271-1:2017 is applicable.

7.9.3.2 Ripple on DC input power port immunity test

~~Subclause 6.9.2 of IEC 62271-1 is applicable with the following addition.~~

If no electronic components are used in the control unit and the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete by-pass switch equipped with its entire control unit, the ripple on DC input power port immunity test ~~according to subclause 6.9.2 of IEC 62271-1~~ is regarded as covered and additional tests shall be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

Where electronic components are used, tests according to subclause 7.9.2 of IEC 62271-1:2017 on the individual components are sufficient.

~~NOTE This subclause is applicable to both, complete electronic boards (e.g. control modules) and devices containing at least one electronic component (e.g. electronic timing relays).~~

7.9.3.3 Voltage dips, short interruptions and voltage variations on input power port immunity tests

Subclause 7.9.3.3 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

7.10.1 General

Subclause 7.10.1 of IEC 62271-1:2017 is applicable.

7.10.2 Functional tests

Subclause 7.10.2 of IEC 62271-1:2017 is applicable with the following addition.

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete by-pass switch equipped with its entire control unit, the functional tests according to 7.10.2 of IEC 62271-1:2017 are regarded as covered and additional tests shall be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

~~6.10.3 Electrical continuity of earthed metallic parts test~~

~~Subclause 6.10.3 of IEC 62271-1 is applicable.~~

7.10.3 Verification of the operational characteristics of auxiliary contacts

Subclause 7.10.3 of IEC 62271-1:2017 is applicable.

7.10.4 Environmental tests

Subclause 7.10.4 of IEC 62271-1:2017 is applicable with the following addition.

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 and the low and high temperature tests in accordance with 7.101.3 ~~and, if applicable, the humidity test in accordance with 6.101.4~~ are performed on the complete by-pass switch equipped with its entire control unit ~~or in case of the humidity test on the control equipment respectively~~, the environmental tests according to 7.10.4 of IEC 62271-1:2017 is regarded as covered and additional tests can be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

NOTE Seismic tests are not covered. If a seismic test is requested, it should be performed by agreement between manufacturer and user.

7.10.5 Dielectric test

Subclause 7.10.5 of IEC 62271-1:2017 is applicable

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

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Mechanical and environmental tests

7.101.1 Miscellaneous provisions for mechanical and environmental tests

7.101.1.1 Mechanical characteristics

~~At the beginning of the type tests, the mechanical characteristics of the by-pass switch shall be established, for example, by recording no-load travel curves. This may be done also by the use of characteristic parameters, for example, momentary speed at a certain stroke etc. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the by-pass switch. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, by-passing and insertion type tests behave mechanically in a similar way. The test in which this reference is gained is referred to as reference no-load test and the curves or other parameters resulting from it as reference mechanical characteristics. The reference no-load test may be taken from any appropriate no-load test being part of an individual type test.~~

~~The following operating characteristics shall be recorded:~~

- ~~— mechanical characteristics for opening and closing operation;~~
- ~~— closing time;~~
- ~~— opening time.~~

At the beginning of the type tests, the mechanical characteristics of the by-pass switch shall be established. The mechanical characteristics shall be measured similarly as circuit-breakers, 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 by-pass switch. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, by-pass making current and insertion 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 C operation and a single O 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 p_{me} for by-passing, insertion and insulation.

~~The opening time and the closing time recorded in the reference no-load test shall be used as reference closing and reference opening time. The allowable deviations from these reference times correspond to the tolerances given by the manufacturer when performed under the same conditions as used for the procedure to produce the reference mechanical characteristics.~~

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

7.101.1.2 Component tests

When testing of a complete by-pass switch is not practicable, component tests may be accepted as type tests. The manufacturer shall determine the components that are suitable for testing.

Components are separate functional sub-assemblies that can be operated independently of the complete by-pass switch (for example, pole, by-pass unit, operating mechanism).

When component tests are made, the manufacturer shall prove that the mechanical and environmental stresses on the component during the tests are not less than those applied to the same component when the complete by-pass switch is tested. Component tests shall cover all different types of components of the complete by-pass switch, provided that the particular test is applicable to the component. The conditions for the component type tests shall be the same as those which could be employed for the complete by-pass switch.

Parts of auxiliary and control equipment that have been manufactured in accordance with relevant standards shall comply with these standards. The proper function of such parts in connection with the function of the other parts of the by-pass switch shall be verified.

7.101.1.3 Characteristics and settings of the by-pass switch to be recorded before and after the tests

Before and after the tests, the following operating characteristics or settings shall be recorded and evaluated:

- a) closing time;
- b) opening time;
- c) time spread between units of one pole;
- d) time spread between poles (if multi-pole tested);
- e) recharging time of the operating device;
- f) consumption of the control circuit;
- g) consumption of the tripping devices, possible recording of the current of the releases;
- h) duration of opening and closing command impulse;
- i) tightness, if applicable;
- j) gas densities or pressures, if applicable;
- k) resistance of the main circuit;
- l) time-travel chart;
- m) other important characteristics or settings as specified by the manufacturer.

The above operating characteristics shall be recorded at

- rated supply voltage and ~~rated~~ filling pressure for operation,
- maximum supply voltage and maximum ~~filling~~ pressure for operation,
- maximum supply voltage and minimum functional pressure for operation,
- minimum supply voltage and minimum functional pressure for operation,
- minimum supply voltage and maximum ~~filling~~ pressure for operation.

7.101.1.4 Condition of the by-pass switch during and after the tests

During and after the tests, the by-pass switch shall be in a condition such that it is capable of operating normally, carrying its rated normal current, by-passing its rated by-pass making current and inserting its rated insertion current and withstanding the voltage values according to its rated insulation levels.

In general, these requirements are fulfilled if

- during the tests, the by-pass switch operates on command and does not operate without command;
- after the tests, the characteristics measured according to 7.101.1.3 are within the tolerances given by the manufacturer;
- after the tests, all parts, including contacts, do not show undue wear;
- after the tests, coated contacts are such that a layer of coating material remains at the contact area. If this is not the case, the contacts shall be regarded as bare and the test requirements are fulfilled only if the temperature rise of the contacts during the ~~temperature rise~~ continuous current test (according to 7.5) does not exceed the value permitted for bare contacts;
- during and after the tests, any distortion of mechanical parts is not such that it adversely affects the operation of the by-pass switch or prevents the proper fitting of any replacement part;
- after the tests, the insulating properties of the by-pass switch in the open position shall be in essentially the same condition as before the tests. Visual inspection of the by-pass switch after the tests is usually sufficient for verification of the insulating properties. In the case of by-pass switches with sealed-for-life by-pass units, a voltage test as a condition check in accordance with 7.2.12 may be necessary;
- 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 14 of IEC 62271-1:2017 by more than 10 K.

7.101.1.5 Condition of the auxiliary and control equipment during and after the tests

During and after the tests, the following conditions for the auxiliary and control equipment shall be fulfilled:

- during the tests, care shall be taken to prevent undue heating;
- during the tests, a set of contacts (both make and break auxiliary contacts) shall be arranged to switch the current of the circuits to be controlled (see 6.4);
- during and after the tests, the auxiliary and control equipment shall fulfil its functions;
- during and after the tests, the capability of the auxiliary circuits, the auxiliary switches and of the control equipment shall not be impaired. In case of doubt, the tests according to 7.10.3 of IEC 62271-1:2017 shall be performed;
- during and after the tests, the contact resistance of the auxiliary switches shall not be affected adversely. The temperature rise when carrying the rated current shall not exceed the specified values (see Table 14 of IEC 62271-1:2017).

7.101.2 Mechanical operation test at ambient air temperature

7.101.2.1 General

The mechanical operation test shall be made at the ambient air temperature of the test location. The ambient air temperature shall be recorded in the test report. Auxiliary equipment forming part of the operating devices shall be included.

The mechanical operation test shall consist of 2 000 operating sequences.

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 any other kind of maintenance is allowed.

NOTE A by-pass switch design may can be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.9 and 5.10. These variants do not need to be tested if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

7.101.2.2 Condition of the by-pass switch before the test

The by-pass switch for test shall be mounted on its own support and its operating mechanism shall be operated in a specified manner. It shall be tested according to its type as follows.

A three-pole by-pass switch actuated by a single operating device and/or with all poles mounted on a common frame shall be tested as a complete unit.

Tests shall be conducted at the rated filling pressure for by-passing and insertion according to 7.101.1.3, item j).

A three-pole by-pass switch in which each pole or even each column is actuated by a separate operating device shall be tested preferably as a complete three-pole by-pass switch. However, for convenience, or owing to limitations of the dimensions of the test bay, one single-pole unit of the by-pass switch may be tested, provided that it is equivalent to, or not in a more favourable condition than, the complete three-pole by-pass switch over the range of tests, for example in respect of:

- reference mechanical travel characteristics,
- power and strength of closing and opening mechanism,
- the rigidity of the structure.

7.101.2.3 Description of the test on class M1 by-pass switches

The by-pass switch shall be tested in accordance with Table 6.

Table 6 – Number of operating sequences

Operating sequence	Supply voltage and operating pressure	Number of operating sequences
$O - t_a - C - t_a$	Minimum	500
	Rated	500
	Maximum	500
$C - t - OC - t_a - O - t_a$	Rated	250
O = opening; C = closing; OC = an opening operation followed immediately (i.e., without any intentional time-delay) by a closing operation; t_a = time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the by-pass switch (this time can be different according to the type of operation); t = 0,3 s for by-pass switches intended for rapid auto-reopening, if not otherwise specified.		

7.101.2.4 Extended mechanical endurance tests on class M2 by-pass switches for special service requirements (multi-segmented series capacitor banks)

For special service requirements in the case of frequently operated by-pass switches (for example in multi-segmented series capacitor banks), extended mechanical endurance tests may be carried out, as follows.

The tests shall be made according to 7.101.1, 7.101.2.1, 7.101.2.2 and 7.101.2.3 with the following addition:

- the tests shall consist of 10 000 operating sequences comprising five times the test series specified in Table 6;
- 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. ~~Change of contacts is not~~ Only the change of parts outside of the main circuit, which are not being part of the kinematic chain, and are listed in the programme of maintenance, is permitted;
- the programme of maintenance during the tests shall be defined by the manufacturer before the tests are recorded in the test report.

7.101.2.5 Acceptance criteria for the mechanical operation tests

The criteria given below apply for mechanical operation tests on class M1 and class M2 by-pass switches.

- a) Before and after the total test programme, the following operations shall be performed:
- five open-close operations at the rated supply voltage of closing and opening devices and of auxiliary and control circuits and the ~~rated~~ filling pressure for operation;
 - five open-close operations at the minimum supply voltage of closing and opening devices and of auxiliary and control circuits and the minimum pressure for operation;
 - five open-close operations at the maximum supply voltage of closing and opening devices and of auxiliary and control circuits and the maximum pressure for operation.

During these operations, the operating characteristics (see 7.101.1.3) shall be recorded and evaluated. It is not necessary to publish all the oscillograms recorded. However, at

least one oscillogram for each set of conditions given above shall be included in the test report.

In addition, the following checks and measurements shall be performed (see 11.101.2):

- measurements of characteristic operating fluid pressures and consumption during operations, if applicable;
- verification of the rated operating sequence;
- checks of certain specific operations, if applicable.

The variation between the mean values of each parameter measured before and after the extended mechanical endurance tests shall be within the tolerances given by the manufacturer.

- b) After each series of 2 000 operating sequences, the operating characteristics a), b), c), d), e) and l) in 7.101.1.3 shall be recorded.
- c) After the total test programme, the condition of the by-pass switch shall be in accordance with 7.101.1.4.

7.101.3 Low and high temperature tests

7.101.3.1 General

The two tests need not be performed in succession, and the order in which they are made is arbitrary. For ~~class 10 °C outdoor~~ by-pass switches not subjected to a temperature lower than -10 °C , no low temperature test is required.

For single enclosure by-pass switches or multi-enclosure by-pass switches with a common operating device, three-pole tests shall be made. For multi-enclosure by-pass switches with independent poles, testing of one complete pole is permitted.

Owing to limitations of the test facilities, multi-enclosure type by-pass switches may be tested using one or more of the following alternatives, provided that the by-pass switch, in its testing arrangement, is not in a more favourable condition than the normal condition for mechanical operation (see 7.101.2.2):

- a) reduced length of phase-to-earth insulation;
- b) reduced pole spacing;
- c) reduced number of modules.

If heat sources are required, they shall be in operation.

Liquid or gas supplies for by-pass switch operation shall be at the test air temperature unless the by-pass switch design requires a heat source for these supplies.

No maintenance, replacement of parts, lubrication or readjustment of the by-pass switch is permissible during the tests.

NOTE In order to determine the material temperature characteristics, ageing, etc., tests of longer duration than those specified in the following subclauses ~~may~~ can be necessary.

As an alternative approach to the methods given in this document, a manufacturer may establish compliance with performance requirements for an established by-pass switch family by documenting satisfactory by-pass switch field experience in at least one location with ambient air temperatures frequently at, or above, the specified maximum ambient air temperature of 40 °C , and at least one location with satisfactory field experience in specified minimum ambient air temperature, depending on the ~~class of by-pass switch~~ ambient temperature range (see Clause 4 of IEC 62271-1:2017).

The by-pass switch has passed the test if the conditions stated in 7.101.1.4 and 7.101.1.5 are fulfilled. Furthermore, the conditions in 7.101.3.3 and 7.101.3.4 shall be fulfilled and the

leakage rates recorded shall not exceed the limits given in Table 15 of IEC 62271-1:2017. In the test report, the testing conditions and the condition of the by-pass switch before, during and after the test shall be reported. The recorded quantities shall be presented in an appropriate way and the oscillograms taken shall be shown. To reduce the number of oscillograms in the test report, it is allowed to show a single representative oscillogram of every relevant type of operation under each specified testing condition.

Vacuum by-pass switches are excluded from the tightness verification tests during the high and low temperature tests. The integrity of the vacuum shall be verified by a power frequency voltage (or equivalent) test after the high and low temperature tests. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF₆, the tightness verification tests during the high and low temperature tests shall also be performed on this enclosure.

NOTE A by-pass switch design may be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.9 and 5.10. These variants do not need to be tested if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

For dead-tank by-pass switches equipped with tank heater(s) for the purpose of avoiding gas liquefaction during low ambient temperature conditions, the test sequence prescribed in 7.101.3.3 is not sufficient to demonstrate that the gas heating element is properly designed to avoid gas liquefaction during low ambient temperature conditions. For such by-pass switches, the test sequence prescribed in 7.101.3.3 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 by-pass switch. The wind shall be applied from step c) to j) of the test procedure described in 7.101.3.3.

The wind speed shall be measured by at least 5 positions along the longitudinal axis of the by-pass switch and at a distance of 0,5 m ($\pm 0,1$ m) to the outer by-pass switch tank (see Figure 5). Each measurement shall be spaced by approximately 0,3 m. The number of measurements shall be such that the measurement length exceeds the by-pass switch 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.

Dimensions in metres

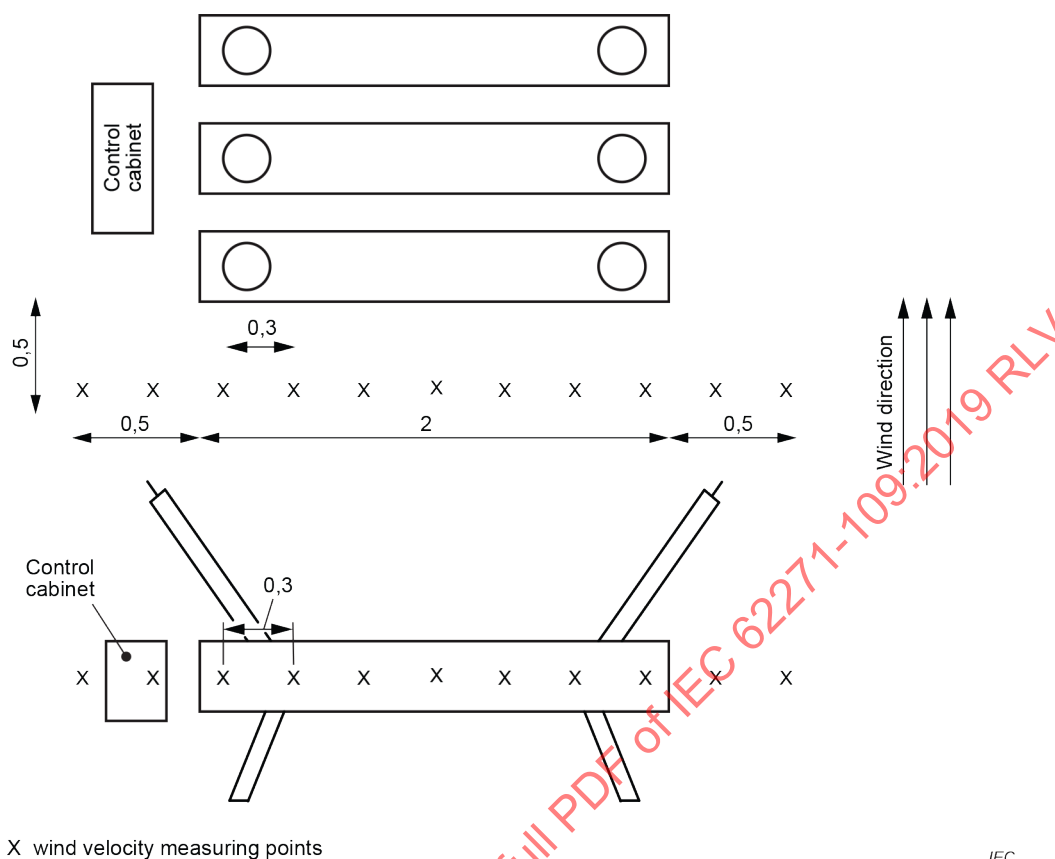


Figure 5 – Example of wind velocity measurement

It is recognised that the wind speed measurements in the relatively small climatic room (in relation to the by-pass switch 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 into 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 a gas heater, at low temperature T_L equal to or lower than the lowest temperature measured during the first test on the by-pass switch 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.

7.101.3.2 Measurement of ambient air temperature

The ambient air temperature of the immediate test environment shall be measured at half the height of the by-pass switch and at a distance of 1 m from the by-pass switch.

The maximum temperature deviation ~~over~~ across the height of the by-pass switch shall not exceed 5 K.

7.101.3.3 Low temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 6a.

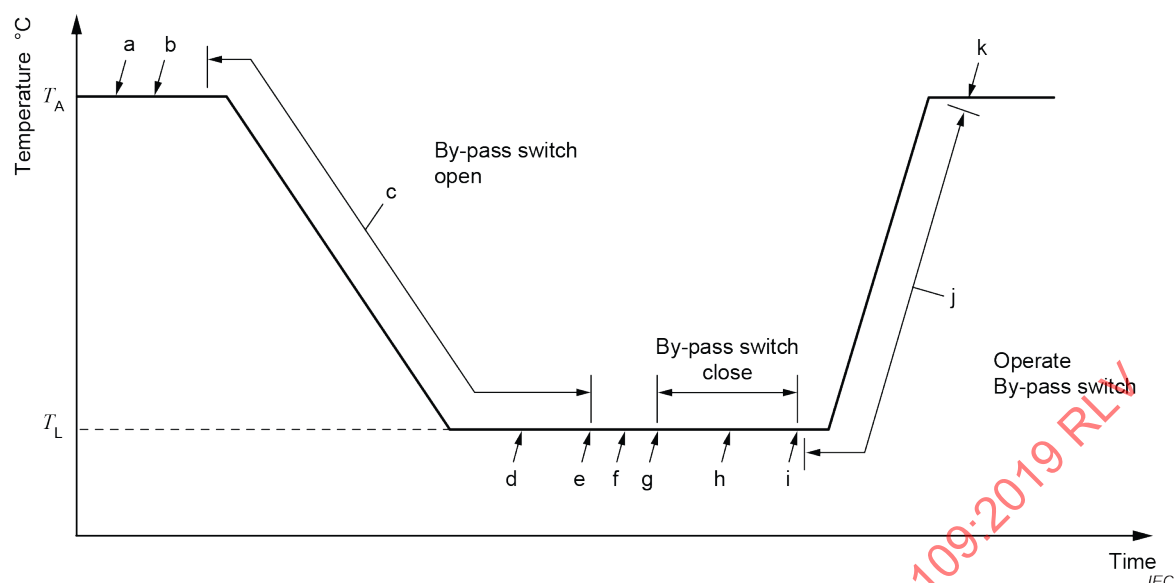


Figure 6a – Low temperature test

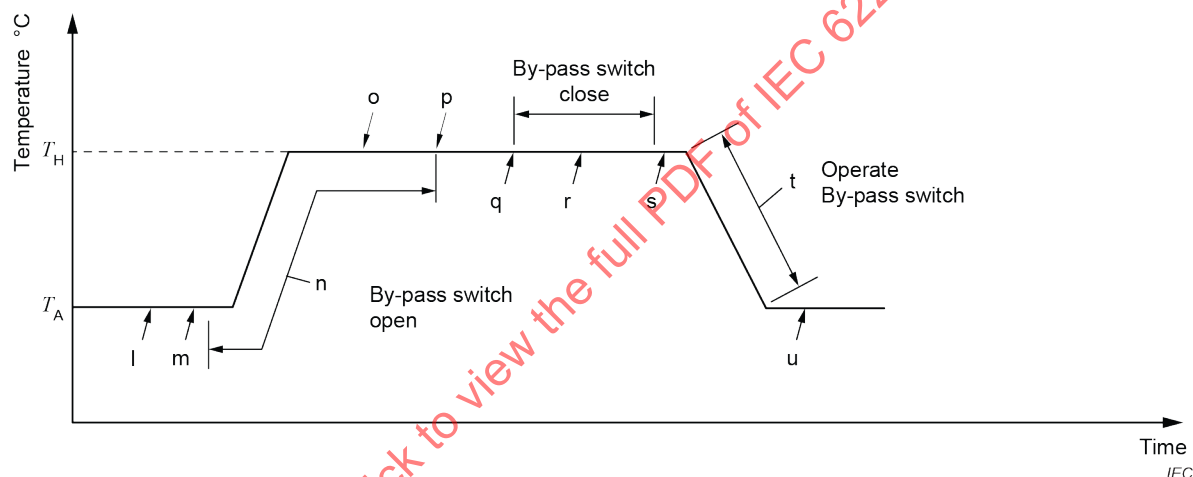


Figure 6b – High temperature test

NOTE Letters a to u identify application points of tests specified in 7.101.3.3 and 7.101.3.4.

Figure 6 – Test sequences for low and high temperature tests

If the low temperature test is performed immediately after the high temperature test, the low temperature test can proceed after completion of item u) of the high temperature test. In this case items a) and b) are omitted.

- The test by-pass switch shall be adjusted in accordance with the manufacturer's instructions.
- Characteristics and settings of the by-pass switch shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.8.
- With the by-pass switch in the open position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the ~~class~~ specified minimum ambient temperature of the by-pass switch as given in Clause 4 of IEC 62271-1:2017. The by-pass switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_L .
- During the 24 h period with the by-pass switch in the open position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the

ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.

NOTE A tightness test is applicable if gases are used for operation, by-passing and insertion and/or insulation. In case of vacuum by-pass switch, no tightness test is required. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF₆, the tightness verification tests have to be performed on this enclosure.

- e) After 24 h at temperature T_L , the by-pass switch shall be closed and opened at rated values of supply voltage and operating pressure. The closing time and the opening time shall be recorded to establish low temperature operating characteristics. Contact velocity shall be recorded if feasible.
- f) The low temperature behaviour of the by-pass switch and its alarms and lock-out systems shall be verified by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . During this interval, occurrence of the alarm is acceptable but lock-out is not. At the end of the interval t_x , a closing order, at rated values of supply voltage and operating pressure, shall be given. The by-pass switch shall then close. The closing time shall be recorded (and the mechanical travel characteristics measured, if feasible) to allow assessment of the by-passing capability.

The manufacturer shall state the value of t_x (not less than 2 h) up to which the by-pass switch is still operable without auxiliary power to the heaters. In the absence of such a statement, the ~~preferred~~ default value shall be equal to 2 h.

NOTE The measurement of the mechanical characteristics is feasible if a location is accessible for the travel sensor to be used.

- g) The by-pass switch shall be left in the closed position for 24 h.
- h) During the 24 h period with the by-pass switch in the closed position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.
- i) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the by-pass switch at temperature T_L . At least a 3 min interval shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded to establish low temperature operating characteristics. Contact velocity shall be recorded, if feasible. Following the first opening operation (O) and the first closing operation (C), three OC operating cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing O – t_a – C – t_a operating sequences (t_a is defined in Table 5).
- j) After completing the 50 opening and 50 closing operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.

During the temperature transition period, the by-pass switch shall be subjected to alternate O – t_a – C – t_a – O and C – t_a – O – t_a – C operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences shall be made at 30 min intervals so that the by-pass switch will be in open and closed positions for 30 min periods between the operating sequences.

- k) After the by-pass switch has stabilized thermally at ambient air temperature T_A , a re-check shall be made of the by-pass switch settings, operating characteristics and tightness as in items a) and b) for comparison with the initial characteristics.

The accumulated leakage during the complete low temperature test sequence from item b) to item j) shall not be such that lock-out pressure is reached (reaching alarm pressure is allowed).

7.101.3.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 6b.

If the high temperature test is performed immediately after the low temperature test, the high temperature test can proceed after completion of item j) of the low temperature test. In this case, items l) and m) below are omitted.

- l) The test by-pass switch shall be adjusted in accordance with the manufacturer's instructions.
- m) Characteristics and settings of the by-pass switch shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.8.
- n) With the by-pass switch in the open position, the air temperature shall be increased to the appropriate, maximum ambient air temperature (T_H), according to the specified upper limit of ambient air temperature as given in Clause 4 of IEC 62271-1:2017. The by-pass switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_H .

NOTE 1 The influence of solar radiation is not considered.

- o) During the 24 h period with the by-pass switch in the open position at the temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.

NOTE A tightness test is applicable if gases are used for operation, by-passing and insertion and/or insulation. In case of vacuum by-pass switches, no tightness test is required. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF_6 , the tightness verification tests have to be performed on this enclosure.

- p) After 24 h at the temperature T_H , the by-pass switch shall be closed and opened at rated values of supply voltage and operating pressure. The closing time and the opening time shall be recorded to establish high temperature operating characteristics. Contact velocity shall be recorded if feasible.

NOTE 2 The measurement of the mechanical characteristics is feasible if a location is accessible for the travel sensor to be used.

- q) The by-pass switch shall be closed and left closed for 24 h at the temperature T_H .
- r) During the 24 h period with the by-pass switch in the closed position at the temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.
- s) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the by-pass switch at the temperature T_H . An interval of at least 3 min shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded to establish high temperature operating characteristics. Contact velocity shall be recorded if feasible.

Following the first opening operation (O) and the first closing operation (C), three OC operation cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing $O - t_a - C - t_a$ operating sequences (t_a is defined in Table 5).

- t) After completing the 50 opening and 50 closing operations, the air temperature shall be decreased to ambient air temperature T_A , at a rate of change of approximately 10 K/h.

During the temperature transition period, the by-pass switch shall be subjected to alternate $O - t_a - C - t_a - O$ and $C - t_a - O - t_a - C$ operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences shall be made at 30 min intervals so that the by-pass switch will be in the closed and open positions for 30 min periods between the operating sequences.

- u) After the by-pass switch has stabilized thermally at ambient air temperature T_A , a re-check shall be made of the by-pass switch settings, operating characteristics and tightness as in items l) and m) for comparison with the initial characteristics.

The accumulated leakage during the complete high temperature test sequence from item l) to item u) shall not be such that lock-out pressure is reached (reaching alarm pressure is allowed).

7.101.4 Humidity test

The humidity test does not apply to by-pass switches.

7.101.5 Test to prove the operation under severe ice conditions

The test under severe ice conditions is applicable only to by-pass switches having moving external parts and for which a class of 10 mm or 20 mm of ice thickness is specified. The test shall be performed under the conditions described in IEC 62271-102:2018.

~~6.101.6 Static terminal load test~~

~~6.101.6.1 General~~

~~If the manufacturer can prove by means of calculations that the by-pass switch can withstand the specified stresses, then test needs not be performed.~~

~~The static terminal load test is performed to demonstrate that the by-pass switch operates correctly when loaded by stresses resulting from ice, wind and connected conductors.~~

~~Ice coating and wind pressure on the by-pass switch shall be in accordance with 2.1.2 of IEC 62271-1.~~

~~Some examples of forces due to flexible and tubular connected conductors (not including wind or ice load or the dynamic loads on the by-pass switch itself) are given as a guide in Table 5.~~

~~The tensile force due to the connected conductors is assumed to act at the outermost end of the by-pass switch terminal.~~

~~For simultaneous action of ice, wind and connected conductors, the resultant terminal forces, F_{sr1} , F_{sr2} , F_{sr3} and F_{sr4} respectively (see Figure 5) are defined as rated static terminal loads.~~

~~6.101.6.2 Tests~~

~~The tests should be performed at the ambient air temperature of the test room.~~

~~The tests shall be made on at least one complete pole of the by-pass switch. If the manufacturer can prove that there is no interaction between different columns in the pole, it is sufficient to test only one column. For by-pass switches that are symmetrical about the pole unit vertical centreline, only one terminal need be tested with the rated static terminal load. For by-pass switches which are not symmetrical, each terminal shall be tested.~~

~~Two testing methods are available.~~

- ~~a) The tests shall be carried out with the resultant forces F_{sr1} , F_{sr2} , F_{sr3} and F_{sr4} of the 3 components: vertical, longitudinal and transversal (as defined in Figure 5). The following tests shall be performed:~~

~~— Test 1 with: $F_{sr1} = F_{th A} + F_{th B1} + F_{tv C2} + F_{wh}$~~

~~— Test 2 with: $F_{sr2} = F_{th A} + F_{th B1} + F_{tv C1} + F_{wh}$~~

~~— Test 3 with: $F_{sr3} = F_{th A} + F_{th B2} + F_{tv C2} + F_{wh}$~~

~~— Test 4 with: $F_{sr4} = F_{thA} + F_{thB2} + F_{tvC1} + F_{wh}$~~

~~— For convenience of testing, the order of the individual tests is arbitrary. If the structure of the by-pass switch is symmetrical to the longitudinal axis of its by-pass (or insertion) units, either tests number 2 and 4 or tests number 1 and 3 may be omitted.~~

~~b) As an alternative, the tests may be made separately, applying the forces subsequently as follows:~~

~~— with a horizontal force, F_{shA} , applied in longitudinal axis of the terminal (directions A_1 and A_2 in Figure 5);~~

~~— with a horizontal force, F_{shB} , applied in two directions successively at 90° from the longitudinal axis of the terminals (directions B_1 and B_2 in Figure 5);~~

~~— with a vertical force, F_{sv} , applied in two directions successively (directions C_1 and C_2 in Figure 5).~~

~~In case of a three pole by-pass switch with a common base frame, the middle pole should be tested.~~

~~To avoid the need to apply a special force representing the force of wind acting at the by-pass switch's centre of application of pressure, this wind load may be applied at the terminal (see Figure 5) and reduced in magnitude in proportion to the longer lever arm (the bending moment at the lowest part of the by-pass switch should be the same).~~

~~Before and after each of the individual terminal load tests two operating cycles (OC operation) shall be performed. For this purpose the by-pass switch may need to be pressurized. For safety reasons the pressure may be at any appropriate value.~~

~~The test is considered to be satisfactory if the by-pass switch operates normally when the mechanical load is applied. This is fulfilled if the travel of the contact, the opening and the closing time after the series of tests show no significant change from the values recorded before the tests; the rules given in 6.101.1.1 and Annex G shall be applied accordingly.~~

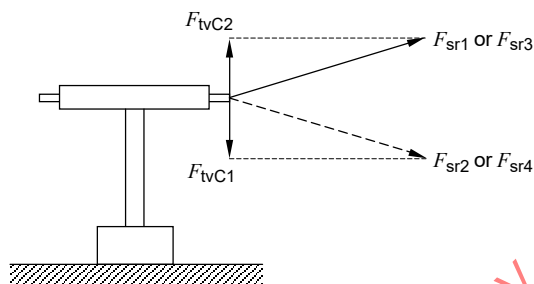
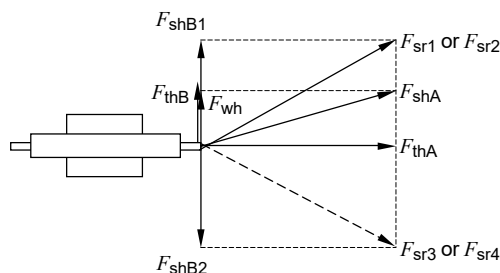
~~NOTE As the pressure in the by-pass switch for the static terminal load tests may deviate from the value prescribed for the test specified in 6.101.1.1 and in Annex G, a direct comparison of the mechanical parameters recorded during the static terminal load tests with the reference mechanical characteristics is not practicable. However, the rules given in 6.101.1.1 and Annex G may be applied in an adapted way.~~

~~After the tests, no leakage or deterioration of the seals shall be noticed.~~

Table 5 — Examples of static horizontal and vertical forces for static terminal load test

Rated voltage range to earth U_{Fe} kV	Rated current range I_r A	Static horizontal force F_{th}		Static vertical force (vertical axis upward and downward) F_{tv} N
		Longitudinal F_{thA} N	Transversal F_{thB} N	
52—72,5	800—1 250	500	400	500
52—72,5	1 600—2 500	750	500	750
100—170	1 250—2 000	1 000	750	750
100—170	2 500—4 000	1 250	750	1 000
245—362	1 600—4 000	1 250	1 000	1 250
420—800	2 000—4 000	1 750	1 250	1 500

By-pass switch with more than one by-pass and insertion unit

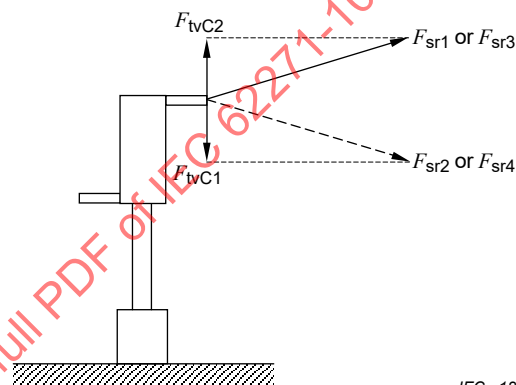
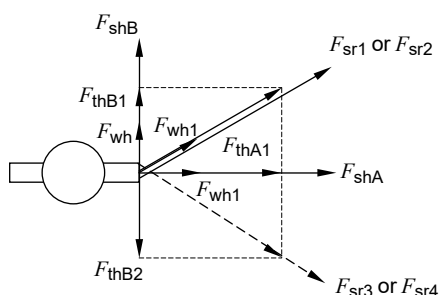


$$F_{shB1} = F_{thB1} + F_{wh} \text{ and } F_{shB2} = F_{thB2} + F_{wh}$$

$$F_{tv} = F_{sv} \text{ (see 6.101.6.2)}$$

IEC 1863/08

By-pass switch with one by-pass and insertion unit



IEC 1864/08

Test to item 6.101.6.2 a): F_{wh} acts in direction of the resultant of F_{thB} and F_{thA}

Test to item 6.101.6.2 b): F_{wh} acts in direction F_{thB} and F_{thA}

Key

F_{thA} _____ tensile force due to connected conductor (direction A)

F_{thB} _____ tensile force due to connected conductor (direction B)

F_{tv} _____ tensile vertical force due to connected conductor (direction C)

F_{wh} _____ horizontal force on by-pass switch due to wind pressure on ice-coated by-pass switch

F_{shA} , F_{shB} _____ horizontal forces resulting from F_{thA} , F_{thB} and F_{wh}

F_{sr1} , F_{sr2} , F_{sr3} , F_{sr4} _____ rated static terminal loads (resultant forces)

NOTE 1 Refer to Figure 6 for directions A, B and C.

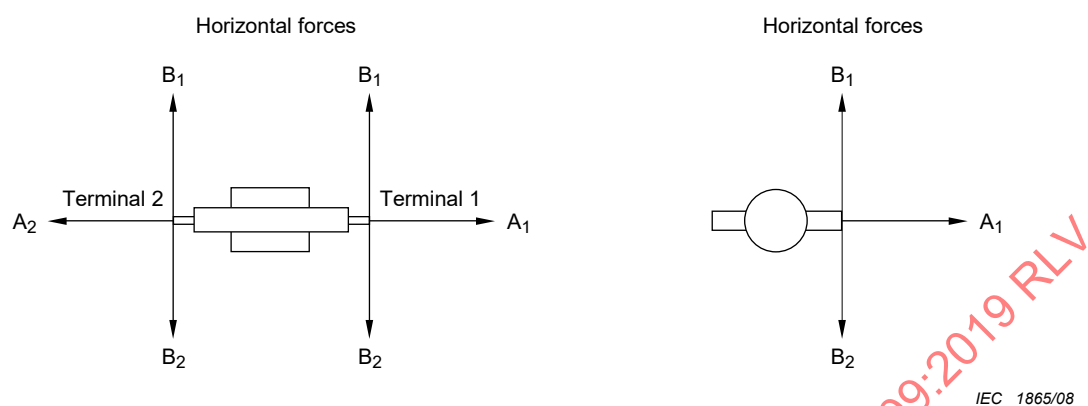
NOTE 2 The index letter "s" characterises testing values.

	Horizontal	Vertical	Remark
Forces due to dead weight, wind and ice on connected conductor	F_{thA} , F_{thB}	F_{tv}	According to Table 5
Forces due to wind and ice on by-pass switch ^a	F_{wh}	0	Calculated by manufacturer
^a The horizontal force on the by-pass switch, due to wind, may be moved from the centre of pressure to the terminal and reduced in magnitude in proportion to the longer lever arm. (The bending moment at the lowest part of the by-pass switch should be the same.)			

Figure 5 – Static terminal load forces

~~By-pass switch with more than one~~ ~~By-pass switch with one~~

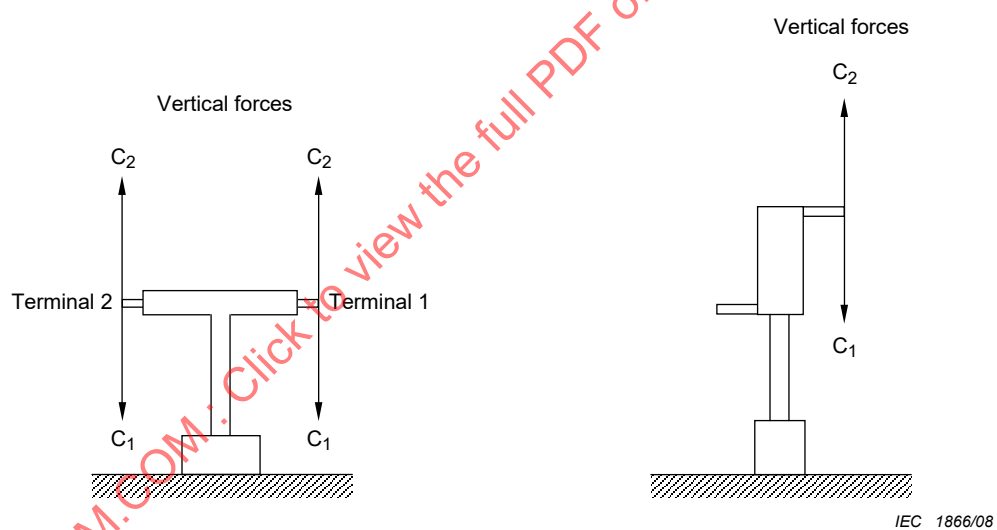
~~by-pass and/or insertion units~~ ~~by-pass and/or insertion units~~



Force directions: A_1 , B_1 , B_2 for terminal 1

Force directions: A_2 , B_1 , B_2 for terminal 2

Horizontal test forces: F_{ehA} and F_{ehB} (see Figure 5)



Force directions: C_1 , C_2 for terminal 1

Force directions: C_1 , C_2 for terminal 2

Vertical test forces (both directions): F_{sv} (see Figure 5)

NOTE For by-pass switches that are symmetrical about the pole unit vertical centreline, only one terminal needs to be tested.

Figure 6 — Directions for static terminal load tests

7.102 Miscellaneous provisions for by-pass making and insertion tests

7.102.1 General

The following subclauses are applicable to all by-pass making and insertion tests.

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 by-pass (or insertion) unit guaranteeing the rated operating sequence (for example the minimum functional pressure for by-passing and insertion in case of a gas by-pass switch).

By-pass switches shall be capable of by-passing all currents up to and including the rated by-pass making current. In addition, by-pass switches shall be capable of inserting all currents up to and including the rated by-pass insertion current.

This is demonstrated when the by-pass switch is subjected to the particular by-pass making current and insertion current tests outlined in this document.

By-pass making current and insertion current tests are normally performed in single-phase on a complete pole, see also 7.102.4.1.

The by-pass making current test is normally performed with a single power source (pre-charged capacitor bank) while the insertion current test may be performed with several sources where all of the current, or a major part of it, is obtained from one source and the recovery voltage is obtained only, or in part, from a separate source (synthetic tests).

During testing of a metal enclosed by-pass switch, the insulation to earth is not stressed with the full voltage phase-to-earth voltage occurring during a by-pass or insertion operation. It may be necessary to prove that the insulation to earth is capable of withstanding this full voltage after the required test duties. The influence of exhaust gases shall also be taken into account.

NOTE Where the by-pass switch consists of three poles in one enclosure, the test procedure should be modified as suggested in IEC 62271-100 and IEC 62271-101 for capacitive current switching tests.

If due to limitations of the testing facilities, the overall performance of the by-pass switch cannot be proved in the above way, several methods employing either direct or synthetic test methods may be used either singly or in combination, unit testing, depending on the by-pass switch type.

7.102.2 Number of test specimens

~~Subclause 6.1.1 of IEC 62271-1 is applicable with the following addition.~~

For the performance of by-pass making current and insertion current tests, a unique test specimen shall be used without any maintenance permitted between the test duties.

7.102.3 Arrangement of by-pass switch for tests

7.102.3.1 General

The by-pass switch under test shall be mounted on its own support or on an equivalent support. A by-pass switch supplied as an integral part of an enclosed unit shall be assembled

on its own supporting structure and enclosure, complete with any disconnecting features, with vent outlets forming part of the unit and, where practicable, with main connections and busbars.

To facilitate consistent control of the closing and opening operation, the closing and/or opening releases can be supplied at their maximum supply voltage, provided that the contact speed is not affected.

If the contact speed is dependent on the supply voltage, the operating device shall be operated in the manner specified and in particular, if it is electrically or spring operated, closing solenoid or shunt-closing releases and shunt opening releases shall be supplied at their respective minimum voltages (see Table 7) guaranteeing successful operation (~~85 % of the rated voltage if a.c. 70 % if d.c. of the rated voltage for the closing solenoid or shunt closing releases, 85 % of the rated voltage for the opening releases~~).

Table 7 – Limits of supply voltage for closing and opening releases

	AC		DC	
	Minimum %	Maximum %	Minimum %	Maximum %
Closing	85	110	70	110
Opening	85	110	85	110

When it is required that pneumatically or hydraulically operated devices be operated at the minimum functional pressure for operation the following procedure applies. This procedure is based on the fact that the by-pass making and insertion test duties call for separate C and O operations:

- before performing by-pass making current and insertion current tests and starting from the minimum functional pressure for operation as per 3.7.135, all the pressures during the rated operating sequence carried out at no-load shall be recorded;
- the recorded values shall be compared with the minimum values declared by the manufacturer as guaranteeing successful operations as separate C and O;
- when required, tests shall be carried out at the pressure for operation set at the minimum functional value resulting from a) and b) above, whatever is the lower, for the corresponding operation in the test-duty; the pressure values shall be reported in the test report.

Interlocking devices associated with pressure interlocks shall be made inoperative during the tests if they interfere with the intent of the test.

It shall be shown that the by-pass switch will operate satisfactorily under the above conditions at no-load as specified in 7.102.6. When required, the pressure of the compressed gas for by-passing, insertion and/or insulation, if any, shall be set at its minimum functional value according to 3.7.136.

The by-pass switch shall be tested according to its type as specified in 7.102.3.2 and 7.102.3.3.

7.102.3.2 Common enclosure type

Generally not applicable for by-pass switches, see 7.102.1.

7.102.3.3 Multi-enclosure type

A three-pole, by-pass switch consisting of three independent single-pole switching devices is normally tested single-phase according to 7.102.4.1. The manufacturer shall give testing evidence to show compliance with 6.101.

A three-pole by-pass switch not having completely independent switching devices shall also be tested single-phase. However, the mechanical and electrical conditions applied during the tests shall be equivalent to, or not in a more favourable condition than, the complete three-pole by-pass switch over the range of tests in respect of

- mechanical travel characteristics in a by-pass making current operation (for the evaluation method, see 7.102.4 and 7.102.7),
- mechanical travel characteristics in an insertion current operation (for the evaluation method, see 7.102.4 and 7.102.7),
- availability of arc-extinguishing medium,
- power and strength of closing and opening devices,
- the rigidity of the structure.

If these conditions cannot be fulfilled, the manufacturer and user shall agree upon a suitable test procedure.

7.102.4 General considerations concerning testing methods

7.102.4.1 Single-phase testing of a single pole of a three-pole by-pass switch

According to this method, a single pole of a three-pole by-pass switch is tested single-phase, applying to the pole the same test currents and the same voltage that would be impressed upon the most highly stressed pole during three-phase by-pass making current and insertion current tests by the complete three-pole by-pass switch under corresponding conditions.

A three-pole operated by-pass switch can be tested single-pole provided that a three-pole assembly is provided for the tests.

7.102.4.2 Unit testing

7.102.4.2.1 General

Certain by-pass switches are constructed by assembling identical by-pass and/or insertion units in series, the voltage distribution between the units of each pole often being improved by the use of parallel impedances.

This type of design enables the by-pass making and insertion performance of a by-pass switch to be tested by carrying out tests on one or more units. The requirements of 7.101.1.1, 7.102.3 and 7.102.4.1 also apply for unit testing. Since therefore at least a complete pole assembly has to be made available for the verification tests on one or more units, the test results relate only to this specific pole design.

The following situations can be distinguished.

- a) The by-pass switch pole consists of units (or assemblies of units) which are separately operated and which have no mutual connections for the arc extinguishing medium.

In this case, unit testing is acceptable. However, the mutual influence through the electrodynamic forces of the current on the units and the arc in the units shall be taken into account (see Figure 7). This may be done by substitution of the second unit by a conductor of equivalent shape.

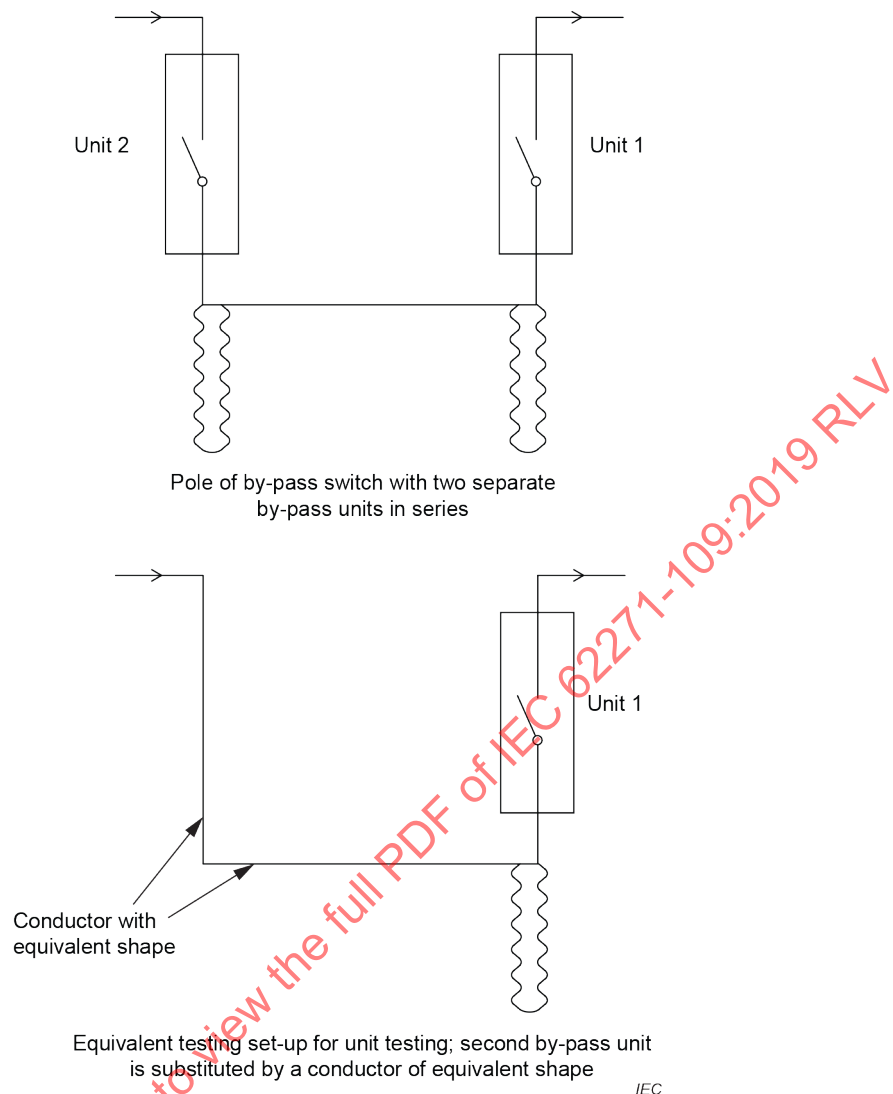


Figure 7 – Equivalent testing set-up for unit testing of by-pass switches with more than one separate by-pass units

- b) The by-pass switch pole consists of units (or assemblies of units) which are separately operated but which have a mutual connection for the arc extinguishing medium.

In this case, unit testing is acceptable and the influence of electrodynamic forces (see also item a) above) shall be covered.

- c) The by-pass switch pole consists of units (or assemblies of units) which are not separately operated.

In this case, unit testing is acceptable for the insertion current test-duty only. Moreover, the influence of electrodynamic forces (see also item a) above) shall be covered.

The by-pass making current test-duty is generally performed on a full pole. Nevertheless, because of test plant limitations, unit testing can be also acceptable if it is demonstrated that this is not influencing the contact travel characteristics as stated in 7.101.1.1.

NOTE The demonstration method should be agreed upon user and manufacturer.

The mechanical no-load travel characteristics for single-unit testing and for full-pole testing shall be the same.

When carrying out unit tests, it is essential that the units are identical and that the static voltage distribution for the type of test is known.

7.102.4.2.2 Identical nature of the units

The units of the by-pass switch shall be identical in their shape, in their dimensions and in their operating conditions; only the devices for controlling the voltage distribution among units may be different. In particular, the following conditions shall be fulfilled.

a) Operation of contacts

The opening, in insertion current tests, or the closing, in by-pass making current tests, of the contacts of one pole, shall be such that the time interval between the opening or closing of the contacts of the unit which is first to operate and the contacts of the unit which is last to operate is not more than one-eighth of a cycle of rated frequency. Rated operating pressures and voltages shall be used to determine this time interval.

b) Supply of the arc-extinguishing medium

For a by-pass switch using a supply of arc-extinguishing medium from a source external to the units, the supply to each unit shall, be independent of the supply to the other units, and the arrangement of the supply pipes shall be such as to ensure that all units are fed essentially together and in an identical manner.

7.102.4.2.3 Voltage distribution

The test voltage is determined by analysing the voltage distribution between the units of the pole.

The voltage distribution between units of a pole, as affected by the influence of earth, shall be determined for the relevant test conditions.

Where the units are not symmetrically arranged, the voltage distribution shall be determined also with reverse connections.

The voltage distribution is determined either by measurements or by calculations. Values used in the calculations shall be supported by measurements of the stray capacitances of the by-pass switch. Such calculations and supporting measurements verifying the assumptions used in the calculations are the responsibility of the manufacturer.

The voltage distribution may be calculated or measured at power frequency only.

The manufacturing tolerances for resistors and capacitors shall be taken into account. The manufacturer shall state the value of these tolerances.

NOTE The influence of pollution is not considered in determining voltage distribution. In some cases, pollution may affect this voltage distribution.

7.102.4.2.4 Requirements for unit testing

When testing a single unit, the test voltage shall be the voltage of the most highly stressed unit of the complete pole of the by-pass switch, determined in accordance with 7.102.4.2.3.

When testing a group of units, the voltage appearing at the terminals of the most highly stressed unit of the group shall be equal to the voltage of the most highly stressed unit of the pole, both determined in accordance with 7.102.4.2.3.

7.102.4.3 Multi-part testing

Multi-part testing is generally not applicable to by-pass switches.

7.102.5 Synthetic tests

Synthetic testing methods can be applied for insertion current tests. Synthetic testing techniques and methods proposed for capacitive current switching as described in IEC 62271-101 ~~can~~ shall be used as a reference.

7.102.6 No-load operations before tests

Before commencing by-pass making current and insertion current tests, no-load operations and no-load operating sequences (C, OC and C – t – OC) shall be made and details of the operating characteristics of the by-pass switch recorded. Details such as closing time and opening time shall be recorded.

In addition, it shall be demonstrated that the mechanical behaviour of the by-pass switch, or sample under test, conforms to that of the reference mechanical travel characteristics required in 7.101.1.1. For this test, the operational conditions stated in 7.101.1.1 apply.

The pressure of the fluid for by-passing and insertion shall be set at its minimum functional value according to 3.7.136.

For electrically or spring-operated by-pass switches, operations shall be made with the closing solenoid or shunt-closing releases energized at 100 % and 85 % in the case of AC or 70 % in the case of DC of the rated supply voltage of the closing device and with the shunt-opening release(s) energized at 100 % and 85 % of the rated supply voltage.

For pneumatic or hydraulic operating devices, the operations shall be made under the following conditions:

- a) pressure of the fluid for operation set at its minimum functional value as per 3.7.135 with the shunt opening releases energized at 85 % and with the shunt closing releases energized at 85 % in case of AC, 70 % in case of DC of the rated supply voltage.
- b) pressure of the fluid for operation set at its rated value as per 5.11 with the shunt releases energized at the rated supply voltage.

7.102.7 Alternative operating mechanisms

If it can be shown that the use of an alternative operating mechanism (see 3.5.126) does not affect the performance of the common portion, particularly with regard to the closing and opening characteristics of the by-pass switch, a repetition of the type tests under by-pass making and insertion test duties is not necessary.

NOTE In this subclause, it is considered that one version of the by-pass switch using a certain operating mechanism, is completely type-tested in accordance with this document; this version is referred to as the completely tested by-pass switch. The other versions, differing only in the operating mechanisms (see definition in 3.5.124) are referred to as by-pass switch with alternative operating mechanisms.

The tests to be performed are limited to the following.

- a) On each of the by-pass switches (the completely tested by-pass switch and the by-pass switches with alternative operating mechanisms), the mechanical characteristics shall be recorded at no-load (single O and single C operations) and compared in accordance with 7.101.1.1 (the use of mechanical characteristics and related requirements are described in Annex G).
- b) On each of the by-pass switches (the completely tested by-pass switch and the by-pass switches with alternative operating mechanisms), a by-pass making current operation shall be performed. The test results shall be evaluated according to the method prescribed under a) above.

If requirements a) or b) or both of them are not met, then the new mechanism is not considered to be an alternative operating mechanism.

NOTE If the above-given requirements are met, the reference mechanical characteristics of the completely tested by-pass switch should apply also to the by-pass switches with alternative operating mechanisms.

7.102.8 Behaviour of by-pass switch during tests

During by-pass and insertion tests, the by-pass switch shall not

- show signs of distress,
- ~~– show harmful interaction with adjacent laboratory equipment,~~
- exhibit behaviour which could endanger an operator.

For by-pass switches which are designed to have discharge of interrupting medium into the atmosphere during the by-passing and insertion tests, the above requirements are considered to have been met, provided that

- for oil by-pass switches, there is no outward emission of flame, and the gases produced, together with the oil carried with the gases, shall be conducted away from the by-pass switch and directed away from all live conductors and locations where persons may be present,
- for other types of by-pass switches, such as air blast or air break, there is an outward emission of flame, gas and/or metallic particles. If such emissions are appreciable, it may be required that the tests shall be made with metallic screens placed in the vicinity of the live parts and separated from them by a safety clearance distance which the manufacturer shall specify. The screens shall be insulated from earth but connected thereto by a suitable device to indicate any significant leakage current to earth. There shall be no indication of significant leakage currents to the by-pass switch earthed structure, or screens when fitted, during the tests.

NOTE If no other devices are available, the earthed parts, etc. should be connected to earth through a fuse consisting of a copper wire of 0,1 mm diameter and 5 cm long. No significant leakage is assumed to have occurred if this fuse wire is intact after the test.

If faults occur which are not persistent or due to defect in design, but rather are due to errors in assembly, the faults can be rectified and the by-pass switch subjected to a repetition of all test duties. In those cases, the test report shall include reference to the invalid tests.

For by-switch comprising vacuum interrupters, NSDDs may occur during the recovery voltage period following an insertion operation. However, their occurrence is not a sign of distress of the by-pass switch under test. Therefore, their number is of no significance to interpreting the performance of the device under test. They shall be reported in the test report in order to differentiate them from restrikes.

NOTE It is not the intent to require the installation of special measuring circuits to detect NSDDs. They should only be reported when seen on an oscillogram.

7.102.9 Condition of by-pass switch after tests

7.102.9.1 General

The by-pass switch shall be inspected after completion of all test duties. Its mechanical parts and insulators shall be in essentially the same condition as before the test duties. Visual inspection is usually sufficient for verification of the insulating properties. In case of doubt, the condition checking test according to 7.2.12 is sufficient to prove the insulation properties.

For by-pass switches with sealed-for-life units, the condition checking test is mandatory, except as stated in 7.102.9.2.

7.102.9.2 Condition after the by-pass current making and insertion test duties

The by-pass switch shall, after performing the by-pass making current and insertion current test duties specified in 7.103.2 and 7.103.4, be capable of operating satisfactorily at any by-pass making current and insertion current up to its rated by-pass making current and insertion current.

In addition, the by-pass switch shall be capable of carrying its rated normal current with a temperature rise, not in excess of the temperature rise permitted by Table 14 of IEC 62271-1:2017.

For other than sealed for life by-pass and insertion units, visual inspection is usually sufficient for verification of the capability of the by-pass switch to carry the rated normal current and to by-pass and insert at any current up to its rated by-pass making current and insertion current.

There shall be no evidence of puncture, flashover or tracking of the internal insulating materials, except that moderate wear of the parts of arc control devices exposed to the arc is permissible.

Degradation of the components in the current carrying path shall not reduce the integrity of the normal current carrying path.

If during the insertion current tests, one restrike occurred, the dielectric condition checking test according to 7.2.12 shall be performed before visual inspection, provided that the tested peak ~~transient~~ recovery voltage during the insertion current tests is lower than the peak voltage of the specified dielectric condition checking test. The subsequent visual inspection shall demonstrate that the restrike occurred between the arcing contacts only. There shall be no evidence of puncture, flashover or permanent tracking of internal insulating materials. Wear of the parts of arc control devices exposed to the arc is permissible as long as it does not impair the by-pass making and insertion capability. Moreover, the inspection of the insulating gap between the main contacts, if they are different from the arcing contacts, shall not show any trace of a restrike.

If no restrike occurred during the insertion current tests visual inspection is sufficient. The dielectric condition checking test according to 7.2.12 is not necessary.

For by-pass switches with sealed-for-life by-pass units, the dielectric condition checking test according to 7.2.12 shall be performed, whether a restrike occurs during testing or not, provided that the tested peak ~~transient~~ recovery voltage during the insertion current tests is lower than the peak voltage of the specified dielectric condition checking test.

7.102.9.3 Reconditioning after a test-duty

The by-pass switch shall not be reconditioned during and between the by-pass making current and insertion current test duties.

If local safety rules require depressurising to enter the test cell, it is allowed to decrease the pressure in the by-pass switch provided that the gas is reused when refilling the by-pass switch.

NOTE When refilling is necessary, the used gas cannot be reused totally due to vacuum pump limitations. For such cases, new gas can be used for topping up and the quantity of new gas should not exceed 10 % of the total gas quantity.

7.103 By-pass making current test-duty and insertion current test-duty, sequence of tests

7.103.1 General

The by-pass making current test-duty and the insertion current test-duty shall be performed in the following order:

- a) half of the required making operations at minimum functional pressures for operation and/or by-passing, insertion and insulation;

These making operations are including two of the making operations at rated by-pass making current and 10 making operations at capacitor bank discharge current.

- b) half of the required insertion operations at minimum functional pressures for operation and/or by-passing, insertion and insulation;

- c) half of the required making operations at ~~rated~~ filling functional pressures for operation and/or by-passing, insertion and insulation;

These making operations include two of the making operations at rated by-pass making current and 10 making operations at capacitor bank discharge current.

- d) half of the required insertion operations at ~~rated~~ filling functional pressures for operation and/or by-passing, insertion and insulation.

Maintenance is not permitted between the test duties.

If the by-pass switch has a non-symmetrical current path, the terminal connections shall be reversed for half of the number of required operations. This reversal should be carried out between the test series required at minimum functional pressures and the test series required at ~~rated~~ filling functional pressures (between test series b) and c) above).

NOTE It is also acceptable to perform the tests in the order a), c), b), d). This procedure requires more gas ~~treatment~~ handling operations and more terminal reversals. This should not be done without the consent of the manufacturer.

NOTE It is also acceptable to perform all tests at minimum functional pressures for operation and/or by-passing, insertion and insulation. This should not be done without the consent of the manufacturer.

7.103.2 By-pass making current test-duty

7.103.2.1 General

This test-duty is valid for both rated frequencies, i.e. for 50 Hz or 60 Hz systems.

7.103.2.2 Characteristics of supply circuit

It is recommended to use an oscillatory circuit (LC circuit, see Figures 8 and 9). The test circuit shall fulfil the following requirements.

- a) The characteristics of the test circuit shall be such that the instantaneous applied voltage, just before the making operation, be equal to the limiting peak voltage of the overvoltage protector (U_{PL}). A DC voltage can be applied.
- b) The components of the oscillatory circuit (series inductance and precharged capacitor bank) shall be selected in order to obtain the required by-pass current (first peak, I_{BP}) at the frequency of the by-pass making current (f_{BP}).

NOTE The by-pass making performance is ~~to be~~ covered when the required peak by-pass making current is equal to or lower than the actual value used in the test-duty. This equivalency rule is considered to be valid only when the frequency of the by-pass making current f_{BP} is equal to or lower than 130 % of the value used during type tests.

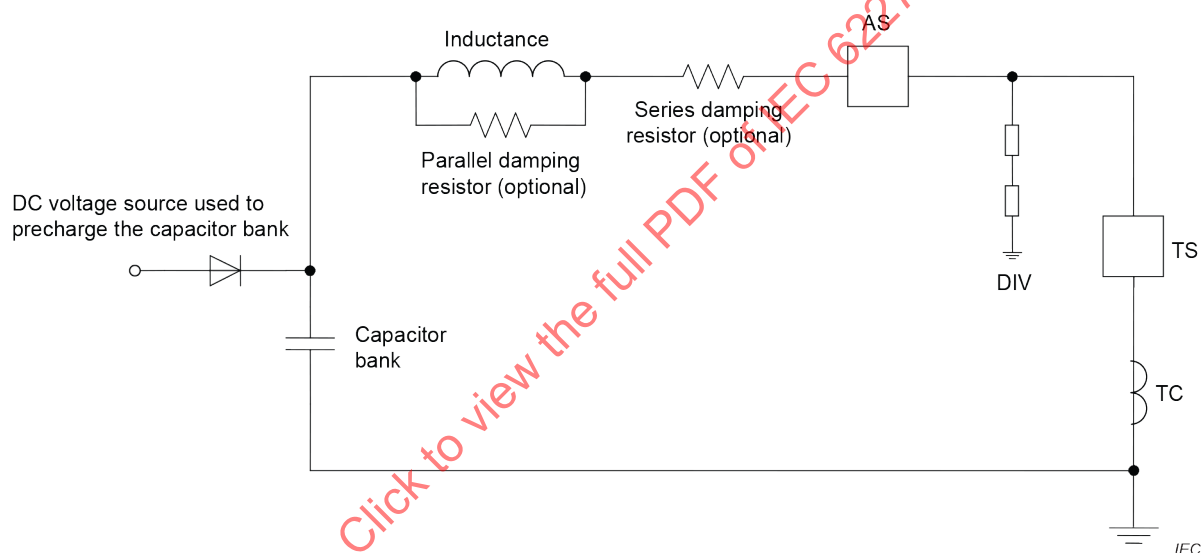
- c) The damping ratio of the by-pass current (sinusoidal exponential decaying current) may be adjusted to the service condition damping ratio by inserting an additional resistor in the oscillatory circuit. The damping ratio is defined as the ratio between the second peak and the first peak of the same polarity of the by-pass discharge current.

The damping ratio obtained during tests shall be indicated in the test report.

In order to be a valid test-duty for a specific series capacitor installation, the damping ratio obtained during tests shall ~~not be equal to or higher~~ less than 10 % of than the actual damping ratio at the site.

NOTE A test performed without intentional damping automatically covers applications where a damping resistor is used and when the condition given in b) above and in 5.102 are covered. Specific damping ratings can generally not be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings.

NOTE 3 ~~A deficiency to meet the damping ratio can be compensated by a higher by-pass making test current, provided that the arc energy during the pre-arcing period is equal to or higher than the pre-arcing energy required by the applicable test parameters.~~



Key

- DIV voltage divider
 AS auxiliary switch
 TS tested by-pass switch
 TC current measuring device

Figure 8 – Typical test circuit for the by-pass making current test-duty

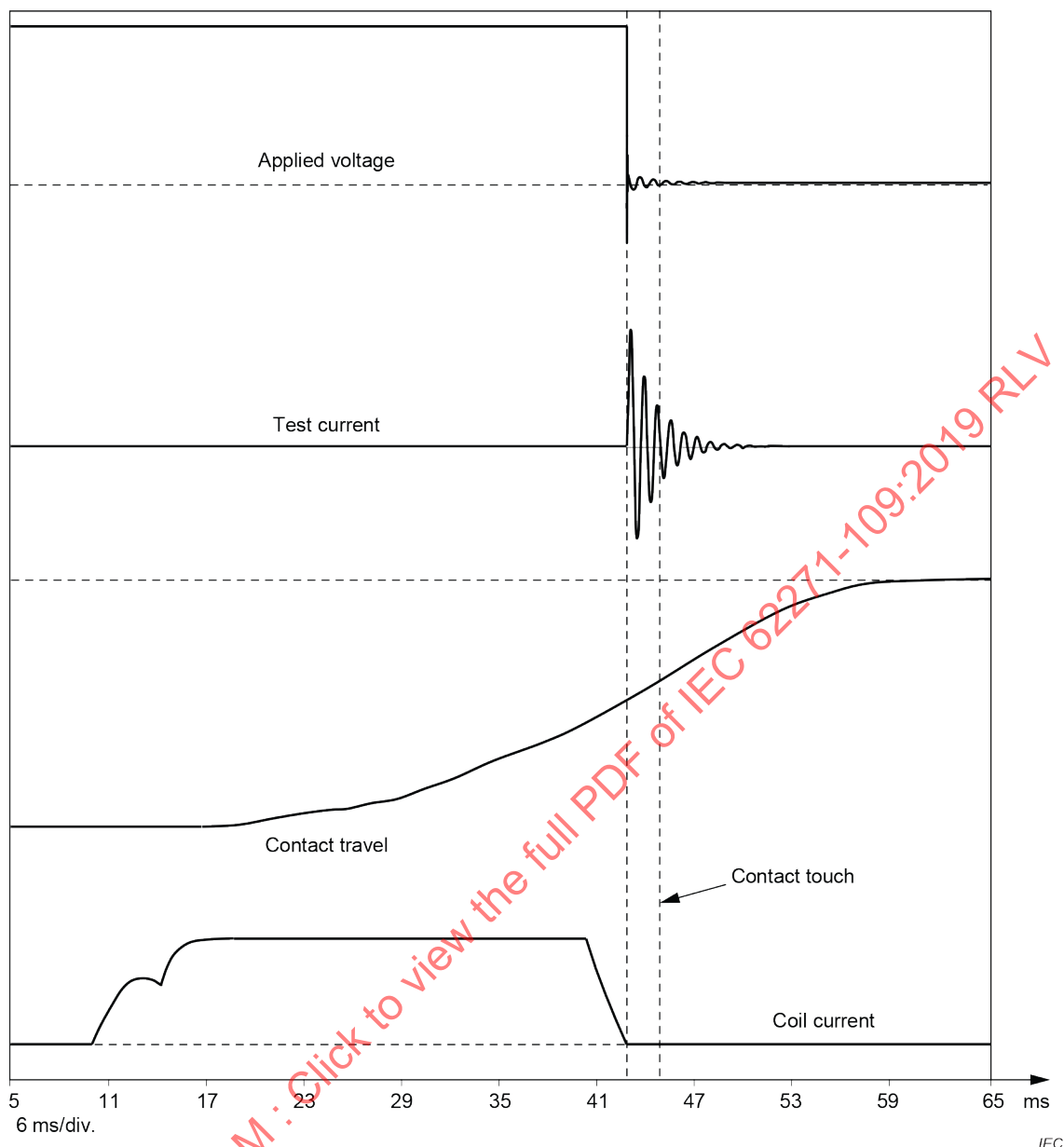


Figure 9 – Oscillogram obtained from the typical test circuit for the by-pass making current test-duty

7.103.2.3 Test voltage

The instantaneous test voltage to be applied across the by-pass switch, prior to the by-pass making tests, shall be the limiting peak voltage of the overvoltage protector (U_{PL} ; $+5\%$).

7.103.2.4 Test current

For four making operations, the first peak of the test current shall be the rated by-pass making current I_{BP} at the frequency of the by-pass making current f_{BP} . The tolerance on the by-pass making current shall be within ($+5\%$) of the by-pass making current I_{BP} . The effective damping of the making current component should be taken into consideration.

NOTE If because of laboratory limitations, the rated peak by-pass making current cannot be obtained, then it is permissible to perform the test differently. For such cases, the frequency

f_{BP} should be as close as possible to the rated value. Deviations from rated values may affect the applicability range (see 5.102).

For the remaining 20 making operations, the first peak of the test current shall be limited to the capacitor bank discharge current $I_{DISCHARGE}$ (without considering the power-frequency fault current component) when the bank is precharged to the limiting voltage of the overvoltage protector (U_{PL}) ($+5_0$ %) at by-pass making frequency f_{BP} . The effective damping of the capacitor bank discharge current should also be taken into consideration.

NOTE If because of laboratory limitations, the capacitor bank discharge current at by-pass making current frequency cannot be obtained, then it is permissible to perform the test differently. For such cases, f_{BP} should be as close as possible to the rated value. Deviations from rated values may affect the applicability range (see 5.102).

NOTE If, because of laboratory limitations, the rated peak by-pass making current and/or the capacitor bank discharge current at by-pass making current frequency cannot be obtained, then it is permissible to perform the test series with test currents higher than the tolerance stated above. This should not be performed without the consent of the manufacturer.

7.103.2.5 Number of making operations

The by-pass making current test ~~duty comprises four making operations (4 C) at rated by-pass making current plus 20 making operations at the capacitor bank discharge current component (20 C)~~ can be performed using one of the two alternatives given in Table 8. The by-pass switch conditions shall be in accordance with 7.102.3.1.

~~NOTE As an alternative, the complete test duty can be limited to 20 making operations at the by-pass making current (discharge current component plus power-frequency fault current component). This alternative should not be performed without the consent of the manufacturer.~~

Table 8 – Test procedures for by-pass making current tests

Alternative	Number of making operations	Test current
Alternative 1	20	I_{BP}
Alternative 2	4	I_{BP}
	20	$I_{DISCHARGE}$

7.103.3 Insertion current test-duty

7.103.3.1 General

Re-ignitions during the insertion current test-duty are permitted but restrikes are not permitted unless otherwise indicated (a low expected probability of restrike is required).

NOTE 1 The restrike probability is related to the performance during the series of type tests.

NOTE 2 Phenomena occurring after a restrike or a re-ignition event are not representative of service conditions as the test circuit does not adequately reproduce the post-event voltage and current conditions.

NOTE 3 Since the quantity of energy trapped in the capacitor bank used during tests is generally much lower than the energy trapped in the service series capacitor bank, it is important to have a low probability of restrike to limit possible damages to the internal components of by-pass units.

Several ~~transient~~ reinsertion voltage waveshapes can be obtained in service. The reinsertion voltage waveshape should be determined by systems studies. For standardization purposes, in order to cover most of the practical cases, this document recommends a "1-cos" waveshape having a preferred first time-to-peak of 5,6 ms to cover 50 Hz and 60 Hz applications with one single test-duty. Other waveshapes may be required and should be

clearly specified to the manufacturer at the time of enquiry. The tolerance on the time-to-peak of the ~~transient~~ recovery voltage shall be $\pm 5\%$.

NOTE For by-pass switches exclusively rated for 50 Hz systems, the ~~transient~~ recovery voltage time-to-peak may be increased to 6,7 ms.

The border delimiting a re-ignition and a restrike shall be set to half of the time to peak of the ~~transient~~ recovery voltage.

NOTE 4 The border delimiting re-ignition and restrike has been set to half of the time-to-peak of the ~~transient~~ recovery voltage for limiting the amount of energy released during restrike which ~~may~~ can affect internal components of the by-pass switch as well as other equipment on the series capacitor platform.

The test circuit branch supplying the power-frequency test current shall have a frequency ranging from 49 Hz to 61 Hz.

NOTE 5 Tests performed with a current source frequency ranging from 49 Hz to 61 Hz are considered to prove the insertion capability for both system frequencies i.e. 50 Hz or 60 Hz.

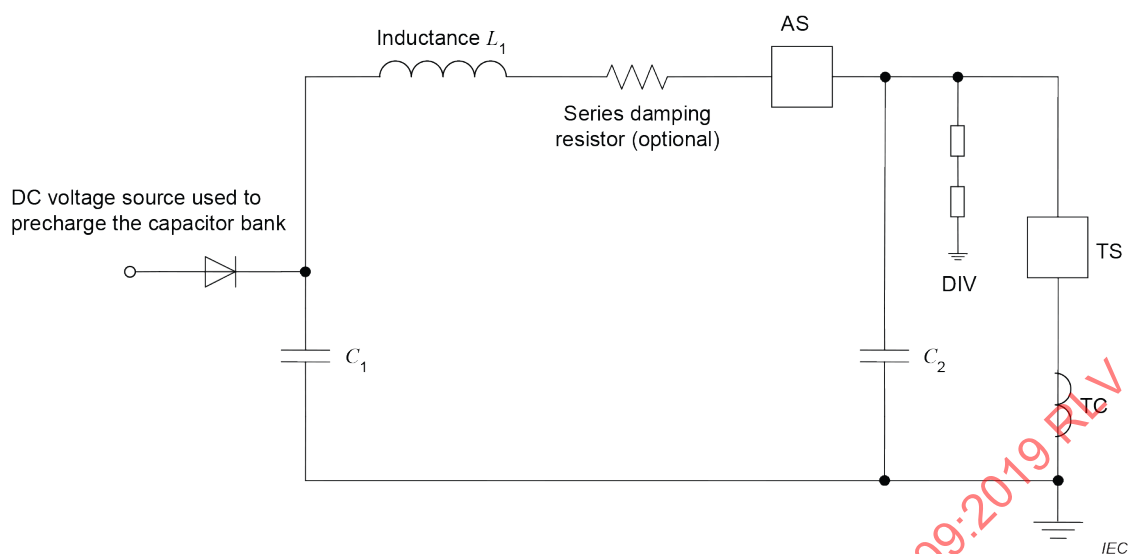
7.103.3.2 Characteristics of supply circuit

An oscillatory circuit (double frequency LC circuit, see Figures 10 and 11 with one oscillatory circuit branch feeding the power-frequency current and another circuit branch producing the ~~transient~~ recovery voltage is suggested. Other test circuits as proposed by IEC 62271-101 for synthetic capacitive current switching tests may also be used. Other examples of synthetic and direct test circuits are shown in Figures 12, 13, 14 and 15. The test circuit shall fulfil the following requirements.

- a) The characteristics of the test circuit current branch shall be such that the instantaneous peak current, just before the interruption, is the peak value of the rated insertion current. The current circuit shall produce, as nearly as possible, a sinusoidal current waveshape (with the proposed synthetic test circuit, it will be a sinusoidal exponential decaying current). This condition is considered to be met if the ratio of the RMS value to the RMS value of the fundamental component does not exceed 1,2.

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

- b) Unless otherwise specified, the characteristics of the test circuit voltage branch should be such that a ~~transient~~ recovery voltage having "1-cos" waveshape is generated across the by-pass switch terminals. The time-to-peak of the voltage waveshape should be 5,6 ms unless otherwise specified. The initial voltage jump that can appear at the beginning of the "1-cos" waveshape should be as small as possible and should never exceed 5 % of the ~~transient~~ recovery voltage peak.

**Key**

DIV voltage divider

AS auxiliary switch

TS tested by-pass switch

TC current measuring device

 C_1 and L_1 set to the rated frequency (current source components) C_1 , C_2 , and L_1 set to obtain the required time-to-peak of the recovery voltage (voltage source components)**Figure 10 – Typical LC test circuit for the insertion current test-duty**

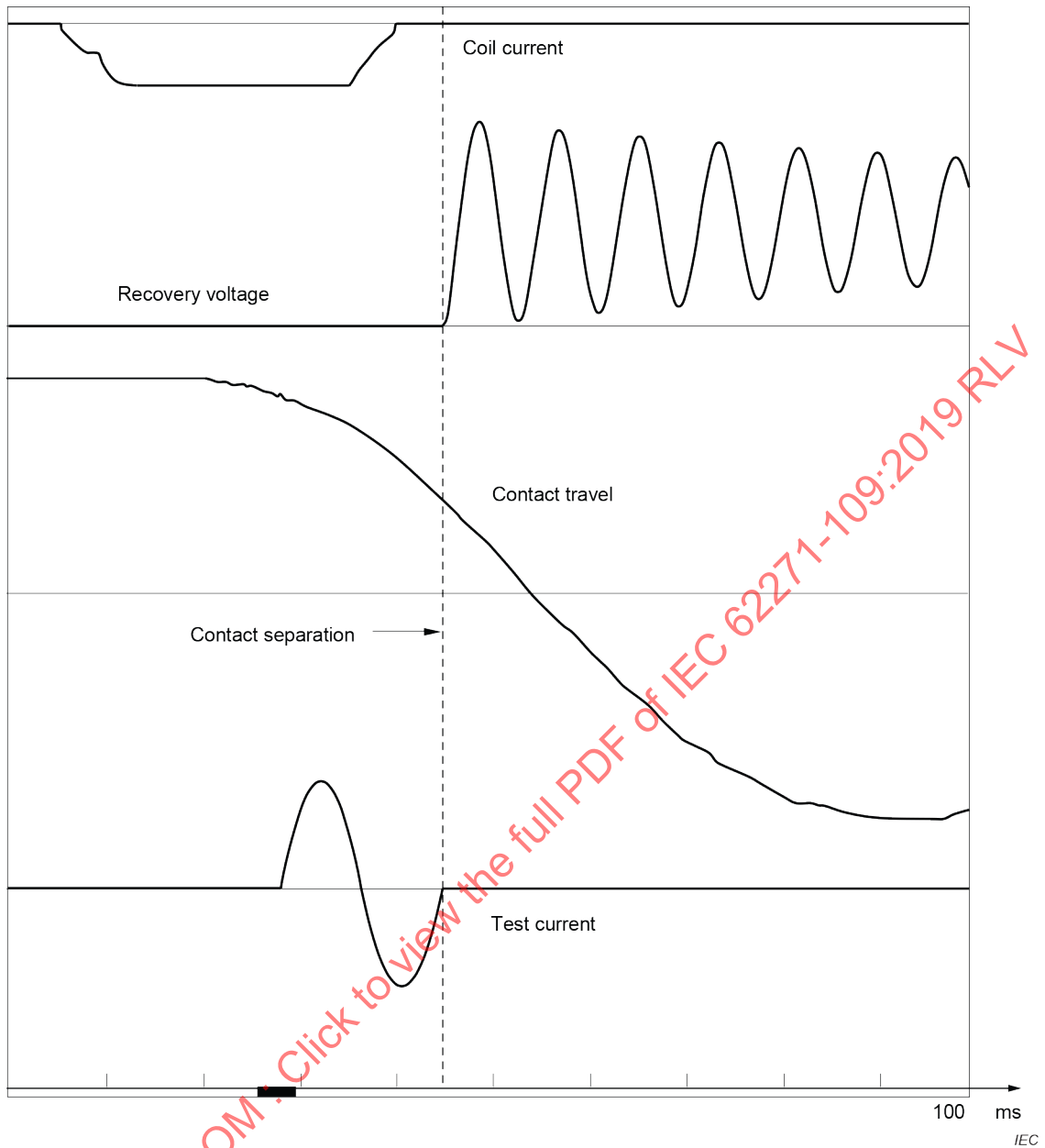
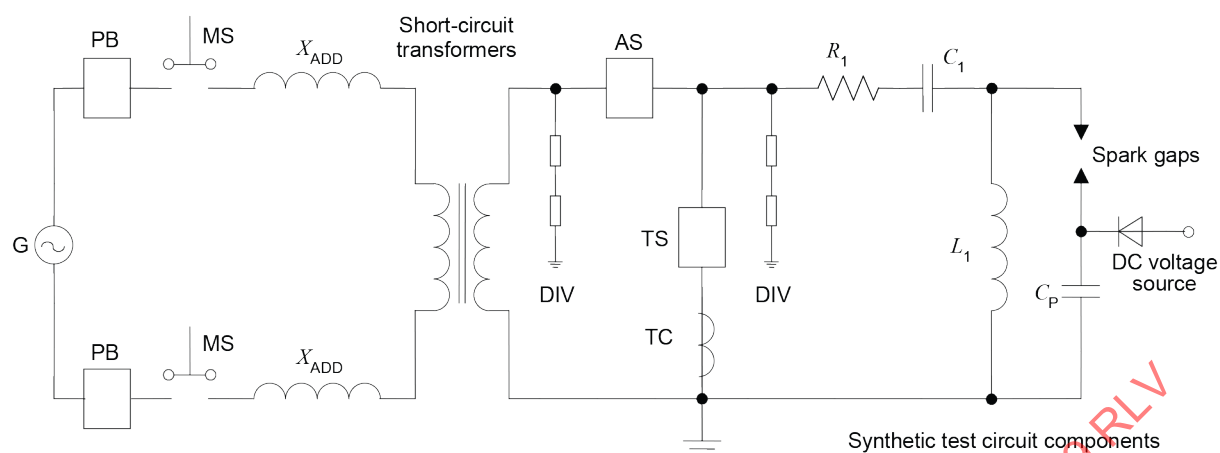


Figure 11 – Oscillogram obtained from the typical LC test circuit for the insertion current test-duty



IEC

Key

G	short-circuit generator supplying the power-frequency current
PB	protection circuit-breakers (back-up)
MS	making switches
X_{ADD}	reactances added to adjust the test current to the required insertion current value
DIV	voltage divider
AS	auxiliary switch
TS	tested by-pass switch
TC	current measuring device
R_1, C_1, L_1, C_p	element of the voltage source (synthetic circuit)

Figure 12 – Typical test circuit for the insertion current test-duty (mainly for high rated insertion current)

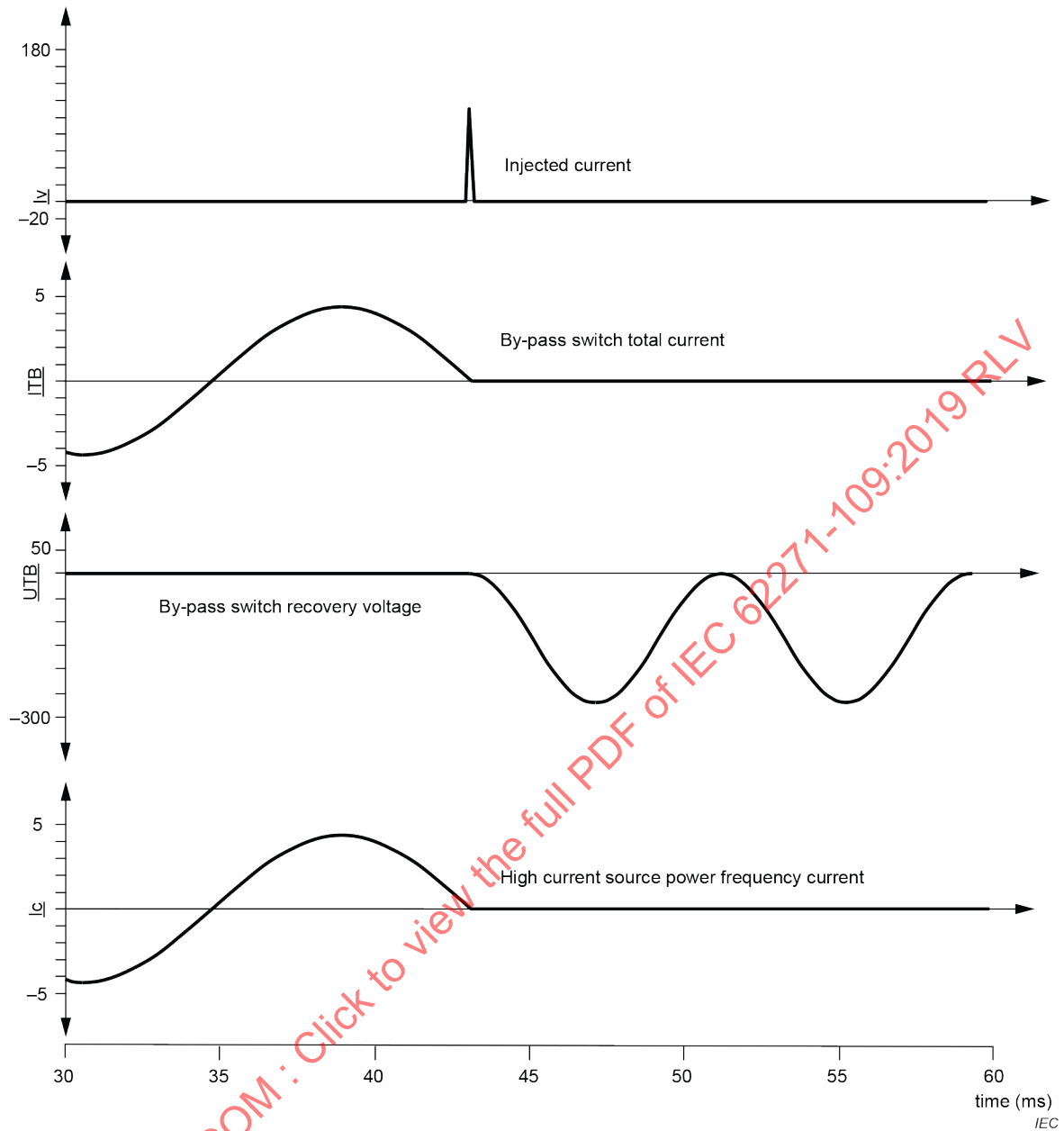
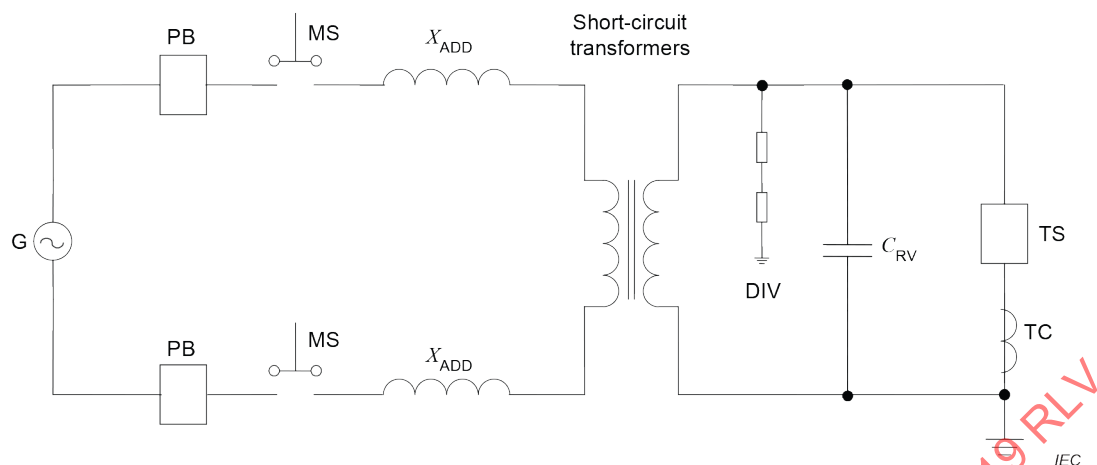


Figure 13 – Oscillogram obtained from the typical test circuit shown in Figure 12 for the insertion current test-duty

**Key**

- G short-circuit generator supplying the power-frequency current
- PB protection circuit-breakers (back-up)
- MS making switches
- X_{ADD} reactances added to adjust the test current to the required insertion current value
- DIV voltage dividers
- TS tested by-pass switch
- TC current measuring device
- C_{RV} capacitor used to adjust the "1-cos" waveshape for to the required recovery voltage. The value of " C_{RV} " should be chosen to obtain a peak value of the recovery voltage of 5,6 ms or 6,7 ms for by-pass switches exclusively rated for 50 Hz).

Because this circuit produces a second recovery voltage peak which is significantly higher than the first recovery voltage peak, it may be necessary to add some voltage-limiting devices (e.g. ZnO arresters) across the tested by-pass switch.

Figure 14 – Typical direct test circuit for the insertion current test-duty

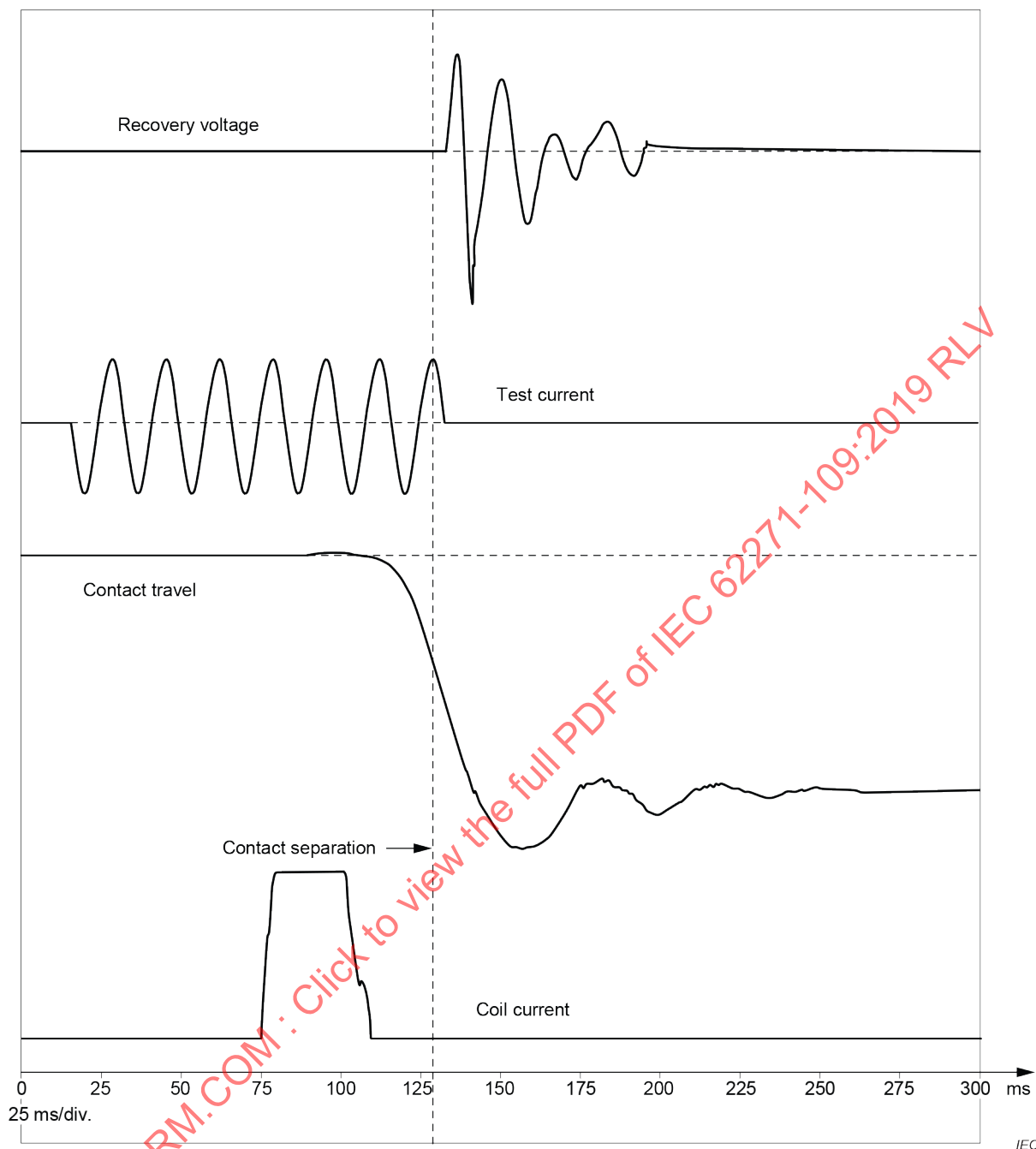


Figure 15 – Oscillogram obtained from the typical direct test circuit for the insertion current test-duty

7.103.3.3 Test voltage

The ~~transient~~ recovery voltage peak to be applied across the by-pass switch shall be the limiting peak voltage of the overvoltage protector (U_{PL} ; $+5$ -0 %).

7.103.3.4 Test current

The test current shall be the rated by-pass insertion current (± 20 %).

7.103.3.5 Number of operations

The insertion current test-duty comprises a total of two test duties of 24 opening operations (2×24 O).

The opening operations should be performed in the following manner:

- O operations for finding the minimum arcing time on one polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on one polarity;
- O operations for finding the minimum arcing time on the other polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on the other polarity;
- additional tests to achieve 24 O, distributed in both polarities (step: 30°)
- reversal of the connections for the second set if the current path is not symmetrical;
- O operations for finding the minimum arcing time on one polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on one polarity;
- O operations for finding the minimum arcing time on the other polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on the other polarity;
- additional tests to achieve 24 O, distributed in both polarities (step: 30°).

NOTE It is understood that to comply with this requirement, a search for the minimum arcing time should be done before doing the required tests with minimum arcing time. These test shots are included in the total of 24 O for each individual set.

NOTE It is understood that when following this procedure, the number of shots distributed at 30° steps at each polarity may not be equal. This is acceptable.

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

NOTE In order to obtain more consistent opening time of the by-pass switch, by agreement of the manufacturer, voltages even higher than the relevant upper tolerance limit of the supply voltages of the operating devices may be applied during these tests.

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

- advance the setting of the control of the tripping impulse by 6° and repeat the test. The new setting should be kept for other tests at minimum arcing time. If with this new setting, another maximum arcing time is obtained instead of an expected minimum arcing time, the setting shall be further advanced by a step of 6° and this procedure repeated until a minimum arcing time is achieved;
- make one less opening operation for each of the above operations resulting in a maximum arcing time to retain the overall total count of tests.

NOTE For relatively high rated insertion current, it may appear that two minimum arcing times are found, one in the thermal reignition zone (typically around 1 ms before current zero) and one in the dielectric reignition zone (typically less than 0,5 ms before current zero). In order to have a consistent test procedure, the minimum arcing time search should start from a contact separation point as close as possible to current zero.

The number of operations at minimum arcing time as stated above shall be achieved, even if the specified total number of operations is exceeded.

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

For tests using the test circuit given in Figure 12, the result will become invalid when the arcing time becomes maximum instead of an expected minimum arcing time. This test cannot be included in the count for the total number of tests.

The by-pass switch conditions shall be in accordance with 7.102.3.1. If the by-pass switch has a non-symmetrical current path, the terminal connections shall be reversed for the second test-duty as shown above.

7.103.4 Criteria to pass the test duties

The by-pass switches shall have successfully passed the tests if the following conditions are fulfilled:

- the behaviour of the by-pass switch during by-pass making current and insertion current test duties fulfils the conditions given in 7.102.8;
- either no restrikes occurred during the insertion current test-duty, or, if only one restrike occurs in one of the two sets, then the set shall be completed and repeated on the same test sample without any maintenance. No restrike shall occur during the further tests. External flashover and phase-to-ground flashover shall not occur;
- the condition of the by-pass switch after the test series corresponds to the conditions given in 7.102.9.2. If no restrike occurred during the insertion test-duty, visual inspection is sufficient.

8 Routine tests

8.1 General

Subclause 8.1 of IEC 62271-1:2017 is applicable ~~with the following addition~~.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable with the following addition.

In the case of by-pass switches constructed by assembling identical by-pass units in series, the test voltage to be applied across each single unit, when open, shall be the higher fraction of the total withstand voltage resulting from actual power-frequency voltage distribution with the by-pass switch fully open and one terminal earthed.

With reference to Figure 2 of IEC 62271-1:2017, which shows a diagram of a three-pole operated by-pass switch, the test voltage shall be applied, according to Table 9. For single pole operated by-pass switches, the required tests are limited to two tests, one with the by-pass switch in the closed position and one with the by-pass switch in the open position. The required test levels for both positions ~~may~~ can be different.

Table 9 – Application of voltage for dielectric test on the main circuit

Test condition No.	By-pass switch	Voltage applied to	Earth connected to
1	Closed	AaCc	BbF
2	Closed	Bb	AaCcF
3	Open	ABC	abcF

NOTE If the insulation between poles is air at atmospheric pressure, test conditions nos. 1 and 2 ~~may~~ can be combined, the test voltage being applied between all parts of the main circuit, connected together, and the base.

In the case of by-pass switches using a gas mixture such as SF₆/CF₄ or SF₆/N₂, the test can be performed using the declared gas mixture at the minimum functional pressure for by-passing, inserting and insulation or pure SF₆ at a total absolute pressure not exceeding the equivalent gas pressure (P_{test}) as calculated by the following equations (see Figure 4.1 of CIGRE TB 163):

- for circuit-breakers using a SF₆/N₂ mixture: $P_{\text{test}} = P_{\text{SF6}} + 0,7 \times P_{\text{add N2}}$. The equation is valid for mixtures having at least 30 % of SF₆ gas volume; (see Note);
- for circuit-breakers using a SF₆/CF₄ mixture: $P_{\text{test}} = P_{\text{SF6}} + 0,45 \times P_{\text{add CF4}}$.

where

P_{test} is the total absolute SF₆ pressure at $T = 20\text{ °C}$ during routine dielectric test on the main circuit;

P_{SF6} is the partial pressure of SF₆ at $T = 20\text{ °C}$ at the minimum functional pressure for by-passing, inserting and insulation according to the declared gas mixture;

P_{add} is the partial pressure of CF₄ or N₂ at $T = 20\text{ °C}$ at the minimum functional pressure for by-passing, inserting and insulation according to the declared gas mixture.

NOTE See CIGRE TB 163 for mixtures having less than 30 % of SF₆.

8.2.101 Partial discharge test

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

The measurement of partial discharges should be preferably performed on the complete by-pass switch. In this case, the measurement of partial discharges shall be performed during the dielectric test (8.2) and preferably after mechanical operating routine tests (8.101).

If a test on the complete by-pass switch is impractical, it is allowed to replace the test on the complete by-pass switch by partial discharge measurements on individual components, before assembly, such as bushings, insulators, partitions, insulated operating rods, etc. For partial discharge tests on bushings, 9.5 of IEC 60137:2017 is applicable.

Partial discharge test on bushings is required for all types of bushings with the exception of gas-insulated bushings and ceramic, glass or analogous inorganic material bushings as defined respectively in 3.6 and 3.13 of IEC 60137:2017.

The measurement shall be made in accordance with IEC 60270.

The applied power-frequency voltage shall be raised to a pre-stress value which is identical to the power-frequency withstand voltage test and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage shall be decreased to the value defined in Table 10.

The extinction voltage shall be recorded during the reduction of the applied test voltage specified in Table 10.

Table 10 – Test voltage for partial discharge test

	System with effectively earthed neutral		System with non-effectively earthed neutral	
	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min.)	Test voltage for PD measurement $U_{\text{pd-test}}$ (> 1 min.)	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min.)	Test voltage for PD measurement $U_{\text{pd-test}}$ (> 1 min.)
Single-phase enclosure designs (phase-to-earth voltage)	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test}} = 1,2 \times U_{\text{re}} / \sqrt{3}$	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test}} = 1,2 \times U_{\text{re}}$
Three-phase enclosure designs	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test, ph-ea}} = 1,2 \times U_{\text{re}} / \sqrt{3}$ $U_{\text{pd-test, ph-ph}} = 1,2 \times U_{\text{re}}$	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test, ph-ea}} = 1,2 \times U_{\text{re}}$
Key U_{re} : rated voltage to earth for equipment. U_{de} : power-frequency withstand test voltage to earth as per Tables 1, 2, 3 and 4 of IEC 62271-1:2017. $U_{\text{pre-stress}}$: pre-stress voltage. $U_{\text{pd-test}}$: test voltage for PD measurement. $U_{\text{pd-test, ph-ea}}$: test voltage for PD measurement, phase-to-earth. $U_{\text{pd-test, ph-ph}}$: test voltage for PD measurement, phase-to-phase.				

8.3 ~~Dielectric~~ Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to circuit diagrams and wiring diagrams

Subclause 8.3.1 of IEC 62271-1:2017 is applicable.

8.3.2 Functional tests

Subclause 8.3.2 of IEC 62271-1:2017 is applicable.

8.3.3 Verification of protection against electrical shock

Subclause 8.3.3 of IEC 62271-1:2017 is applicable.

8.3.4 ~~Dielectric~~ tests

Subclause 8.3.4 of IEC 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 is applicable.

8.5 Tightness test

8.5.1 General

Subclause 8.5.1 of IEC 62271-1:2017 is applicable.

8.5.2 Controlled pressure systems for gas

Subclause 8.5.2 of IEC 62271-1:2017 is applicable.

8.5.3 Closed pressure systems for gas

Subclause 8.5.3 of IEC 62271-1:2017 is applicable.

8.5.4 Sealed pressure systems

Subclause 8.5.4 of IEC 62271-1:2017 is applicable.

8.5.5 Liquid tightness tests

Subclause 8.5.5 of IEC 62271-1:2017 is applicable.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable with the following addition.

The by-pass switch shall be checked to verify its compliance with the order specification.

The following items shall be checked as applicable:

- the language and data on the nameplates;
- identification of any auxiliary equipment;
- the colour and quality of paint and corrosion protection of metallic surfaces;
- the values of the resistors and capacitors connected to the main circuit.

8.101 Mechanical operating tests

Mechanical operating tests shall include the following:

- a) at maximum supply voltage of operating devices and of auxiliary and control circuits and maximum pressure for operation (if applicable)
 - five closing operations;
 - five opening operations.
- b) at specified minimum supply voltage of operating devices and of auxiliary and control circuits and minimum functional pressure for operation (if applicable)
 - five closing operations;
 - five opening operations.
- c) at rated supply voltage of operating devices and of auxiliary and control circuits and rated pressure for operation (if applicable)
 - five open-close operating cycles with the closing mechanism energized by the opening of the main contacts through the auxiliary switch.

Mechanical operating tests shall be made on the complete by-pass switch. However, when by-pass switches are assembled and shipped as separate units, routine tests may be performed on components according to 7.101.1.2. In such cases, the manufacturer shall produce a programme of commissioning tests for use at site to confirm the compatibility of such separate units and components when assembled as a by-pass switch. A guide for commissioning tests is given in 11.101.2.

For all required operating sequences, the following shall be performed and records made of the closing and opening operations:

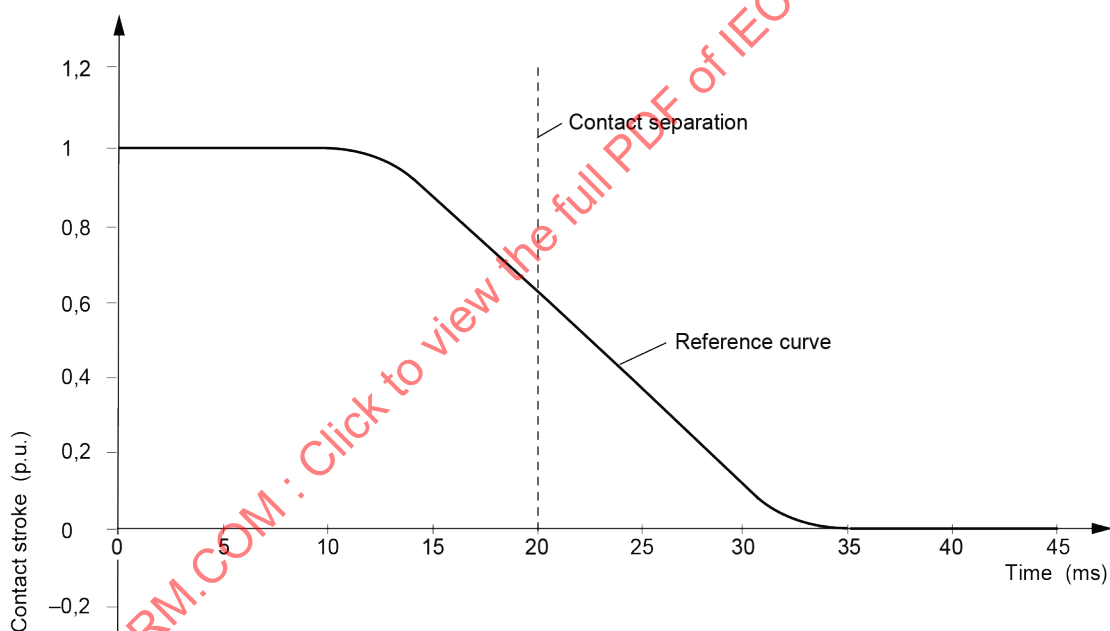
- measurement of operating times;
- where applicable, measurement of fluid consumption during operations, for example, the pressure difference.

Proof shall be given that the mechanical behaviour conforms to that of the test specimen used for type testing. For example, a no-load operating cycle, as described in 7.101.1.1, can be performed to record the no-load travel curves at the end of the routine tests. Where this is done, the curve shall be within the prescribed envelope of the reference mechanical travel characteristic, as defined in 7.101.1.1, from the instant of contact separation to the end of contact travel or from the start of contact travel to the instant of contact touch.

Where the mechanical routine tests are performed on sub-assemblies, the reference mechanical travel characteristics shall be confirmed to be correct, as above, at the end of the commissioning tests on site.

If the measurement is performed on site, the manufacturer shall state the preferred measuring procedure. If other procedures are used, the results may be different and the comparison of the instantaneous contact stroke may be impossible to achieve.

The mechanical travel characteristics can be recorded directly, using a travel transducer or similar device on the by-pass switch contact system or at other convenient locations on the drive to the contact system where there is a direct connection, and a representative image of the contact stroke can be achieved. The mechanical travel characteristics shall be preferably a continuous curve as shown in Figure 16. Where the measurements are taken on site, other methods may be applied which record points of travel during the operating period.



IEC

Figure 16 – Reference mechanical travel characteristics (idealized curve)

In these circumstances, the number of points recorded shall be sufficient to derive the time to, and contact speed at, contact touch and contact separation, together with the total travel time.

After completion of the required operating sequences, the following tests and inspections shall be performed (if applicable):

- connections shall be checked;
- the control and/or auxiliary switches shall correctly indicate the open and closed positions of the by-pass switch;
- all auxiliary equipment shall operate correctly at the limits of the supply voltage of operating devices and of auxiliary and control circuits and/or pressures for operation.

Furthermore, the following tests and inspections shall be made (if applicable):

- measurement of the resistance of heaters (if fitted) and of the control coils;
- inspection of the wiring of the control, heater and auxiliary equipment circuits and checking of the number of auxiliary contacts, in accordance with the order specification;
- inspection of control cubicle (electrical, mechanical, pneumatic and hydraulic systems);
- recharging duration(s);
- functional performance of pressure relief valve;
- the operation of electrical, mechanical, pneumatic or hydraulic interlocks and signalling devices;
- the operation of the anti-pumping device;
- general performance of equipment within the required tolerance of the supply voltage;
- inspection of earthing terminals of the by-pass switch.

9 Guide to the selection of by-pass switches ~~for service~~ (informative)

~~This clause does not apply to by-pass switches.~~ For more information refer to IEC 60143-1, IEC 60143-2 and Annexes E and F of this document.

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

10.1 General

Subclause 10.1 of IEC 62271-1:2017 is applicable.

10.2 Information ~~to be given~~ with enquiries and orders

~~When enquiring about, or ordering a by-pass switch, the following particulars shall be supplied by the enquirer:~~

Subclause 10.2 of IEC 62271-1:2017 is generally applicable with the following additions:

a) Particularities of the systems:

Nominal and highest voltages to earth and across the by-pass unit, frequency, ~~number of phases;~~

b) Service conditions if different than normal (refer to Clause 4): ~~including~~ Minimum and maximum ambient air temperatures, altitude if over 1 000 m and any special condition likely to exist or arise, for example unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air;

c) Particulars of the installation and its components

d) Characteristics of the by-pass switch.

The following information shall be given:

Type of information	Reference
1) number of poles	
2) environmental conditions (temperature, wind, ice, etc.)	4
3) rated voltage to earth and across poles	5.2
4) rated insulation level to earth and across poles where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, the desired insulation levels	5.3
5) rated frequency	5.4
6) rated ~~normal~~ continuous current	5.5
7) rated short-time withstand current	5.6
8) rated peak withstand current	5.7
9) ~~rated~~ duration of short-circuit	5.8
10) rated operating sequence	5.101
11) rated by-pass making current	5.102
12) frequency of the rated by-pass making current	5.102
13) capacitor bank discharge current	3.8.28
14) damping of the by-pass making current	5.102
15) rated by-pass insertion current	5.103
16) rated reinsertion voltage	5.104
~~17) maximum closing time~~	~~4.105~~
~~18) maximum open-close time~~	~~4.105~~
17) maximum limiting peak voltage of the overvoltage protector	5.104
18) minimum time-to-peak voltage during insertion	5.104
19) compensation factor	Annex F
20) amplitude of power swing	Annex F
21) the type tests specified ~~under~~ on special request (for example artificial pollution and radio interference, etc.)	7.1.1
22) the number of mechanical operating sequences (class M1 or M2)	5.105
23) if applicable, any test exceeding the standardised type, routine and commissioning tests	

e) characteristics of the operating mechanism of the by-pass switch and associated equipment, in particular:

- 1) number and type of spare auxiliary switches;
- 2) rated supply voltage and rated supply frequency;
- 3) number of releases for closing, if more than one;
- 4) a number of releases for opening, if more than one.

f) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels.

NOTE The enquirer should give information of any special conditions, not included above, that might influence the tender or order.

10.3 Information ~~to be given~~ with tenders

Subclause 10.3 of IEC 62271-1:2017 is generally applicable with the following additions:

When the enquirer requests technical particulars of a by-pass switch, the following information (those which are applicable) shall be given by the manufacturer, with the descriptive matter and drawings:

a) rated values and characteristics:

Type of information	Reference
1) number of poles	
2) class: environmental conditions (temperature, wind, ice-coating)	4
3) rated voltage to earth and across the pole	5.2
4) rated insulation level to earth and across the pole	5.3
5) rated frequency	5.4
6) rated ~~normal~~ continuous current	5.5
7) rated short-time withstand current	5.6
8) rated peak withstand current	5.7
9) rated duration of short-circuit	5.8
10) rated operating sequence	5.101
11) rated by-pass making current	5.102
12) frequency of the rated by-pass making current	5.102
13) capacitor bank discharge current	3.8.28
14) damping of the by-pass making current	5.102
15) rated by-pass insertion current	5.103
16) maximum limiting peak voltage of the overvoltage protector	3.8.22
17) minimum time-to-peak voltage during insertion	5.104
18) ~~rated~~ maximum closing time and ~~rated~~ maximum open-close time	6.105
19) the type tests specified ~~under~~ on special request (for example, artificial pollution and radio interference, etc.)	7.1.1
20) class M1 or class M2 for mechanical endurance	5.105

b) type tests:

certificate or report on request;

c) constructional features:

The following details are required where they are applicable to the design:

- 1) mass of complete by-pass switch without fluids for insulation, by-passing, insertion and operation;
- 2) mass/volume of fluid for insulation, its quality and operating range, including the minimum functional value;
- 3) mass/volume of fluid for by-passing and insertion (where different fluid to items 2) and/or 4)), its quality and operating range, including the minimum functional value;
- 4) mass/volume of fluid for operation (where different fluid to items 2) and/or 3)), its quality and operating range, including the minimum functional value;
- 5) tightness qualification;
- 6) mass/volume of fluids per pole to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
- 7) number of units in series per pole;
- 8) minimum clearances in air:
 - between poles;
 - to earth;
 - the safety boundaries during a by-passing operation, for by-pass switches with an external exhaust for ionised gasses or flame;
- 9) any special arrangements (for example, heating or cooling) to maintain the rated characteristics of the by-pass switch at the required temperatures of the ambient air;

- d) operating mechanism of the by-pass switch and associated equipment:
- 1) type of operating mechanism;
 - 2) rated supply voltage and/or pressure of closing mechanism, pressure limits were different to or expanding data required in c) 4) of 10.3;
 - 3) the current required at rated supply voltage to close the by-pass switch;
 - 4) energy expended to close the by-pass switch, for example, measured as a fall in pressure;
 - 5) rated supply voltage of shunt opening release;
 - 6) the current required at rated supply voltage for shunt opening release;
 - 7) number and type of spare auxiliary switches;
 - 8) the current required at rated supply voltage by other auxiliaries;
 - 9) the setting of high and low pressure interlocking devices;
 - 10) number of releases for closing, if more than one;
 - 11) number of releases for opening, if more than one;
- e) overall dimensions and other information.

The manufacturer shall give the necessary information as regards the overall dimensions of the by-pass switch and details necessary for the design of the foundation.

General information regarding maintenance of the by-pass switch and its connections shall be given.

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

11.1 General

Subclause 11.1 of IEC 62271-1:2017 is applicable, ~~with the following additions.~~

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC 62271-1:2017 is applicable.

11.3 Installation

~~Subclauses 10.2.1 to 10.2.4 of IEC 62271-1 are applicable, with the following addition.~~

Subclause 11.3 of IEC 62271-1:2017 is applicable.

11.4 ~~Operation~~ Operating instruction

Subclause 11.4 of IEC 62271-1:2017 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC 62271-1:2017 is applicable ~~with the following addition.~~

~~The manufacturer should give information regarding the maintenance of by-pass switches following by-pass making current and insertion current operations.~~

~~This information should include the number of operations after which the by-pass switch is to be overhauled.~~

~~Subclauses 10.4.1 to 10.4.3 of IEC 62271-1 are applicable. The checks required in 10.2.102.1.3 apply.~~

11.101 Guide for commissioning tests

11.101.1 General

After a by-pass switch has been installed and all connections have been completed, commissioning tests are recommended to be performed. The purpose of these tests is to confirm that transportation and storage have not damaged the by-pass switch. In addition, when a large part of the assembly and/or of the adjustment is performed on site, as identified in 8.101, the tests are required to confirm compatibility of the subcomponents and the satisfactory nature of both the site work and the functional characteristics dependent upon it.

In addition to the requirements of 11.101.2, a minimum of 50 no-load operations shall be performed at commissioning, on site, on the by-pass switch where major sub-assemblies are combined at the site without previous routine tests on the complete by-pass switch. These operations shall be performed after assembly, all connections and checks having been made and the programme of commissioning tests having been completed. These operations may include deferred routine test operations forming part of the commissioning programme only where they are made after all site adjustments and tightness checks are complete. The purpose of these tests is to reduce occurrences of maloperation and failure early in the operational life of the by-pass switch.

The manufacturer shall produce a programme of site commissioning checks and tests. Repetition of the full programme of routine tests, already performed in the factory, shall be avoided as the purpose of commissioning tests is for confirmation of:

- the absence of damage;
- compatibility of separate units;
- correct assembly;
- correct performance of the assembled by-pass switch.

In general, this is achieved when the commissioning tests include, but are not limited to, the programme given in 11.101.2. The results of the tests shall be recorded in a test report.

11.101.2 Commissioning checks and test programme

11.101.2.1 Checks after installation

11.101.2.1.1 General

Subclause 11.101.1 requires the manufacturer to produce a programme of commissioning checks and tests. This should be based on but is not limited to, the programme of checks and tests given here.

11.101.2.1.2 General checks

These shall include the following:

- assembly conforms to manufacturer's drawings and instructions;
- the tightness of by-pass switch, its fastenings, fluid systems and control devices;
- external insulation and, where applicable, internal insulation are undamaged and clean;
- paint and other corrosion protection are sound;
- operating devices, especially operating releases, are free from contamination;
- adequacy and integrity of the earth connection up to and including the interface with the substation earthing system;

and, where applicable:

- record the number on the operations counter(s) at delivery;

- record the number on the operations counter(s) at the completion of all site testing;
- record the number on the operations counter(s) at first energisation.

11.101.2.1.3 Checks of electrical circuits

This shall include:

- conformity to the wiring diagram;
- correct operation of signalling (position, alarms, lockouts, etc.);
- correct operation of heating and lighting.

11.101.2.1.4 Checks of the insulation and/or extinguishing fluid(s)

Oil	Type, dielectric strength (IEC 60296), level
SF ₆	Filling pressure/density, and quality checks, to confirm the acceptance levels of IEC 60376, IEC 60480 and ~~IEC 61634~~ IEC 62271-4. These quality checks are not required on sealed equipment and new gas used from sealed bottles. A dew point check and a check of the total impurities shall be carried out to confirm the manufacturer's acceptance levels
Gas mixtures	Quality to be confirmed prior to energisation
Compressed air	Quality (if applicable) and pressure

11.101.2.1.5 Checks on operating fluid(s), where filled or added to on site

Hydraulic oil	Level and, unless otherwise agreed, confirmation that the moisture content is sufficiently low to prevent internal corrosion or other damage to the hydraulic system
Nitrogen	Filling pressure and purity (for example oxygen free or 1 % tracer gas)

11.101.2.1.6 Site operations

Confirmation shall be given that the programme of commissioning checks and tests required by 8.101 has been completed and, where applicable, extended by the additional 50 operations required by 11.101.1.

11.101.2.2 Mechanical tests and measurements

11.101.2.2.1 Measurements of the characteristic insulating and/or by-passing and insertion fluid pressures (where applicable)

11.101.2.2.1.1 General

The following measurements shall be taken in order to compare them with the values both recorded during the routine tests and guaranteed by the manufacturer. These values serve as the reference for future maintenance and other checks and will enable any drift in operating characteristics to be detected.

These measurements involve a check of the operation of the alarm and lockout devices (pressure switches, relays, transducers, etc.) where applicable.

11.101.2.2.1.2 Measurements to be taken

- a) Where applicable, on rising pressure:
- the reset value of the closing lockout;
 - the reset value of the opening lockout;
 - the reset value of the auto-reopening lockout;
 - the disappearance of the low-pressure alarm.
- b) Where applicable, on dropping pressure:
- the appearance of low-pressure alarm;
 - the operating value of lockout of the auto-reopening feature;
 - the operating value of lockout of the opening;
 - the operating value of lockout of the closing.

11.101.2.2.2 Measurements of characteristic operating fluid pressures (if applicable)**11.101.2.2.2.1 General**

The following measurements (list to be adapted as necessary) shall be taken, in order to compare them with the values both recorded during routine tests and guaranteed by the manufacturer. These values may serve as a reference during later checks (maintenance) and will enable any drift in operating characteristics to be detected.

The measurements involve a check of the operation of the lockout or alarm devices (pressure switches, relays, etc.).

11.101.2.2.2.2 Measurements to be taken

- a) On a rise in pressure with the pumping device (pump, compressor, controlled valve, etc.) in service:
- the reset value of the closing lockout;
 - the reset value of the opening lockout;
 - the reset value of the auto-reopening lockout (if applicable);
 - the disappearance of the low-pressure alarm;
 - the cut-off of the pumping device;
 - the opening of the safety valve (if applicable).
- NOTE** The measurements may be combined with the measurements of the recharging time of the operating mechanism (see 11.101.2.2.5.2).
- b) On a drop in pressure with the pumping device switched off:
- the closing of the safety valve (if applicable);
 - starting of the pumping device;
 - the appearance of the low-pressure alarm;
 - lockout of the auto-reopening (if applicable);
 - lockout of the opening;
 - lockout of the closing.

In the case of a hydraulic control, the pre-inflation pressure of the accumulators should be indicated together with the ambient air temperature before the tests are performed.

11.101.2.2.3 Measurement of consumption during operations (if applicable)

With the pumping device switched off and the individual reservoir at the cut-in pressure of the pumping device, the consumption during each of the following operations or operating sequence should be evaluated:

- O;
- C;
- OC.

The steady-state pressure after each operation or operating sequence should be noted.

11.101.2.2.4 Verification of the rated operating sequence

The ability of the by-pass switch to perform its specified rated operating sequence should be verified. The tests should be performed with the recharging device in service, with site supply voltage and, if applicable, starting with the cut-in pressure of the pumping device, as in 11.101.2.2.3.

Evidence should be given to demonstrate the coordination between the interlocking device intervention levels and the minimum pressures for operation measured during the rated operating sequence.

The site supply voltage is the on-load voltage available at the by-pass switch from the normal site supply and should be compatible with the rated supply voltage of auxiliary and control circuits.

11.101.2.2.5 Measurement of time quantities

11.101.2.2.5.1 Characteristic time quantities of the by-pass switch

a) Closing and opening times, time spread

The following measurements should be made at maximum pressure (cut-off of pumping device) and at the supply voltage of the auxiliary and control circuits, measured at the terminals of the equipment and under typical load conditions of the supply voltage source:

- closing time of each pole, time spread of the poles and, when possible, time spread of the by-passing units or groups of units of each pole;
- opening time of each pole, time spread of the poles and, when possible, time spread of the by-passing units or groups of units of each pole.

These measurements should be carried out for separate opening and closing operations and for the individual opening and closing operations of a OC operating cycle, in case of a by-pass switch with a rated operating sequence C – t – OC – t' – OC.

In the case of multiple close and trip coils, all should be tested and the times recorded for each.

The supply voltage before and during the operations should be recorded.

b) Operation of control and auxiliary contacts

The timing of the operation of one of each kind (by-pass and insertion) of control and auxiliary contacts should be determined in relation to the operation of the main contacts, on closing and on opening of the by-pass switch.

11.101.2.2.5.2 Recharging time of the operating mechanism

a) Fluid-operated mechanism

The operation time of the pumping device (pump, compressor, control valve, etc.) should be measured:

- between minimum and maximum pressure (cut-in and cut-off of the pumping device);
- during the following operations or operating sequence, starting each time with minimum pressure (cut-in of the pumping device):
 - C;
 - O;
 - OC.

b) Spring-operated mechanism

The recharging time of the motor after an opening operation should be measured at the site supply voltage.

11.101.2.2.6 Record of mechanical travel characteristics

As required by 8.101, a record can be made of the mechanical travel characteristics where the by-pass switch has been assembled as a complete by-pass switch for the first time on site or where all or part of the routine tests are performed on site. The record shall confirm satisfactory performance by comparison with the reference mechanical travel characteristics obtained during the reference no-load tests detailed in 7.101.1.1.

11.101.2.2.7 Checks of certain specific operations**11.101.2.2.7.1 Auto-reopening at the minimum functional pressure for operation (if applicable)**

With the pumping device out of service, the control pressure should be lowered to the lockout value for auto-reopening and an auto-reopening operating sequence be carried out (under site conditions, it may be necessary to use a separate timing device to initiate reopening). The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted and it should be ensured that there is sufficient safety margin to the minimum functional pressure for operation for closing, as a guard against pressure switch deviation and pressure transients.

In case of doubt, an alternative test to the one described above may be performed, starting with a lower pressure than the minimum functional pressure for operation for auto-reopening (short-circuited contact). It should then be verified that a closing operation is still possible.

11.101.2.2.7.2 Closing at the minimum functional pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for closing and a closing operation be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted.

11.101.2.2.7.3 Opening at the minimum functional pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for opening and an opening operation be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted and a sufficient safety margin is ensured to the minimum functional pressure for closing.

In case of doubt, an alternative test to the one described above may be performed, starting with a lower pressure than the minimum functional pressure for opening (short-circuited contact). It should then be verified that a closing operation is still possible.

11.101.2.2.7.4 Simulation of fault-making operation and check of anti-pumping device

Measurement should be taken of the time during which the by-pass switch remains open ~~on a~~ during an OC operating cycle with the close circuit energized by the closing of the auxiliary contact.

The test also allows checking of the anti-pumping device operation and the absence of malfunction for any mechanical, hydraulic or pneumatic reasons, caused by the rapid application of the closing command.

The opening command should be maintained for 1 s to 2 s in order that the anti-pumping device can be checked for effective operation.

NOTE A simplified anti-pumping test may also be executed, using the local control. In this case, an opening command is applied and maintained, while a consecutive closing command is applied.

11.101.2.2.7.5 Behaviour of the by-pass switch on an opening command while a closing command is already present

It should be verified that the by-pass switch meets the technical specifications in the presence of an opening command when previously a closing command is applied and maintained.

11.101.2.2.7.6 Application of a closing command on both releases simultaneously (if applicable)

It may happen that both releases (normal and emergency) are energized simultaneously (or virtually simultaneously).

It should be ensured that the operations are not subject to any mechanical, hydraulic or pneumatic interference, particularly if the releases do not operate at the same level.

11.101.2.2.7.7 Protection against pole discrepancy (if applicable)

Protection against pole discrepancy should be checked by either of the following tests:

- with the by-pass switch open, the closing release of one of the poles shall be energized and a check carried out to see that all poles close;
- with the by-pass switch closed, the opening release of one of the poles shall be energized and a check carried out to see that it opens and then closes.

11.101.2.3 Electrical tests and measurements

11.101.2.3.1 Dielectric tests

Dielectric tests on auxiliary circuits shall be performed to confirm that transportation and storage of the by-pass switch have not damaged these circuits. However, it is recognized that such circuits contain vulnerable sub-components and the application of the full testing voltage for the full duration can cause damage. In order to avoid this, and to avoid the temporary removal of proven connections, the supplier shall detail the test process that demonstrates that damage has not occurred as well as the method of recording the results from this test process.

For dielectric tests on the main circuit of metal-enclosed switchgear and controlgear, IEC 62271-200 and IEC 62271-203 are applicable (see Bibliography).

11.101.2.3.2 Measurement of the resistance of the main circuit

Measurement of the resistance of the main circuit need only be made if by-passing units have been assembled on site. The measurement shall be made with a direct current in accordance with 8.4 of IEC 62271-1:2017.

11.101.3 Resistors and capacitors (if applicable)

When checking resistors and capacitors, allowed variations of the values should be given.

12 Safety

12.1 General

Subclause 12.1 of IEC 62271-1:2017 is applicable with the following addition.

Any known chemical and environmental impact hazards should be identified in the by-pass switch handbook/manual.

12.2 Precautions by manufacturers

Subclause 12.2 of IEC 62271-1:2017 is applicable.

12.3 Precautions by users

Subclause 12.3 of IEC 62271-1:2017 is applicable.

13 Influence of the product on environment

Clause 13 of IEC 62271-1:2017 is applicable.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex A (normative)

Tolerances on test quantities during type tests

A.1 — Types of tolerances

During type tests, the following types of tolerances may normally be distinguished:

- tolerances on test quantities which directly determine the stress of the test object;
- tolerances concerning features or the behaviour of the test object before and after the test;
- tolerances on test conditions;
- tolerances concerning parameters of measurement devices to be applied.

In the following Table A.1, only tolerances on test quantities are considered.

A tolerance is defined as the range of the test value specified in this document within which the measured test value should lie for a test to be valid. In certain cases (see 7.1.101 and Table 5) the test may remain valid even if the measured value falls outside the tolerance.

Any deviation of the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

The basic rules for the application of tolerances on test quantities during type tests are as follows:

- a) testing stations shall aim wherever possible for the test values specified;
- b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses of the by-pass switch exceeding those tolerances are permitted only with the consent of the manufacturer. Lower stresses render the test invalid;
- c) where, for any test quantity, no tolerance is given within this document, or the document to be applied, the type test shall be performed at values not less severe than specified. The upper-stress limits are subject to the consent of the manufacturer;
- d) if for any test quantity, only one limit is given, the other limit shall be considered to be as close as possible to the specified value.

Table A.1 – Tolerances on test quantities for type tests (1 of 3)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerances/ limits of test values	Reference to
7.2	Dielectric tests				
7.2.7.2 and 7.2.8.2	Power-frequency voltage tests	Test voltage (RMS value)	Rated short-duration power-frequency withstand voltage	±1 %	IEC 62271-1, IEC 60060 (all parts)
7.2.7.3 and 7.2.8.4	Lightning impulse voltage tests	Frequency	--	45 Hz to 65 Hz	IEC 60060 (all parts)
		Wave shape	Peak value / RMS value = $\sqrt{2}$	±5 %	
		Peak value	Rated lightning impulse withstand voltage	±3 %	
		Front time	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	
7.2.8.3	Switching impulse voltage tests	Peak value	Rated switch impulse withstand voltage	±3 %	
		Time to peak	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
7.2.12	Voltage tests as condition check using standard switching impulse voltage	Peak value of switching impulse voltage	See 7.2.12	±3 %	IEC 60060 (all parts)
		Time to peak	250 µs	±20 %	
		Time ~~of~~ to half-value	2 500 µs	±60 %	
	Using TRV circuit of T10	Peak value of switching impulse voltage	See 7.2.12	±3 %	
		Time to peak	Standard value for T10 (see ~~Tables 26 and 27 of~~ IEC 62271-100)	+200 % -10 %	
7.3	Radio interference voltage tests	Test voltage	See 7.3 of IEC 62271-1:2017	±1 %	IEC 60060 (all parts)
7.4	Measurement of the resistance of the main circuit	DC test current I_{DC}	--	$50 A \leq I_{DC} \leq$ rated normal current	IEC 62271-1
7.5	~~Temperature-rise~~ Continuous	Ambient air velocity	--	≤ 0,5 m/s	IEC 62271-1

current tests	Test current frequency	Rated frequency	+2 % –5 %	+2 % 0 % –5 % These limits shall be kept only for the last two hours of the testing period	+10 °C < T < 40 °C
7.6	Test current	Rated normal current	±10 %	±10 %	IEC 62271-1
	Ambient air temperature T	--	±5 %	±5 %	
	Test frequency	Rated frequency	±5 %	±5 %	
	Peak current (in one of the outer phases)	Rated peak withstand current	±5 %	±5 %	
	Average of AC component of the three-phase test current	Rated short-time withstand current	±5 %	±5 %	
	AC component of test current in any phase/average	1	±10 %	±10 %	
	Short-circuit current duration	Rated short-circuit duration	See tolerances for I ² t	See tolerances for I ² t	
7.101.3	Value of I ² t	Rated value I ² t	+10 % 0 %	+10 % 0 %	
	Deviation of ambient air temperature over height of test object	--	≤ 5 K	≤ 5 K	
	Ambient air temperature for recording characteristics before test	20 °C	±5 K	±5 K	
	Minimum and maximum ambient air temperature during tests	According to class of by-pass switch (see IEC 62271-1)	±3 K	±3 K	
	Maximum temperature of a cycle	40 °C	±2 K	±2 K	
	Forces	As specified in 6.101.6	+10 % 0 %	+10 % 0 %	
	Guide for static terminal load test				
6.101.6	By-pass making current test-duty	Applied voltage before making	+5 % 0 %	+5 % 0 %	7.103.2.3
		Rated by-pass making current	+5 % 0 %	+5 % 0 %	7.103.2.4
		Capacitor bank discharge current	+5 % 0 %	+5 % 0 %	7.103.2.4

		Frequency of the rated by-pass making current	f_{BP}		As close as possible to the required value. Shall not be lower than 77 % of the service condition and not higher than 6 000 Hz	7.103.2.4
		Damping factor of the rated by-pass making current	I_2 / I_1		~~Equal to or greater~~ not less than 10 % of service condition	7.103.2.2
		Test current at power frequency	I_{INS}		±20 %	7.103.3.4
		Frequency of the test current	From 49 Hz to 61 Hz			7.103.3.1
		~~Transient~~ Recovery voltage, peak value	U_{PL}		0 %, +5 %	7.103.3.3
		Time to peak of the ~~transient~~ recovery voltage	Specified value		±5 %	7.103.3.1
		Amplitude of the initial voltage jump of the "1-cos" waveshape			≤ 5 % of the peak of the ~~transient~~ recovery voltage	7.103.3.2
		RMS current value/RMS current value of fundamental	≤ 1,2			7.103.3.3
		Waveshape of the recovery voltage		Maximum instantaneous deviation over the theoretical test voltage waveshape of the corresponding "1-cos curve" with the exception of the initial voltage jump	+3 % of the peak -0 recovery voltage u_c	7.103.3.1
7.103.3	Insertion current test-duty					

Annex B (normative)

Records and reports of type tests

B.1 Information and results to be recorded

All relevant information and results of type tests shall be included in the type test report.

Oscillographic records, in accordance with B.2, shall be made for all by-pass making current operations and insertion current operations and no-load operations included in the type test report.

The type test report shall include a statement concerning the uncertainty of the measurement systems used for the tests. This statement shall refer to internal procedures of the laboratory through which traceability of the measuring uncertainty is established.

The type test report shall include a statement of the performance of the by-pass switch during the test duties and of the condition of the by-pass switch at the end of the series of test duties. The statement shall include the following particulars:

- a) the condition of the by-pass switch, giving details of any replacements or adjustments made and condition of contacts, arc control devices, oil (including any quantity loss), statement of any damage to arc shields, enclosures, insulators and bushings;
- b) description of performance during test duties, including observations regarding emission of oil, gas or flame.

B.2 Information to be included in type test reports

B.2.1 General

- a) date of tests;
- b) reference of report number;
- c) test numbers;
- d) oscillogram numbers.

B.2.2 Apparatus tested

Clause 7 of IEC 62271-1:2017 is applicable.

Reference drawing numbers given in the test report shall indicate the manufacturer's reference number, revision number and corresponding contents.

The reference mechanical characteristic, if applicable, shall be included or reference shall be made in the test report by the use of a drawing number or in an equivalent way.

B.2.3 Rated characteristics of by-pass switch, including its operating devices and auxiliary equipment

The values of rated characteristics specified in Clause 5 shall be given by the manufacturer.

B.2.4 Test conditions (for each series of tests; if applicable)

- a) number of poles;
- b) power factor;

- c) frequency, in Hz;
- d) generator neutral (earthed or isolated);
- e) transformer neutral (earthed or isolated);
- f) diagram of test circuit including connection(s) to earth;
- g) details of the connection of the by-pass switch to the test circuit (e.g. orientation);
- h) pressure of fluid for insulation and/or by-passing and insertion;
- i) pressure of fluid for operation.

B.2.5 Short-time withstand current and peak withstand current test

- a) current
 - 1) RMS value in kA,
 - 2) peak value in kA;
- b) duration, in s;
- c) behaviour of the by-pass switch during tests;
- d) condition after tests;
- e) resistance of the main circuit before and after tests, in $\mu\Omega$.

B.2.6 No-load operation

- a) before each by-passing and insertion test set (see 7.102.6);
- b) after the last insertion test set (see 7.102.9.2);
- c) before and after the short-time withstand current and peak withstand current test.

B.2.7 By-pass making current test-duty

- a) applied voltage, in kV;
- b) peak making current, in kA;
- c) frequency in Hz;
- d) damping ratio;
- e) closing time, in ms;
- f) pre-arcing time, in ms;
- g) by-pass time, in ms;
- h) behaviour of the by-pass switch during tests;
- i) condition after tests.

B.2.8 Insertion current test-duty

- a) breaking current, in A;
- b) ~~transient~~ recovery voltage, peak value, in kV;
- c) time to ~~transient~~ recovery voltage peak value, in ms;
- d) details on point-of-wave setting;
- e) arcing time, in ms;
- f) number of restrikes (if any), the occurrence of NSDDs (if any) shall be noted for vacuum by-pass and insertion units;
- g) behaviour of the by-pass switch during tests;
- h) condition after tests.

B.2.9 Oscillographic and other records

Oscillograms shall record the whole of the operations. The following quantities shall be recorded. Certain of these quantities may be recorded separately from the oscillograms, and several oscillographs with different time scales may be necessary:

- a) applied voltage;
- b) current in each pole;
- c) recovery voltage (voltage across the by-pass switch);
- d) current in closing coil;
- e) current in opening coil;
- f) amplitude and timing scale appropriate for the required accuracy;
- g) mechanical travel characteristics (where applicable).

All cases in which the requirements of this document are not strictly complied with and all deviations shall be explicitly mentioned at the beginning of the test report.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex C (informative)

(Void)

List of symbols and abbreviations used

Symbol/ abbreviation	Exemplary reference	Meaning
A, a	Table 6	Designation of a terminal of a by-pass switch
A	6.101.6.2	Direction of horizontal force
A_1	Figure 6	Direction of horizontal force
A_2	Figure 6	Direction of horizontal force
B, b	Table 6	Designation of a terminal of a by-pass switch
B_1	6.101.6.2	Direction of horizontal force
B_2	6.101.6.2	Direction of horizontal force
β	Annex F	Damping of the oscillation between the capacitance of the series capacitor bank and the line inductance
C, c	Table 6	Designation of a terminal of a by-pass switch
C	4.101	Closing operation
C_1	6.101.6.2	Direction of vertical force
C_2	6.101.6.2	Direction of vertical force
$C \text{ — } t \text{ — } OC$	4.101	Close-open-close operating cycle
C_N	3.8.3	Rated capacitance
F	Table 6	Designation of the frame of a by-pass switch
f_{BP}	4.102	Frequency of the rated by-pass making current
f_r	4.3	Rated frequency
F_{shA}	6.101.6.1	Terminal load, horizontal force
F_{shB}	6.101.6.1	Terminal load, horizontal force
F_{ev}	6.101.6.1	Terminal load, vertical force
F_{th}	Table 4	Static horizontal force
F_{thA}	Table 4	Static horizontal force, longitudinal
F_{thB}	Table 4	Static horizontal force, transversal
F_{wh}	Figure 5	Force due to wind and ice coating
F_{tv}	Table 4	Static vertical force
I_1	Table A.1	First current peak during by-pass making current test-duty
I_2	Table A.1	Second current peak (of the same polarity than I_1) during by-pass making current test-duty
I_{BP}	4.102	Rated by-pass making current
$I_{DISCHARGE}$	3.8.28	Capacitor bank discharge current
I_{INS}	4.103	Rated by-pass insertion current
I_k	4.5	Rated short-time withstand current
I_{load}	Annex F	Actual insertion current
I_N	3.8.4	Rated current of a capacitor
I_p	4.6	Rated peak withstand current

Symbol/ abbreviation	Exemplary reference	Meaning
I_F	4.4	Rated normal current
k	Annex F	Compensation factor X_C/X_L
M	Table 1	Mass of the by-pass switch
m	Table 1	Mass of fluid for by-passing and insertion
M1	3.4.104	Class of by-pass switch with basic mechanical endurance
M2	3.4.105	Class of by-pass switch with extended mechanical endurance
O	Table 3	Opening operation
OG	4.101	Open-close operating cycle
P_{re}	Table 1	Rated pressure for by-passing and insertion
P_{rm}	Table 1	Rated pressure for operation
T10	6.2.11	Terminal fault test duty (see IEC 62271-100)
t	4.101	Time interval in the rated operating sequence
t'	4.101	Time interval in the rated operating sequence
t_3	6.2.11	Time coordinate of T10 TRV
T_A	6.101.3.3	Ambient air temperature
t_a	6.101.2.3	Time between two operations for mechanical operation test at ambient air temperature
T_H	6.101.3.4	Maximum ambient air temperature
t_k	4.7	Rated duration of short circuit
T_L	6.101.3.3	Minimum ambient air temperature
TRV	6.2.11	Transient recovery voltage
t_x	6.101.3.3	Time interval in low temperature test
$u(t)$	Annex F	Transient reinsertion voltage across the by-pass switch
U_a	4.8	Rated supply voltage of auxiliary and control circuits
U_{INS}	4.104	Rated reinsertion voltage
U_{LIM}	3.8.7	Limiting voltage
U_{op}	Table 1	Rated supply voltage of operating devices
U_N	3.8.6	Rated voltage of a capacitor
U_{pe}	Table 1	Rated lightning impulse withstand voltage to earth
U_{PL}	3.8.22	Protective level
U_{pp}	Table 1	Rated lightning impulse withstand voltage across the by-pass switch
U_r	4.1	Rated voltage
U_{re}	4.1.101	Rated voltage to earth
U_{rp}	4.1.102	Rated voltage across the by-pass switch
U_{se}	Table 1	Rated switching impulse withstand voltage to earth
U_{sp}	Table 1	Rated switching impulse withstand voltage across the by-pass switch
X_N	4.1.102	Rated reactance of the series capacitor
ω_1	Annex F	Angular frequency derived from the rated power frequency
ω_2	Annex F	Angular frequency of the undertone caused by the oscillation between the capacitance of the series capacitor bank and the line inductance

Annex D

(informative)

Examples of by-pass switch ratings

Tables D.1 to D.3 illustrate case studies of typical series capacitor bank ratings used in recent projects. The tables also illustrate the corresponding by-pass switch ratings. The values given in the tables should be used as a guideline for assigning rated values to by-pass switches since specific ratings cannot be standardized because they are project specific. It should be noted that some insulation levels were specified according to IEEE standards and are given solely as examples. Values given in these tables correspond to the same nomenclature and abbreviation of the various ratings that are outlined in Clause 5.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Table D.1 – Typical ratings for a series capacitor bank by-pass switch – Cases 1 to 6

Rating	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Rated voltage to earth U_{re}	kV RMS	500	500	500	500	500	500
Line maximum system voltage	kV RMS	560	560	560	560	560	560
Capacitor bank rated voltage U_N	kV RMS	101,3	63,9	63,5	70,4	69,9	94,8
Overload voltage	kV RMS	136,8	86,3	81,3	87,3	86,7	117,5
Protective level U_{PL}	kV ~~peak~~	310,9	225,9	195,7	204	197,7	268,1
Rated frequency f_r	Hz	60	60	60	60	60	60
Rated normal current I_r	A RMS	4 000	4 000	3 000	3 000	3 000	3 000
Rated 30 min current	A RMS	5 400	5 400	4 050	4 050	4 050	4 050
Swing current (max. 30 s)	A RMS						
Insulation levels to earth							
~~— Rated lightning impulse withstand voltage, U_{pe}~~	kV RMS	710	710	710	710	860	860
~~— Rated power-frequency withstand voltage, dry, 1 min U_{de}~~	kV RMS						
~~— Rated power-frequency withstand voltage, wet, 10 s U_{de}~~	kV peak	1 050	1 050	1 050	1 050	1 175	1 175
~~— Rated switching impulse withstand voltage, U_{se}~~	kV peak	1 550	1 550	1 550	1 550	1 800	1 800
— Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	710	710	710	710	860	860
— Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
— Rated lightning impulse withstand voltage, U_{pe}	kV	1 550	1 550	1 550	1 550	1 800	1 800
— Rated switching impulse withstand voltage, U_{se}	kV	1 050	1 050	1 050	1 050	1 175	1 175
Insulation levels between terminals							
— Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	425	260	310	310	310	365
— Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS	350	230	275	275	275	315
— Rated lightning impulse withstand voltage, U_{pp}	kV ~~peak~~	900	550	650	650	650	750
Short time current withstand							
— Rated short-time withstand current I_k	kA RMS	63	40	40	40	40	40
— Rated duration of short-circuit t_k	s	3	3	3	3	3	3
— Rated peak withstand current I_p	kA ~~peak~~	164	128	128	128	128	128

Rating		Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Rated operating sequence			O-C-I-O-C-I-O-I-O-I-C-I-O-C	C-I-O-C-I-I-O-I-I-C-I-O-C	C-I-O-C-I-I-O-I-I-C-I-O-C	C-I-O-C-I-I-O-I-I-C-I-O-C	C-I-O-C-I-I-O-I-I-C-I-O-C	C-I-O-C-I-I-O-I-I-C-I-O-C
-	t	s	0,3	0,3	0,3	0,3	0,3	0,3
-	t'	s	30	30	30	30	30	30
Maximum closing time		ms	34	34	34	34	34	34
Maximum opening time		ms	50	50	50	50	50	50
Insertion current								
-	Rated by-pass insertion current I_{INS}	A RMS	5 400	4 050	3 240	3 240	3 240	4 250
-	Rated reinsertion voltage U_{INS}	kV peak	310,9	225,9	195,7	204	197,7	268,1
-	Reinsertion voltage, first time-to-peak	ms	8	8	8	8	8	8
By-pass making current under normal operating condition								
-	Capacitor bank discharge current component $I_{DISCHARGE}$	kA peak	37	28	21	23	23	25
-	Power-frequency current	kA peak	5,7	4,5	4,2	4,1	4,0	4,0
-	By-pass making current	kA peak	42,7	32,5	25,2	27,1	27,0	29,0
-	Frequency of the by-pass making current f_{BP}	Hz	385,2	509,4	408,1	470,5	471,2	530,2
-	Applied voltage	kV peak	143,3	90,4	89,8	99,6	98,9	134,1
By-pass making current under fault condition								
-	Capacitor bank discharge current component $I_{DISCHARGE}$	kA peak	80	71	52	56	57	67
-	Power-frequency fault current	kA peak	65	34	27	21	24	24
-	By-pass making current	kA peak	139	105	79	77	81	91
-	Frequency of the by-pass making current f_{BP}	Hz	385,2	509,4	408,1	470,5	471,2	530,2
-	Applied voltage	kV peak	310,9	225,9	195,7	204	197,7	268,1
-	Damping factor							
Specified electrical and mechanical endurance								
-	No-load operations	CO						
-	Number of operations/year at rated current	CO	20	20	20	20	20	20
-	Number of operations/year under fault condition	CO	1	1	1	1	1	1
-	Operations under fault condition (lifetime)	CO						

Table D.2 – Typical series capacitor bank by-pass switch ratings – Cases 7 to 12

Rating	Unit	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Rated voltage to earth U_{re}	kV RMS	500	500	735	245	345	345
Line maximum system voltage	kV RMS	550	550	800	245	362	362
Capacitor bank rated voltage U_N	kV RMS	19,9	19,9	80	46	42,6	55,6
Overload voltage	kV RMS	29,9	29,9	140	68/105		
Protective level U_{PL}	kV ~~peak~~	81,6	81,6	270	148	144,4	188,6
Rated frequency f_r	Hz	60	60	60	60	60	60
Rated normal current I_r	A RMS	3 150	3 150	4 000	630	2 000	2 000
Rated 30 min. current	A RMS			6 000	945		
Swing current (max. 30 s)	A RMS			7 000	1 103	2 700	2 700
Insulation levels to earth							
– Rated lightning impulse withstand voltage, U_{pe}	kV RMS	650	650	830	450	740	740
– Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS						
– Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV peak	1 550	1 550	1 550	850	1 550	1 550
– Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	650	650	830	450	710	710
– Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
– Rated lightning impulse withstand voltage, U_{pe}	kV	1 550	1 550	1 550	850	1 550	1 550
– Rated switching impulse withstand voltage, U_{se}	kV ~~peak~~	1 175	1 175	2 100	1 175	1 050	1 050
Insulation levels between terminals							
– Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	110	110	230	140	145	185
– Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS	69,3	69,3		185 (1 s)		
– Rated lightning impulse withstand voltage, U_{pp}	kV ~~peak~~	200	200	550	325	350	450
Short time current withstand							
– Rated short-time withstand current I_k	kA RMS	40	40	40	25	40	40
– Rated duration of short-circuit t_k	s	1	1	1	1	1	1
– Rated peak withstand current I_p	kA ~~peak~~	128	128	108	65		

Rating	Unit	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Rated operating sequence		O-C-t-OC-t'-O- O-t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC	C-t-OC-t'- OC	C-t-OC-t'- OC	C-O-C-t'-O- C	C-O-C-t'-O- C
– t	s	0,3	0,3	0,3	0,3		
– t'	s	30	30	15	15	30	30
Maximum closing time	ms	34	34	100	50	30	30
Maximum opening time	ms						
Insertion current							
– Rated insertion current I_{INS}	A RMS	4 800	4 800	4 000	400	3 000	3 000
– Rated reinsertion voltage U_{INS}	kV-peak	81,6	81,6	270	148		
– Reinsertion voltage, first time-to-peak	ms	4	4	4	4		
By-pass making current under normal operating condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA-peak	18,3	18,3	30	23	37	37
– Power-frequency current	kA-peak			4	0,6		
– By-pass making current	kA-peak			34	24	37	37
– Frequency of the by-pass making current f_{BP}	Hz	708	744	1 000	840	900	900
– Applied voltage	kV-peak	28,1	28,1	115	65,1	60,2	78,6
By-pass making current under fault condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA-peak	75	75	70	52	85	85
– Power-frequency fault current	kA-peak	65	65	5,6	8	15	15
– By-pass making current	kA-peak	140	140	75,6	60	100	100
– Frequency of the by-pass making current f_{BP}	Hz	708	744	1 000	840	900	900
– Applied voltage	kV-peak	81,6	81,6	270	148	144,4	188,6
– Damping factor				0,5	0,5		
Specified electrical and mechanical endurance							
– No-load operations	CO			2 000	2 000		
– Number of operations/year at rated current	CO	5	5	15	20		
– Number of operations/year under fault condition	CO			5	10		
– Operations under fault condition (lifetime)	CO	1	1	150	300		

Table D.3 – Typical series capacitor bank by-pass switch ratings – Cases 13 to 18

Rating	Unit	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18
Rated voltage to earth U_{re}	kV RMS	500	500	400	400	500	500
Line Maximum system voltage	kV RMS	550	550	460	460	550	550
Capacitor bank rated voltage U_N	kV RMS	65,4		33,8	33,8	61,7	170
Overload voltage	kV RMS			45,6	45,6		
Protective level U_{PL}	kV ~~peak~~	212,7		110	110	200,6	383
Rated frequency f_r	Hz	60	50	60	60	50	60
Rated normal current I_r	A RMS	3 000	3 150	2 000	2 000	2 500	3 000
Rated 30 min. current	A RMS	4 500					
Swing current (max. 30 s)	A RMS	5 700					
Insulation levels to earth							
— Rated lightning impulse withstand voltage, U_{pe}	kV r.m.s.	710		860	860	680	860
— Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV r.m.s.						775
— Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV peak	1 800	1 500	1 550	1 550	1 550	1 550
— Rated switching impulse withstand voltage, U_{se}	kV peak					1 175	1 175
— Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	710		860	860	680	860
— Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
— Rated lightning impulse withstand voltage, U_{pe}	kV					1 175	1 175
— Rated switching impulse withstand voltage, U_{se}	kV ~~peak~~	1 800	1 500	1 550	1 550	1 550	1 550
Insulation levels between terminals							
— Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	185					325
— Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS						
— Rated lightning impulse withstand voltage, U_{pp}	kV ~~peak~~	450					750
Short time current withstand							
— Rated short-time withstand current I_k	kA RMS	40	50	40	40	50	40
— Rated duration of short-circuit t_k	s	1	3	3	3	3	1
— Rated peak withstand current I_p	kA ~~peak~~		125	100	100	125	108

Rating	Unit	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18
Rated operating sequence		(O)-C-O-C	C-O-C-t'-O-C	O-t'-CO-t'-CO	O-t'-CO-t'-CO	C-O-C-t'-O-C	C-O-C-t'-O-C
– t	s			0,3	0,3		
– t'	s		30	30	30	30	30
Maximum closing time	ms	< 35	< 50	36	36		< 50
Maximum opening time	ms		< 50				< 50
Insertion current							
– Rated insertion current I_{INS}	A RMS	4 500	3 150			3 600	3 650
– Rated reinsertion voltage U_{INS}	kV ~~peak~~					200,6	383
– Reinsertion voltage, first time-to-peak	ms					6,7	8,3
By-pass making current under normal operating condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA ~~peak~~	40				52,8	
– Power-frequency current	kA ~~peak~~	15					
– By-pass making current	kA ~~peak~~	55				52,8	
– Frequency of the by-pass making current f_{BP}	Hz	430				620	680
– Applied voltage	kV ~~peak~~	92,5				123,3	240,4
By-pass making current under fault condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA ~~peak~~	70		68	68	80,9	91
– Power-frequency fault current	kA ~~peak~~	30		40	40	24,7	
– By-pass making current	kA ~~peak~~	100		108	108	105,6	108
– Frequency of the by-pass making current f_{BP}	Hz	430		1 048	1 048	620	680
– Applied voltage	kV ~~peak~~	150,4		110	110	200,6	383
– Damping factor						0,3	
Specified electrical and mechanical endurance							

– No-load operations	CO					5 000				6 000	
– Number of operations/year at rated current	CO										
– Number of operations/year under fault condition	CO										
– Operations under fault condition (lifetime)	CO										

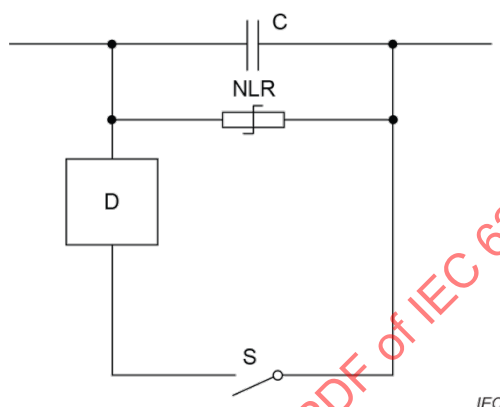
IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex E

(informative normative)

By-pass switches used as the primary by-passing devices

By-pass switches are sometimes used as the primary protection of the overvoltage protector of the series capacitor bank (e.g. without the use of a fast by-passing device such as a spark-gap) for cases where the power-frequency fault current is relatively low (capacitor banks generally located in the middle of the line length) or where the use of a spark-gap could result in non-reliable operation of the spark-gap. For such series capacitor schemes, the varistor bank is designed to absorb the resulting energy produced by a line fault until the by-pass switch is closed. Figure E.1 illustrates the typical components layout.



Key

C	series capacitor
NLR	non-linear resistor (varistor)
D	damping circuit
S	by-pass switch

Figure E.1 – Typical component layout for by-pass switches used as the primary by-passing device

For this particular application, the requirements stated in this document also apply with the following addition.

~~In such configuration,~~ The by-pass switch will be subjected, for all line faults, to the capacitor bank discharge current component ($I_{\text{DISCHARGE}}$) and to the power-frequency fault current. For schemes using fast by-passing devices (for example spark-gap), these types of stresses are not frequent since they are almost always seen by the fast by-passing device and not by the by-pass switch.

~~For such applications and because of this increased electrical duty, it may be necessary to specify a greater number of making operations during the by-pass making current test duty (see 6.104). The number of operations should be determined based on the expected number of line faults per year, the required service time before maintenance and associated electrical parameters. If such an increase duty is required, it should be clearly notified in the enquiry.~~

Test parameters of already performed by-pass making current tests can be used to qualify a by-pass switch for this specific application as follows:

- A by-pass switch has been tested following alternative 1 (see 7.103.2.5) at a by-pass making current I_{BP} . This by-pass switch can be used as a primary by-passing device in an installation having a by-pass making current of up to the tested I_{BP} .

- A by-pass switch has been tested following alternative 2 (see 7.103.2.5) at a by-pass making current I_{BP} and a discharge current $I_{DISCHARGE}$. The tested parameters result in an equivalent I_{BPE} for gapless application as follows:

$$(I_{BP})^2 \times 4 + (I_{DISCHARGE})^2 \times 20 = (I_{BPE})^2 \times 20 \rightarrow I_{BPE} = \sqrt{\frac{(I_{BP})^2}{5} + (I_{DISCHARGE})^2}$$

Example: A by-pass switch has been tested following alternative 2 (see 7.103.2.5) at a by-pass making current of 120 kA and a discharge current of 70 kA. The tested parameters give an equivalent I_{BPE} for gapless application as follows:

$$(120)^2 \times 4 + (70)^2 \times 20 = (I_{BPE})^2 \times 20 \rightarrow I_{BPE} = 88,2 \text{ kA.}$$

This by-pass switch can be used as the primary by-passing device in an installation having a by-pass making current of up to 88,2 kA.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex F (informative)

Explanatory note regarding ~~transient~~ recovery voltage during reinsertion

When a by-pass switch reinserts a series capacitor bank, the ~~transient~~ reinsertion voltage appearing across the open contacts of the by-pass switch is function of the load current at power frequency, including any power swing and emergency load current, if applicable, and the transient damped oscillatory current produced by the resonance of the capacitive impedance and line impedance. This ~~transient~~ reinsertion voltage across the by-pass switch can be determined the following equation:

$$u(t) = U_N \times \sqrt{2} \times (\cos \omega_1 t - e^{-\beta t} \cos \omega_2 t) \times I_{\text{load}} / I_N$$

where

- $u(t)$ is the ~~transient~~ reinsertion voltage across the by-pass switch;
- U_N is the rated voltage of the series capacitor bank (RMS value);
- ω_1 is the angular frequency derived from the rated power frequency;
- t is the time, in s;
- β is the damping of the oscillation between the capacitance of the series capacitor bank and the line inductance, usually between 0,8 and 0,9;
- ω_2 is the angular frequency of the undertone caused by the oscillation between the capacitance of the series capacitor bank and the line inductance

$$\omega_2 = \omega_1 \times \sqrt{k}$$

and

$$k = X_C / X_L$$

- k is the compensation factor;
- I_{load} is the actual insertion current of the series capacitor bank (RMS value);
- I_N is the rated current of the series capacitor bank (RMS value).
- X_C is the capacitive reactance in Ω of the series capacitor bank ($X_C = 1/\omega_1 C$);
- X_L is the inductive reactance in Ω of the series compensated line ($X_L = \omega_1 L$);
- C is the capacitance of the series capacitor bank;
- L is the inductance of the series compensated line.

In IEC 60143-1, typical emergency overload currents range from 1,2 p.u. to 1,6 p.u. and power swings range from 1,7 p.u. to 2,5 p.u. According to IEC 60143-1, typical compensation factors range from 0,2 p.u. to 0,8 p.u. and protective levels U_{PL} range from between 2,0 p.u. and 2,5 p.u.

The combined effect of the undertone frequency, load current, including emergency and power swing currents and the operation level (U_{PL}) of the non-linear, voltage-limiting device (varistors) may cause the first voltage peak of the ~~transient~~ reinsertion voltage across the by-pass switch to be earlier than half of the power-frequency period e.g. 10 ms for 50 Hz systems or 8,3 ms for 60 Hz systems.

The protective level in p.u. is defined as $U_{PL} / (U_N / \sqrt{2})$ with U_{PL} being a peak value and U_N being an RMS value.

Therefore, the reinsertion voltage given in p.u. of the rated capacitor peak voltage is given by:

$$u(t) \text{ p.u.} = (\cos \omega_1 t - e^{-\beta t} \cos \omega_2 t) \times I_{\text{load}} / I_N$$

Tables F.1 to F.16 illustrate some examples.

**Table F.1 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing nor emergency overload,
 $I_{\text{load}} = 1,0$ p.u.; $U_{\text{PL}} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,26	8,6	No
0,3	1,00	8,2	No
0,4	0,79	7,8	No
0,5	0,61	7,5	No
0,6	0,46	7,3	No
0,7	0,32	7,1	No
0,8	0,20	6,9	No

**Table F.2 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{\text{load}} = 1,2$ p.u.; $U_{\text{PL}} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,51	8,6	No
0,3	1,20	8,2	No
0,4	0,95	7,8	No
0,5	0,74	7,5	No
0,6	0,55	7,3	No
0,7	0,39	7,1	No
0,8	0,25	6,9	No

**Table F.3 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,76	8,6	No
0,3	1,40	8,2	No
0,4	1,11	7,8	No
0,5	0,86	7,5	No
0,6	0,64	7,3	No
0,7	0,45	7,1	No
0,8	0,29	6,9	No

**Table F.4 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,01	8,6	No
0,3	1,60	8,2	No
0,4	1,27	7,8	No
0,5	0,98	7,5	No
0,6	0,73	7,3	No
0,7	0,52	7,1	No
0,8	0,33	6,9	No

Table F.5 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	7,8	Yes
0,3	1,80	8,2	No
0,4	1,43	7,8	No
0,5	1,10	7,5	No
0,6	0,83	7,3	No
0,7	0,58	7,1	No
0,8	0,37	6,9	No

Table F.6 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	6,7	Yes
0,3	2,01	8,2	No
0,4	1,58	7,8	No
0,5	1,23	7,5	No
0,6	0,92	7,3	No
0,7	0,65	7,1	No
0,8	0,41	6,9	No

Table F.7 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,9	Yes
0,3	2,20	7,2	Yes
0,4	1,82	7,8	No
0,5	1,41	7,5	No
0,6	1,05	7,3	No
0,7	0,74	7,1	No
0,8	0,47	6,9	No

Table F.8 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,6	Yes
0,3	2,20	6,4	Yes
0,4	1,98	7,8	No
0,5	1,53	7,5	No
0,6	1,15	7,3	No
0,7	0,81	7,1	No
0,8	0,51	6,9	No

**Table F.9 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing nor emergency overload,
 $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,26	7,2	No
0,3	1,00	6,8	No
0,4	0,79	6,5	No
0,5	0,61	6,3	No
0,6	0,46	6,1	No
0,7	0,32	5,9	No
0,8	0,20	5,7	No

**Table F.10 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,51	7,2	No
0,3	1,20	6,8	No
0,4	0,95	6,5	No
0,5	0,74	6,3	No
0,6	0,55	6,1	No
0,7	0,39	5,9	No
0,8	0,25	5,7	No

**Table F.11 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,76	7,2	No
0,3	1,40	6,8	No
0,4	1,11	6,5	No
0,5	0,86	6,3	No
0,6	0,64	6,1	No
0,7	0,45	5,9	No
0,8	0,29	5,7	No

**Table F.12 – Typical examples of ~~transient~~ reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,01	7,2	No
0,3	1,60	6,8	No
0,4	1,27	6,5	No
0,5	0,98	6,3	No
0,6	0,73	6,1	No
0,7	0,52	5,9	No
0,8	0,33	5,7	No

Table F.13 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	6,5	Yes
0,3	1,80	6,8	No
0,4	1,43	6,5	No
0,5	1,10	6,3	No
0,6	0,83	6,1	No
0,7	0,58	5,9	No
0,8	0,37	5,7	No

Table F.14 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,6	Yes
0,3	2,01	6,8	No
0,4	1,58	6,5	No
0,5	1,23	6,3	No
0,6	0,91	6,1	No
0,7	0,65	5,9	No
0,8	0,41	5,7	No

Table F.15 – Typical examples of ~~transient~~ reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	4,9	Yes
0,3	2,20	6,0	Yes
0,4	1,82	6,5	No
0,5	1,41	6,3	No
0,6	1,05	6,1	No
0,7	0,74	5,9	No
0,8	0,47	5,7	No

Table F.16 – Typical examples of reinsertion recovery voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	~~Transient~~ Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	4,6	Yes
0,3	2,20	5,4	Yes
0,4	1,98	6,5	No
0,5	1,53	6,3	No
0,6	1,15	6,1	No
0,7	0,81	5,9	No
0,8	0,51	5,7	No

Based on these values, the following conclusion can be given:

- For series capacitor schemes having a low compensation factor ($k \leq 0,3$), the first ~~transient~~ reinsertion voltage peak across the by-pass switch is significant and can reach the varistor protective level (U_{PL}) for typical emergency overload or power swing ranges given in IEC 60143-1. The first voltage peak can be attained in relatively short time after current zero (less than $\frac{1}{2}$ of the power-frequency period).
- For series capacitor schemes having a relatively high compensation factor ($k > 0,3$), the first ~~transient~~ reinsertion voltage peak across the by-pass switch is lower and cannot reach the varistor protective level (U_{PL}) for typical emergency overload or power swing ranges given in IEC 60143-1. Nevertheless, for such schemes, the varistor protective level (U_{PL}) is reached on the following reinsertion voltage loops and the by-pass switch should be designed to withstand the varistor protective level.

Figures F.1 and F.2 give examples of typical recovery voltage waveshapes.

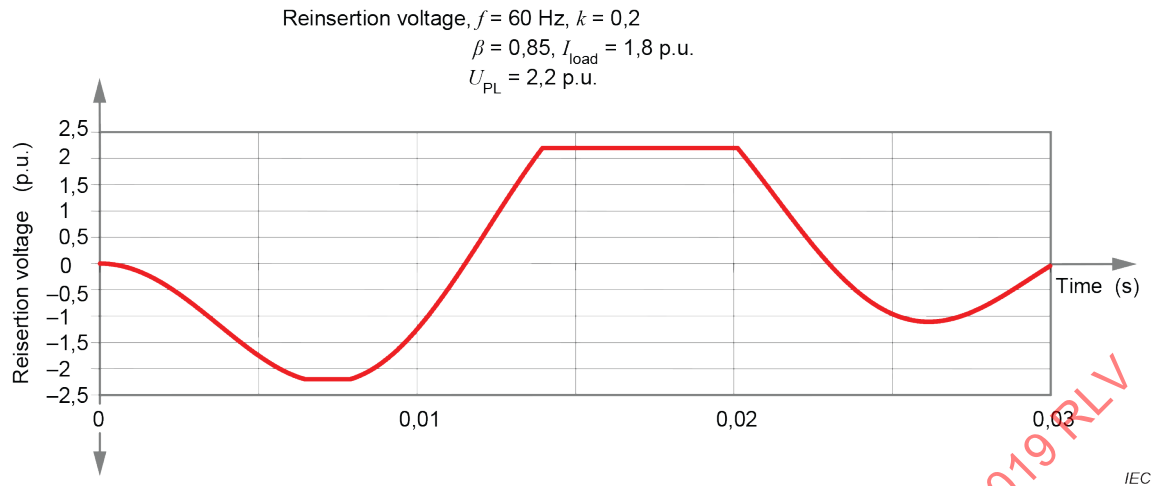


Figure F.1 – Typical example of the transient reinsertion voltage across a by-switch for a low compensation factor scheme ($k = 0,2$) and for a power swing of 1,8 p.u.

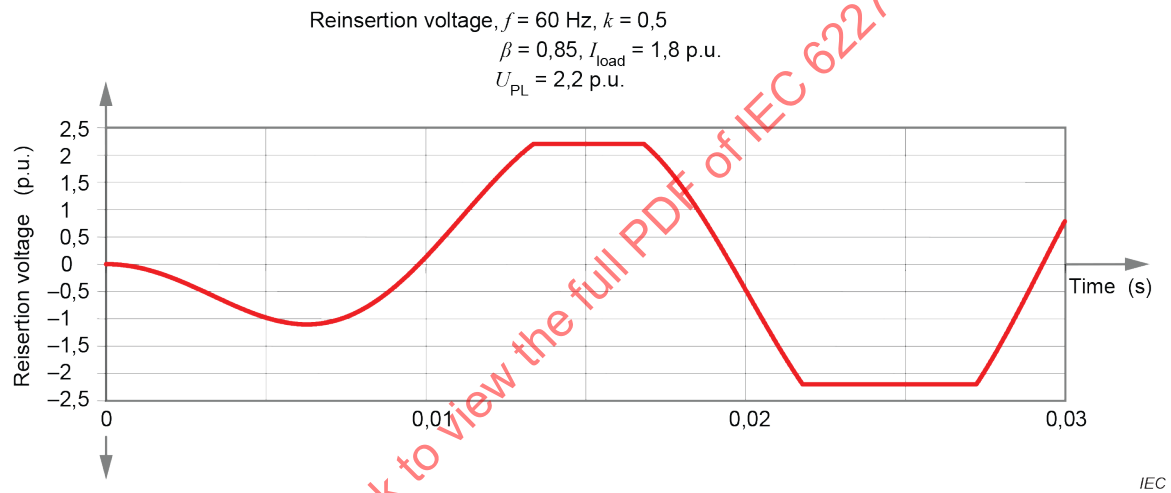


Figure F.2 – Typical example of the transient reinsertion voltage across a by-switch for a high compensation factor scheme ($k = 0,5$) and for a power swing of 1,8 p.u.

The cases shown in Tables F.1 to F.16 have been compiled in Figures F.3 and F.4, for 50 Hz and 60 Hz system frequencies, respectively. Different transient reinsertion voltage envelopes have been superimposed.

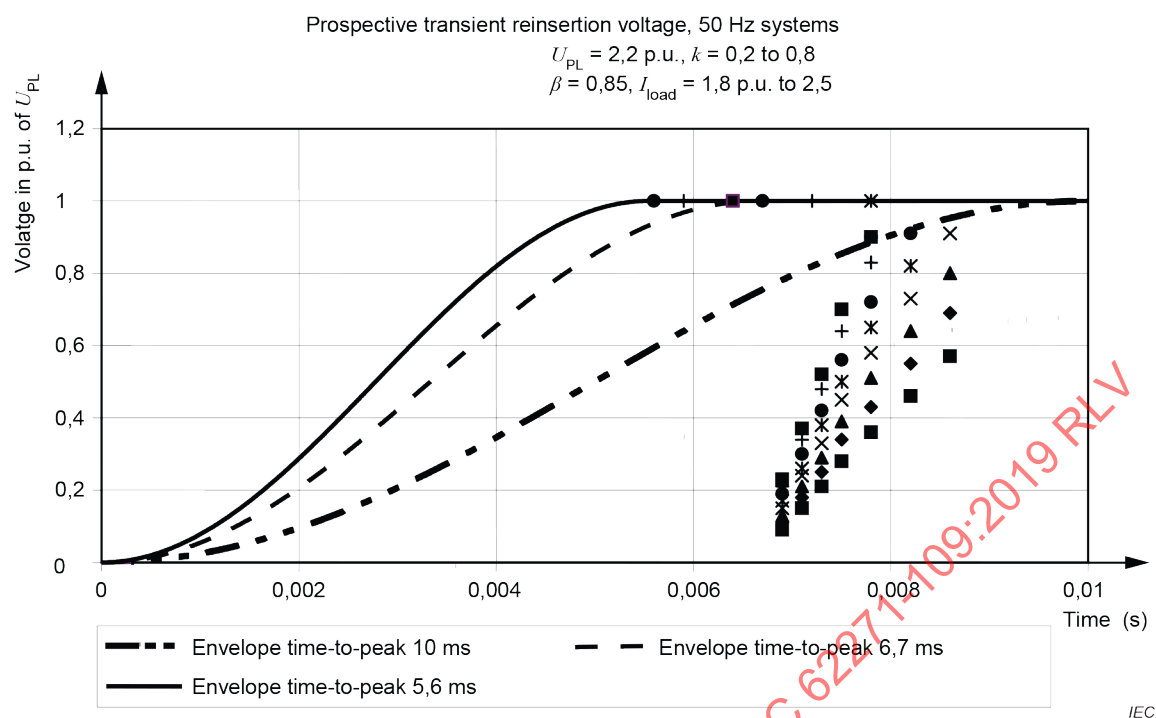


Figure F.3 – Comparison of the calculated ~~transient~~ reinsertion voltage examples and possible testing envelopes for 50 Hz systems

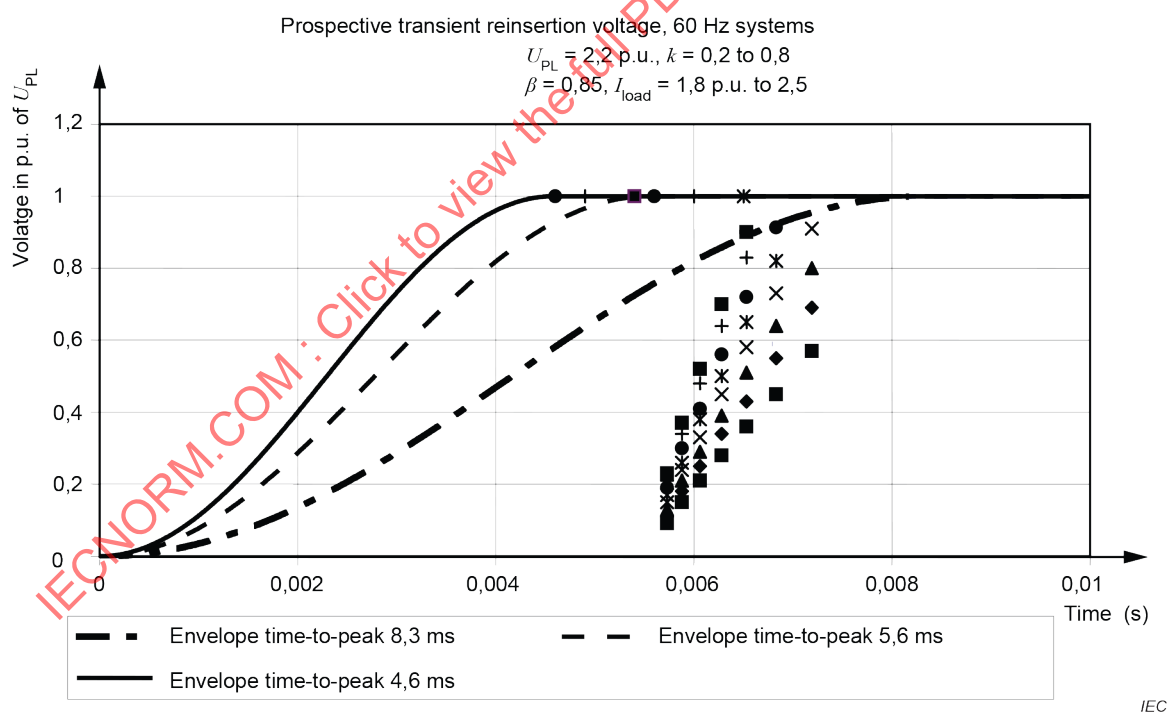


Figure F.4 – Comparison of the calculated ~~transient~~ reinsertion voltage examples and possible testing envelopes for 60 Hz systems

Based on the data shown in Figures F.3 and F.4, the following conclusions can be given:

- with the preferred reinsertion voltage first time-to-peak of 5,6 ms given in 5.104, 100 % of the computed examples will be covered for 50 Hz systems;
- with a reinsertion voltage first time-to-peak of 6,7 ms, 95 % of the computed examples will be covered for 50 Hz systems;

- with a reinsertion voltage first time-to-peak of 10 ms, 88 % of the computed examples will be covered for 50 Hz systems;
- with the preferred reinsertion voltage first time-to-peak of 5,6 ms given in 5.104, 95 % of the computed examples will be covered for 60 Hz systems;
- with a reinsertion voltage first time-to-peak of 4,6 ms, 100 % of the computed examples will be covered for 60 Hz systems;
- with a reinsertion voltage first time-to-peak of 8,3 ms, 89 % of the computed examples will be covered for 60 Hz systems.

Based on these results, the preferred first-time-to-peak value (5,6 ms) given in 5.104 will cover most of the practical cases for 50 Hz and 60 Hz and may be used as a uniform value for standardization purposes and for limiting the number of type tests required to a minimum. Nevertheless, this value may be too restrictive for certain schemes (e.g. high compensation factors $k > 0,3$ or low emergency current or low power swing) and higher first-time-to-peak values may be specified in order to get a more economical solution regarding the by-pass switch reinsertion capabilities.

If a different value than the preferred first time-to-peak value of the ~~transient~~ reinsertion voltage is specified, it should be supported by detailed system studies and the study should consider emergency overloads and power swings as well as the actual value of the varistor protective level associated with the load currents during emergency overloads and power swings.

Annex G (normative)

Use of mechanical characteristics and related requirements

At the beginning of the type tests, the mechanical characteristics of the by-pass switch shall be established, for example, by recording no-load travel curves. ~~This may be done also and by the use of~~ defining additional characteristic parameters, such as, if applicable, momentary speed at a certain stroke, closing and opening times, damping time, etc. An example of such a no-load travel curve is given in Figure G.1. The tolerances applicable to these additional parameters shall also be defined and declared by the manufacturer. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behavior of the ~~by-pass switch~~ circuit-breaker.

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

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

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

The ~~mechanical characteristics~~ no-load contact travel curves shall be used for determining the limits of the allowable deviations over or under this reference curve. From this reference curve, two envelope curves shall be drawn from the instant of contact separation to the end of the contact travel for the opening operation and from the beginning of the contact travel to the instant of contact touch for the closing operation. The distance of the two envelopes from the original course shall be $\pm 5\%$ of the total stroke as shown in Figure ~~8~~ G.2. In case of by-pass switches with a total stroke of 40 mm or less the distance of the two envelopes from the original course shall be ± 2 mm. It is recognised that for some designs of by-pass switches, these methods may be unsuitable, as for example for vacuum by-pass switches or for some by-pass switches rated less than 52 kV. In such cases, the manufacturer shall define an appropriate method to verify the proper operation of the by-pass switch.

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

The series of Figures ~~7 through 10~~ G.1 to G.4 are for illustrative purposes and only illustrate the opening operation. They are idealised and do not show the variation in profile caused by the friction effect of the contacts or the end of travel damping. In particular, it is important to note that the effects of damping are not shown in these diagrams. The oscillations produced at the end of travel are dependent upon the efficiency of the damping of the drive system. The shape of these oscillations may be a deliberate function of the design and may slightly vary from one specimen to another. Therefore, it is important that any variations in the curve at the end of the stroke, which are outside the tolerance margin given by the envelope, are fully explained and understood before they are rejected or accepted as showing equivalence with the reference curves. In general, all curves should fall within the envelopes for acceptance.

~~The envelopes can be moved in the vertical direction until one of the curves covers the reference curve. This gives maximum tolerances over the mechanical characteristics of 0 %;~~

~~+10 % and –10 %, +0 %, respectively as shown in Figures 9 and 10. The displacement of the envelope can be used only once for the complete procedure in each test in order to get a maximum total deviation from the reference characteristic of 10 %.~~

~~Table G.1 lists type tests and relevant reference mechanical characteristics for no-load, making and breaking tests.~~

Table G.1 – Summary of type tests related to mechanical characteristics

Applicable subclause	Tests where the records shall be taken	Evaluation method	Application/Notes
6.101.1.1—Mechanical characteristics	No-load test before the beginning of type tests	Not applicable	General guide for reference mechanical characteristics
6.101.1.3—Characteristics and setting of the by-pass switch to be recorded before and after the tests	Before and after the mechanical and environmental tests	Not applicable	List of items to be recorded
6.101.2.2—Condition of the by-pass switch before the (mechanical) test	No-load test before the mechanical test	^a	Mechanical test on separately operated single pole of a three-pole by-pass switch
6.101.2.5—Acceptance criteria for the mechanical operation test	No-load test after the mechanical test	^b	
6.101.3.3—Low temperature test	No-load test before and after the low temperature test	^b	Depending on minimum temperature class
6.101.3.4—High temperature test	No-load test before and after the high temperature test	^b	Conditional when required
6.101.6—Static terminal load test	No-load test before and after the terminal load test	^a	Refer also to the note in 6.101.6.2
6.102.3.3—Multi-enclosure type	No-load test before tests	^a	For commonly operated multi-enclosure type
6.102.4.2—Unit testing	No-load test before tests	^a	For by-pass switches with two or more units not separately operated within one pole
6.102.6—No-load operation before (by-pass making and insertion) test	No-load test before tests ^d	^a	For all by-pass making and insertion tests
6.102.7—Alternative operating mechanism	No-load test before the test	^a	For equivalent alternative operating mechanisms
	By-pass making test	^c	
^a Evaluation to the method given in 6.101.1.1 and Annex G; comparison of the mechanical characteristics.			
^b Evaluation to the method given in 6.101.1.3 and 6.101.1.4.			
^c Evaluation to the method given in 6.102.7.			

The travel characteristics of all production units shall lie within the 10 % total allowable tolerance around the reference travel characteristic. The reference travel characteristic may lie at any point within the defined tolerance band but the parameters of the 10 % tolerance and, once defined, shall remain unchanged. Figures G.3 and G.4 show the two extremes of the allowable cases which are –0 %, +10 % and –10 %, +0 % respectively.

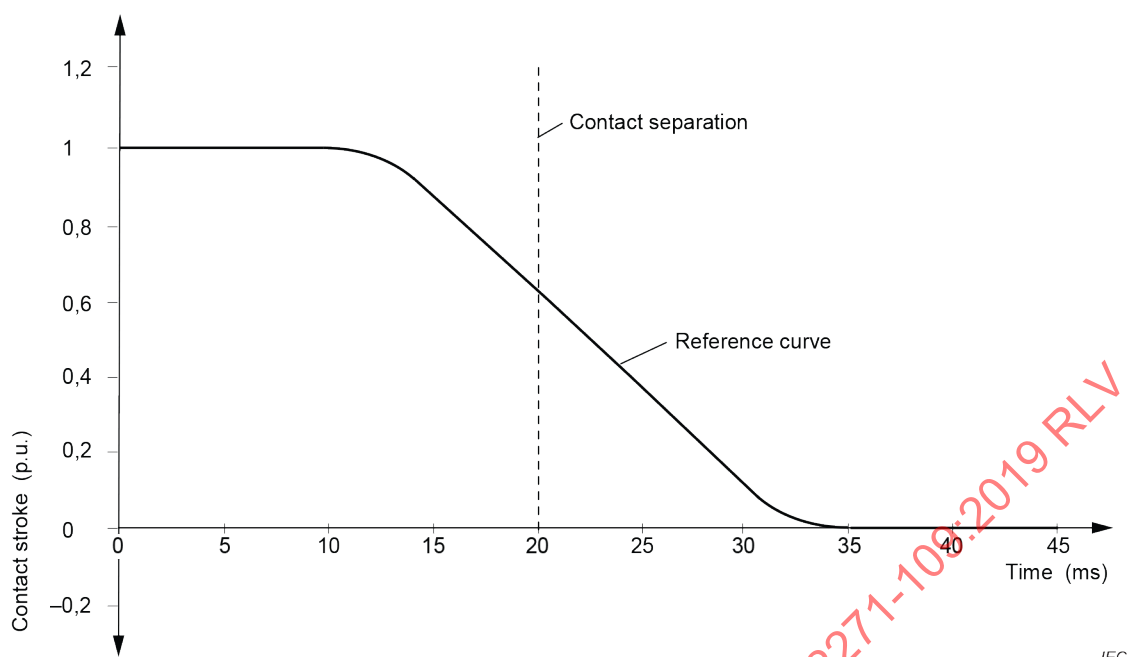


Figure G.1 – Reference mechanical travel characteristics (idealized curve)

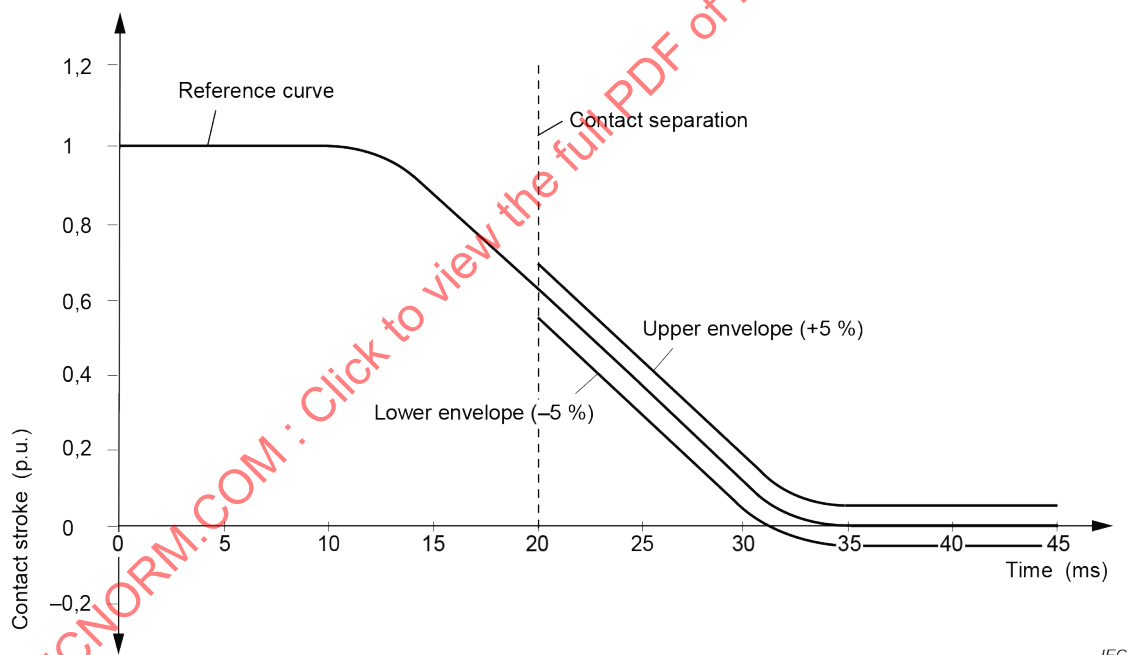


Figure G.2 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes centered over the reference curve ($\pm 5\%$), contact separation in this example at time $t = 20$ ms

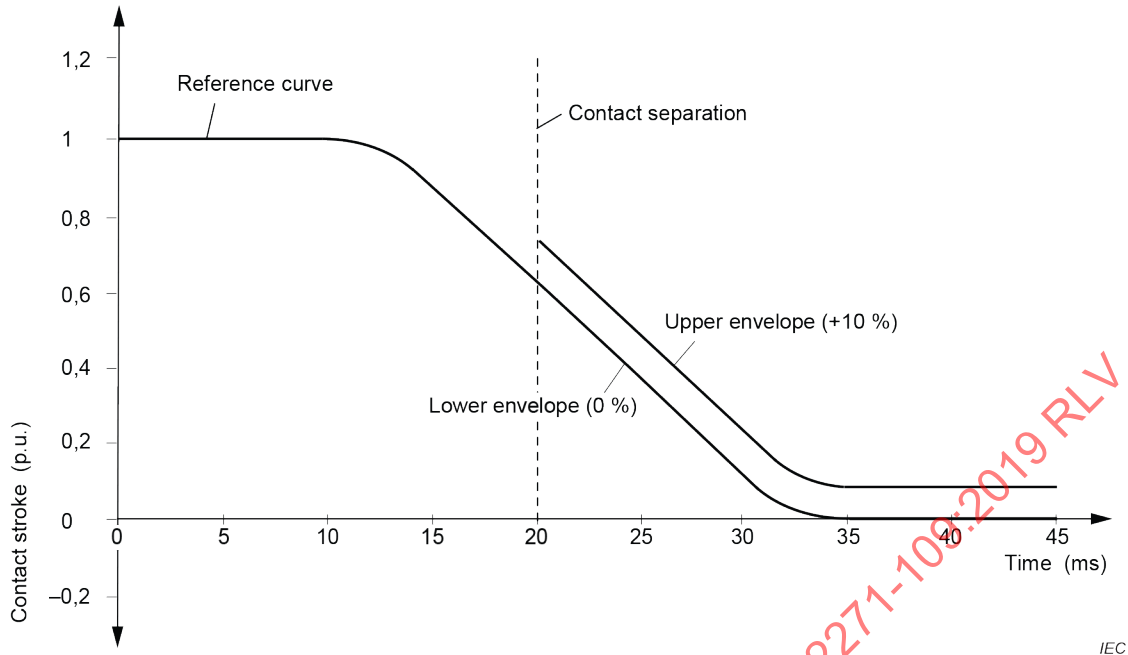


Figure G.3 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced upward from the reference curve ($+10\%$), contact separation in this example at time $t = 20$ ms

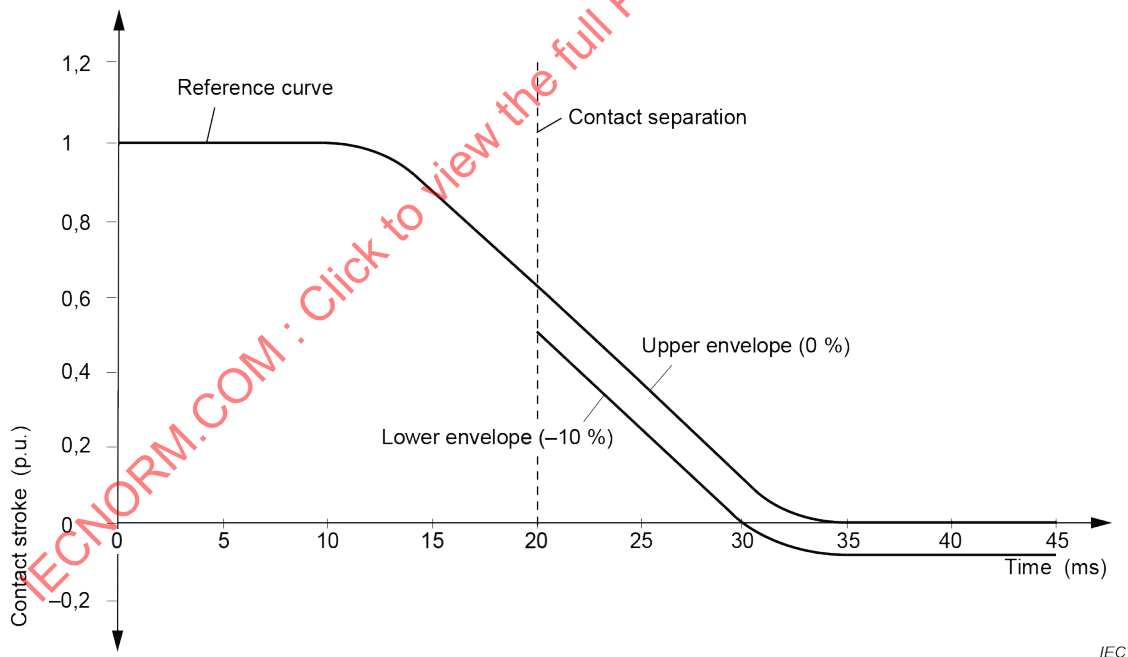


Figure G.4 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced downward from the reference curve (-10%), contact separation in this example at time $t = 20$ ms

Bibliography

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guidelines*

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

IEC 62271-200:2003, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-203:2003, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC TR 62271-300:2006, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

IEC TR 62271-306, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

ISO/IEC Guide 98-1:2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

~~BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML: 1995, *Guide to the Expression of Uncertainty in Measurement*~~

CIGRE Technical Brochure 163:2000, *Guide for SF₆ gas mixtures*

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**High-voltage switchgear and controlgear –
Part 109: Alternating-current series capacitor by-pass switches**

**Appareillage à haute tension –
Partie 109: Interrupteurs de contournement pour condensateurs série à courant alternatif**

CONTENTS

FOREWORD	9
1 Scope	11
2 Normative references	11
3 Terms and definitions	12
3.1 General terms and definitions	12
3.2 Assemblies	15
3.3 Parts of assemblies	15
3.4 Switching devices	15
3.5 Parts of by-pass switches	17
3.6 Operational characteristics of by-pass switches	20
3.7 Characteristic quantities	22
3.8 Terms and definitions related to series capacitor banks	30
3.9 Index of definitions	33
4 Normal and special service conditions	37
5 Ratings	37
5.1 General	37
5.2 Rated voltage (U_r)	38
5.2.1 General	38
5.2.2 Range I for rated voltage of 245 kV and below	38
5.2.3 Range II for rated voltage above 245 kV	38
5.3 Rated insulation level (U_p , U_d , U_s)	38
5.3.101 Rated insulation level to earth (U_{pe} , U_{de} , U_{se})	38
5.3.102 Rated insulation level across the by-pass switch (U_{pp} , U_{dp} , U_{sp})	38
5.4 Rated frequency (f_r)	39
5.5 Rated continuous current (I_r)	39
5.6 Rated short-time withstand current (I_k)	39
5.7 Rated peak withstand current (I_p)	39
5.8 Rated duration of short-circuit (t_k)	39
5.9 Rated supply voltage of auxiliary and control circuits (U_a)	39
5.10 Rated supply frequency of auxiliary and control circuits	39
5.11 Rated pressures of compressed gas supply for controlled pressure systems	39
5.101 Rated operating sequence	39
5.102 Rated by-pass making current (I_{BP})	40
5.103 Rated by-pass insertion current (I_{INS})	41
5.104 Rated reinsertion voltage (U_{INS})	41
5.105 Number of mechanical operations	41
6 Design and construction	41
6.1 Requirements for liquids in by-pass switches	41
6.2 Requirements for gases in by-pass switches	42
6.3 Earthing of by-pass switches	42
6.4 Auxiliary and control equipment and circuits	42
6.4.1 General	42
6.4.2 Protection against electrical shock	42
6.4.3 Components installed in enclosures	42
6.5 Dependent power operation	43
6.6 Stored energy operation	43

6.7	Independent unlatched operation (independent manual or power operation)	43
6.8	Manually operated actuators	43
6.9	Operation of releases	43
6.9.1	General	43
6.9.2	Shunt closing releases	43
6.9.3	Shunt opening releases	43
6.9.4	Capacitor operation of shunt releases	44
6.9.5	Under-voltage release	44
6.9.101	Multiple releases	44
6.9.102	Operation limits of releases	44
6.9.103	Power consumption of releases	44
6.10	Pressure/level indication	44
6.10.101	Low- and high-pressure interlocking devices	44
6.11	Nameplates	44
6.12	Locking devices	46
6.13	Position indication	46
6.14	Degrees of protection provided by enclosures	46
6.15	Creepage distances for outdoor insulators	46
6.16	Gas and vacuum tightness	46
6.17	Tightness for liquid systems	46
6.18	Fire hazard (flammability)	46
6.19	Electromagnetic compatibility	46
6.20	X-ray emission	46
6.21	Corrosion	46
6.22	Filling levels for insulation, by-passing, insertion and/or operation	46
6.101	Requirements for simultaneity within a pole	46
6.102	General requirement for operation	46
6.103	Pressure limits of fluids for operation	47
6.104	Vent outlets	47
6.105	Time quantities	47
6.106	Static mechanical loads	48
7	Type tests	48
7.1	General	48
7.1.1	Basics	48
7.1.2	Information for identification of test objects	49
7.1.3	Information to be included in type test reports	49
7.1.101	Invalid tests	50
7.1.102	Type tests to repeat for by-pass switches with alternative operating mechanisms	50
7.2	Dielectric tests	50
7.2.1	General	50
7.2.2	Ambient air conditions during tests	50
7.2.3	Wet test procedure	51
7.2.4	Arrangement of the equipment	51
7.2.5	Criteria to pass the test	51
7.2.6	Application of test voltage and test conditions	51
7.2.7	Tests of by-pass switches of $U_{re} \leq 245$ kV or $U_{rp} \leq 245$ kV	51
7.2.8	Tests of by-pass switches of $U_{re} > 245$ kV or $U_{rp} > 245$ kV	52
7.2.9	Artificial pollution tests for outdoor insulators	52

7.2.10	Partial discharge tests	52
7.2.11	Dielectric tests on auxiliary and control circuits	53
7.2.12	Voltage test as condition check	53
7.3	Radio interference voltage (RIV) tests	54
7.4	Resistance measurement	54
7.5	Continuous current tests	55
7.5.1	Conditions of the test object	55
7.5.2	Arrangement of the equipment	55
7.5.3	Test current and duration	55
7.5.4	Temperature measurement during test	56
7.5.5	Resistance of the main circuit	56
7.5.6	Criteria to pass test	56
7.6	Short-time withstand current and peak withstand current tests	56
7.6.1	General	56
7.6.2	Arrangement of the by-pass switch and of the test circuit	56
7.6.3	Test current and duration	56
7.6.4	Condition of the by-pass switch after test	56
7.7	Verification of the protection	56
7.7.1	Verification of the IP coding	56
7.7.2	Verification of the IK coding	56
7.8	Tightness tests	56
7.9	Electromagnetic compatibility tests (EMC)	56
7.9.1	Emission tests	56
7.9.2	Immunity tests on auxiliary and control circuits	57
7.9.3	Additional EMC tests on auxiliary and control circuits	57
7.10	Additional tests on auxiliary and control circuits	57
7.10.1	General	57
7.10.2	Functional tests	57
7.10.3	Verification of the operational characteristics of auxiliary contacts	57
7.10.4	Environmental tests	57
7.10.5	Dielectric test	58
7.11	X-Radiation test for vacuum interrupters	58
7.101	Mechanical and environmental tests	58
7.101.1	Miscellaneous provisions for mechanical and environmental tests	58
7.101.2	Mechanical operation test at ambient air temperature	60
7.101.3	Low and high temperature tests	62
7.101.4	Humidity test	68
7.101.5	Test to prove the operation under severe ice conditions	68
7.102	Miscellaneous provisions for by-pass making and insertion tests	68
7.102.1	General	68
7.102.2	Number of test specimens	69
7.102.3	Arrangement of by-pass switch for tests	69
7.102.4	General considerations concerning testing methods	70
7.102.5	Synthetic tests	73
7.102.6	No-load operations before tests	73
7.102.7	Alternative operating mechanisms	73
7.102.8	Behaviour of by-pass switch during tests	74
7.102.9	Condition of by-pass switch after tests	74

7.103	By-pass making current test-duty and insertion current test-duty, sequence of tests	76
7.103.1	General	76
7.103.2	By-pass making current test-duty	76
7.103.3	Insertion current test-duty	79
7.103.4	Criteria to pass the test duties	88
8	Routine tests	88
8.1	General	88
8.2	Dielectric test on the main circuit	88
8.3	Tests on auxiliary and control circuits	90
8.3.1	Inspection of auxiliary and control circuits, and verification of conformity to circuit diagrams and wiring diagrams	90
8.3.2	Functional tests	90
8.3.3	Verification of protection against electrical shock	90
8.3.4	Dielectric tests	90
8.4	Measurement of the resistance of the main circuit	90
8.5	Tightness test	90
8.5.1	General	90
8.5.2	Controlled pressure systems for gas	90
8.5.3	Closed pressure systems for gas	91
8.5.4	Sealed pressure systems	91
8.5.5	Liquid tightness tests	91
8.6	Design and visual checks	91
8.101	Mechanical operating tests	91
9	Guide to the selection of by-pass switches (informative)	93
10	Information to be given with enquiries, tenders and orders (informative)	93
10.1	General	93
10.2	Information with enquiries and orders	93
10.3	Information with tenders	94
11	Transport, storage, installation, operating instructions and maintenance	96
11.1	General	96
11.2	Conditions during transport, storage and installation	96
11.3	Installation	96
11.4	Operating instruction	96
11.5	Maintenance	96
11.101	Guide for commissioning tests	96
11.101.1	General	96
11.101.2	Commissioning checks and test programme	97
11.101.3	Resistors and capacitors (if applicable)	102
12	Safety	102
12.1	General	102
12.2	Precautions by manufacturers	103
12.3	Precautions by users	103
13	Influence of the product on environment	103
Annex A (normative)	Tolerances on test quantities during type tests	104
Annex B (normative)	Records and reports of type tests	108
B.1	Information and results to be recorded	108
B.2	Information to be included in type test reports	108

B.2.1	General	108
B.2.2	Apparatus tested	108
B.2.3	Rated characteristics of by-pass switch, including its operating devices and auxiliary equipment	108
B.2.4	Test conditions (for each series of tests; if applicable)	108
B.2.5	Short-time withstand current and peak withstand current test	109
B.2.6	No-load operation	109
B.2.7	By-pass making current test-duty	109
B.2.8	Insertion current test-duty	109
B.2.9	Oscillographic and other records	110
Annex C (informative)	(Void)	111
Annex D (informative)	Examples of by-pass switch ratings	112
Annex E (normative)	By-pass switches used as the primary by-passing devices	119
Annex F (informative)	Explanatory note regarding recovery voltage during reinsertion	121
Annex G (normative)	Use of mechanical characteristics and related requirements	131
Bibliography		134
Figure 1	– Different layouts for series capacitor banks	16
Figure 2	– By-pass switch – Opening and closing operations	23
Figure 3	– By-pass switch – Close-open cycle	24
Figure 4	– By-pass switch – Open-close cycle	25
Figure 5	– Example of wind velocity measurement	64
Figure 6	– Test sequences for low and high temperature tests	65
Figure 7	– Equivalent testing set-up for unit testing of by-pass switches with more than one separate by-pass units	71
Figure 8	– Typical test circuit for the by-pass making current test-duty	77
Figure 9	– Oscillogram obtained from the typical test circuit for the by-pass making current test-duty	78
Figure 10	– Typical LC test circuit for the insertion current test-duty	81
Figure 11	– Oscillogram obtained from the typical LC test circuit for the insertion current test-duty	82
Figure 12	– Typical test circuit for the insertion current test-duty (mainly for high rated insertion current)	83
Figure 13	– Oscillogram obtained from the typical test circuit shown in Figure 12 for the insertion current test-duty	84
Figure 14	– Typical direct test circuit for the insertion current test-duty	85
Figure 15	– Oscillogram obtained from the typical direct test circuit for the insertion current test-duty	86
Figure 16	– Reference mechanical travel characteristics (idealized curve)	92
Figure E.1	– Typical component layout for by-pass switches used as the primary by-passing device	119
Figure F.1	– Typical example of the reinsertion voltage across a by-switch for a low compensation factor scheme ($k = 0,2$) and for a power swing of 1,8 p.u.	128
Figure F.2	– Typical example of the reinsertion voltage across a by-switch for a high compensation factor scheme ($k = 0,5$) and for a power swing of 1,8 p.u.	128
Figure F.3	– Comparison of the calculated reinsertion voltage examples and possible testing envelopes for 50 Hz systems	129

Figure F.4 – Comparison of the calculated reinsertion voltage examples and possible testing envelopes for 60 Hz systems	129
Figure G.1 – Reference mechanical travel characteristics (idealized curve)	132
Figure G.2 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes centered over the reference curve ($\pm 5\%$), contact separation in this example at time $t = 20$ ms	132
Figure G.3 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced upward from the reference curve ($+10\%$), contact separation in this example at time $t = 20$ ms	133
Figure G.4 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced downward from the reference curve (-10%), contact separation in this example at time $t = 20$ ms	133
Table 1 – Number of mechanical operations	41
Table 2 – Nameplate information	45
Table 3 – Examples of static horizontal and vertical forces for static terminal load	48
Table 4 – Type tests	49
Table 5 – Invalid tests	50
Table 6 – Number of operating sequences	61
Table 7 – Limits of supply voltage for closing and opening releases	69
Table 8 – Test procedures for by-pass making current tests	79
Table 9 – Application of voltage for dielectric test on the main circuit	88
Table 10 – Test voltage for partial discharge test	90
Table A.1 – Tolerances on test quantities for type tests (1 of 3)	105
Table D.1 – Typical ratings for a series capacitor bank by-pass switch – Cases 1 to 6	113
Table D.2 – Typical series capacitor bank by-pass switch ratings – Cases 7 to 12	115
Table D.3 – Typical series capacitor bank by-pass switch ratings – Cases 13 to 18	117
Table F.1 – Typical examples of reinsertion voltages for systems not having power swing nor emergency overload, $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	122
Table F.2 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	122
Table F.3 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	123
Table F.4 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	123
Table F.5 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	123
Table F.6 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	124
Table F.7 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	124
Table F.8 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz	124

Table F.9 – Typical examples of reinsertion voltages for systems not having power swing nor emergency overload, $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	125
Table F.10 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	125
Table F.11 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	125
Table F.12 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload, $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	126
Table F.13 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	126
Table F.14 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	126
Table F.15 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	127
Table F.16 – Typical examples of reinsertion recovery voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz	127

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –**Part 109: Alternating-current series capacitor
by-pass switches****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62271-109 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This third edition cancels and replaces the second edition published in 2008 and Amendment 1:2013. This edition constitutes a technical revision.

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

- a) the document has been restructured according to edition 2.0 of IEC 62271-1;
- b) the rated voltage assignation across the by-pass switch has been aligned to the rule defined in IEC 60143-1;
- c) clarification has been given regarding rated continuous current of compensated and uncompensated line;
- d) some clarifications have been given following a loss of "suitable precautions";

- e) as per Amendment 2 of IEC 62271-100, the section "Rated time quantities" has been moved to Clause 6 under "Time quantities";
- f) as per Amendment 2 of IEC 62271-100, the section "Test for static mechanical loads" have been moved to Clause 6 under "Static mechanical loads";
- g) additional rules have been introduced for vacuum interrupters during impulse tests;
- h) additional clarifications have been given regarding the number of reduced impulses during impulse tests;
- i) a wider tolerance on the current damping during by-pass making current test-duty has been introduced.

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

FDIS	Report on voting
17A/1208/FDIS	17A/1215/RVD

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

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

A list of all parts of the IEC 62271 series can be found, under the general title *High-voltage switchgear and controlgear*, on the IEC website.

This standard is to be read in conjunction with IEC 62271-100:2008 with its Amendment 1:2012 and Amendment 2:2017, and IEC 62271-1:2017, 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 IEC 62271-1:2017. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

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

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

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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 109: Alternating-current series capacitor by-pass switches

1 Scope

This part of IEC 62271 is applicable to AC series capacitor by-pass switches designed for outdoor installation and for operation at frequencies of 50 Hz and 60 Hz on systems having voltages above 52 kV.

It is only applicable to by-pass switches for use in three-phase systems.

This document is also applicable to the operating devices of by-pass switches and to their auxiliary equipment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-436:1990, *International Electrotechnical Vocabulary – Chapter 436: Power capacitors*

IEC 60050-441:1984, *International Electrotechnical Vocabulary – Chapter 441: Switchgear, controlgear and fuses*

IEC 60050-614:2016, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60060 (all parts), *High-voltage test techniques*

IEC 60137:2017, *Insulated bushings for alternating voltages above 1000 V*

IEC 60143-1:2015, *Series capacitors for power systems – Part 1: General*

IEC 60143-2:2012, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*

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

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF₆) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use*

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

IEC 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF₆) and its mixtures*

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

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60050-151, IEC 60050-436, IEC 60050-441, IEC 60050-614, IEC 60143-1, IEC 60143-2 and IEC 62271-1 apply. Some of them are recalled here for ease of reference.

Additional terms and definitions are classified so as to be aligned with the classification used in IEC 60050-441.

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

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

3.1 General terms and definitions

3.1.101

switchgear and controlgear

a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:2000, 441-11-01]

3.1.102

outdoor switchgear and controlgear

switchgear and controlgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103

short-circuit current

overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:2000, 441-11-07]

3.1.104**ambient air temperature**

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

Note 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.1.105**temperature rise**

<of a part of a by-pass switch>

difference between the temperature of the part under consideration and the ambient air temperature

[SOURCE: IEC 60050-151:2001, 151-16-26, modified – "A reference" has been replaced by "the ambient air".]

3.1.106**overvoltage**

<in an electric power system>

voltage:

- between one line conductor and earth or across a longitudinal insulation having a peak value exceeding the corresponding peak of the highest voltage of the system divided by $\sqrt{3}$

or;

- between phase conductors having a peak value exceeding the amplitude of the highest voltage of the system

[SOURCE: IEC 60050-614:2016, 614-03-10]

3.1.107**unit test**

test carried out on a by-passing or insertion unit or group of units at the by-pass making current or the insertion current, specified for the test on the complete pole of a by-pass switch and at the appropriate fraction of the applied voltage, or the recovery voltage, specified for the test on the complete pole of the by-pass switch

3.1.108**external insulation**

distances in atmospheric air, and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

Note 1 to entry: Examples of environmental conditions are pollution, humidity, vermin.

[SOURCE: IEC 60050-614:2016, 614-03-02]

3.1.109**internal insulation**

internal distances of the solid, liquid or gaseous insulation of equipment, which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.1.110

self-restoring insulation

insulation which completely recovers its insulating properties within a short time interval after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.1.111

non-self-restoring insulation

insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge

[SOURCE: IEC 60050-614:2016, 614-03-05]

3.1.112

disruptive discharge

phenomenon associated with the failure of insulation under electric stress, which includes a collapse of voltage and the passage of current

Note 1 to entry: This term applies to electric breakdown in solid, liquid and gaseous dielectrics and combinations of these.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss may be temporary only.

Note 3 to entry: The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term "flashover" is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

[SOURCE: IEC 60050-614:2016, 614-03-16, modified – Note 3 to entry added.]

3.1.113

restrike performance

expected probability of restrike during insertion current test-duty as demonstrated by specified type test

Note 1 to entry: Specific numeric probabilities cannot be applied throughout a by-pass switch service life.

3.1.114

re-ignition

<of an AC mechanical switching device>

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency

[SOURCE: IEC 60050-441:2000, 441-17-45]

3.1.115

restrike

<of an AC mechanical switching device>

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of a quarter cycle of power frequency or longer

[SOURCE: IEC 60050-441:2000, 441-17-46]

3.1.116**non-sustained disruptive discharge****NSDD**

disruptive discharge associated with current interruption which does not result in the resumption of power frequency current or, in the case of insertion does not result in a current in the series capacitor bank

Note 1 to entry: Oscillations following NSDDs are associated with the parasitic capacitance and inductance local to or of the by-pass switch itself. NSDDs may also involve the stray capacitance to ground of nearby equipment.

Note 2 to entry: This note applies to the French language only.

3.2 Assemblies

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices**3.4.101****switching device**

device designed to make or break the current in one or more electric circuits

[SOURCE: IEC 60050-441:2000, 441-14-01]

3.4.102**mechanical switching device**

switching device designed to close and open one or more electric circuits by means of separable contacts

Note 1 to entry: Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g. air, SF₆, oil.

[SOURCE: IEC 60050-441:2000, 441-14-02]

3.4.103**by-pass switch**

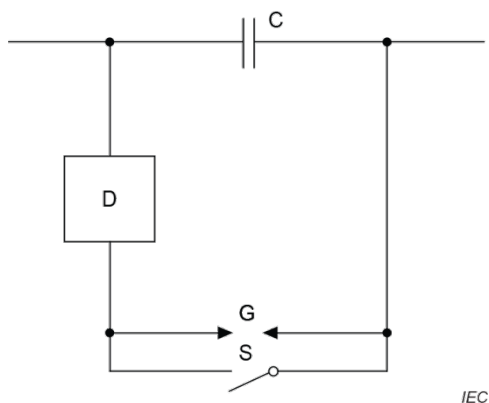
three-phase switching device used in parallel with a series capacitor and its overvoltage protector to shunt line current of a specified level for a specified time, or continuously

Note 1 to entry: By-pass switches can be three-pole or single-pole operated

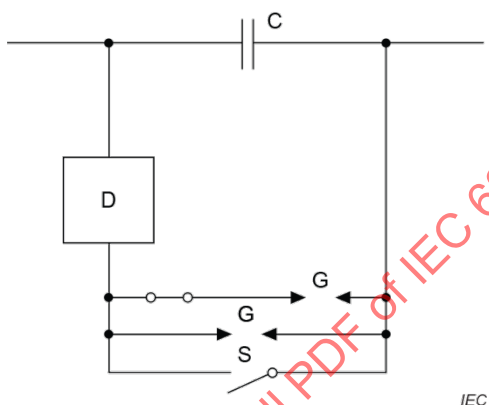
Note 2 to entry: Besides by-passing the capacitor, this device normally has the capability to insert the capacitor into a circuit that carries a specified level of current.

Note 3 to entry: By-pass switches are normally used in conjunction with a fast by-passing device, for example, spark-gap (for special applications without the use of a fast by-passing device, see Annex E).

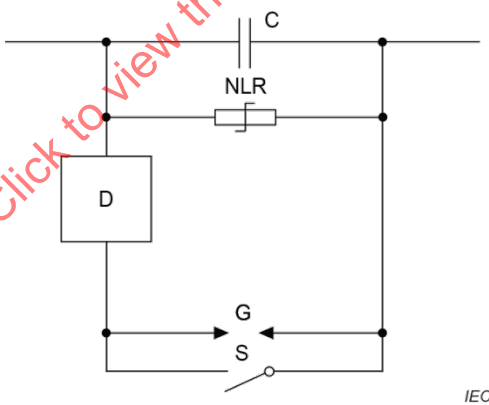
Note 4 to entry: Examples of series capacitor layouts using a fast by-passing device in parallel with the by-pass switch (see IEC 60143-1) are given in Figure 1.



Single gap



Dual gap



Non-linear resistor with by-pass gap

Key

C	series capacitor
D	damping circuit
G	spark-gap
S	by-pass switch
NLR	non-linear resistor

Figure 1 – Different layouts for series capacitor banks

3.4.104

by-pass switch class M1

by-pass switch with normal mechanical endurance as demonstrated by specific type tests

3.4.105**by-pass switch class M2**

frequently operated by-pass switch for special service requirements and designed so as to require only limited maintenance as demonstrated by specific type tests.

Note 1 to entry: This type of by-pass switch is normally used on multi-segmented capacitors where the control of the capacitor impedance is a frequent duty.

3.5 Parts of by-pass switches**3.5.101****pole of a switching device**

the portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102**main circuit**

<of a switching device>

all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103**control circuit**

<of a switching device>

all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.104**auxiliary circuit**

<of a switching device>

all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:2000, 441-15-04]

3.5.105**contact**

<of a mechanical switching device>

conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.106

contact

contact piece

one of the conductive parts forming a contact

[SOURCE: IEC 60050-441:2000, 441-15-06]

3.5.107

main contact

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.108

arcing contact

contact on which the arc is intended to be established

Note 1 to entry: An arcing contact may serve as a main contact; it may be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from injury.

[SOURCE: IEC 60050-441:2000, 441-15-08]

3.5.109

control contact

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.110

auxiliary contact

contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:2000, 441-15-10]

3.5.111

auxiliary switch

<of a mechanical switching device>

switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:2000, 441-15-11]

3.5.112

“a” contact

make contact

control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.113

“b” contact;

break contact

control or auxiliary contact which is open when the main contacts of a mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.114

sliding contact

contact in which relative movement of the contact pieces is substantially in a direction parallel to the contact surface

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

3.5.115

rolling contact

contact in which one contact piece rolls on the other

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

3.5.116

release

<of a mechanical switching device>

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

[SOURCE: IEC 60050-441:2000, 441-15-17]

3.5.117

arc control device

device, surrounding the arcing contacts of a mechanical switching device, designed to confine the arc and to assist in its extinction

[SOURCE: IEC 60050-441:2000, 441-15-18]

3.5.118

position indicating device

part of a mechanical switching device which indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.119

connection

two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.5.120

terminal

component provided for the connection of a device to external conductors

3.5.121

by-pass unit

insertion unit

part of a by-pass switch which in itself acts as a by-pass switch and which, in series with one or more identical and simultaneously operated by-pass or insertion units, forms the complete by-pass switch

Note 1 to entry: By-pass units and insertion units are normally combined but may be separated. Each unit may have several contacts.

Note 2 to entry: The means controlling the voltage distribution between units may differ from unit to unit.

3.5.122 **module**

<of a by-pass switch> assembly which generally comprises by-pass or insertion units, post-insulators (for live tank by-pass switches), bushings (for dead tank by-pass switches) and mechanical parts and which is mechanically and electrically connected to other identical assemblies to form a pole of a by-pass switch

3.5.123 **enclosure**

part of switchgear and controlgear providing a specified degree of protection of equipment against external influences and a specified degree of protection against an approach to or contact with live parts and against contact with moving parts

[SOURCE: IEC 60050-441:2000, 441-13-01, modified – "a part of an assembly" has been changed for "part of switchgear and controlgear"]

3.5.124 **operating mechanism**

part of the by-pass switch that actuates, through the power kinematic chain, the main circuit contacts of the by-pass switch

3.5.125 **power kinematic chain**

mechanical connecting system from and including the operating mechanism up to and including the moving contacts

Note 1 to entry: See also Figure 1 of IEC 62271-102:2018.

3.5.126 **alternative operating mechanism**

mechanism obtained when a change in the power kinematic chain of the original operating mechanism or the use of an entirely different operating mechanism leads to the same mechanical characteristics

Note 1 to entry: Mechanical characteristics are defined in 7.101.1.1. The use of mechanical characteristics and related requirements are described in Annex G.

Note 2 to entry: An alternative operating mechanism can implement an operating principle different from the original one (for example the alternative mechanism can be spring-operated and the original hydraulic).

Note 3 to entry: A change in the secondary equipment does not lead to an alternative operating mechanism.

3.6 Operational characteristics of by-pass switches

3.6.101 **operation**

<of a mechanical switching device>
transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this may be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102 **operating cycle**

<of a mechanical switching device>
succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

operating sequence

<of a mechanical switching device>

succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:2000, 441-16-03]

3.6.104

closing operation

<of a mechanical switching device>

operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.105

opening operation

<of a mechanical switching device>

operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.106

auto-reopening

operating sequence of a by-pass switch whereby, following its closing, it opens automatically after a predetermined time

3.6.107

positive opening operation

<of a mechanical switching device>

opening operation which, in accordance with specified requirements, ensures that all the main contacts are in the open position when the actuator is in the position corresponding to the open position of the device

[SOURCE: IEC 60050-441:2000, 441-16-11]

3.6.108

positively driven operation

operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts

[SOURCE: IEC 60050-441:2000, 441-16-12]

3.6.109

dependent power operation

<of a mechanical switching device>

operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.110

stored energy operation

operation by means of energy stored in the mechanism itself prior to the switching operation and sufficient to complete the specified operating sequence under predetermined conditions

3.6.111

independent manual operation

<of a mechanical switching device>

stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

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

3.6.112

closed position

<of a mechanical switching device>

position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-22]

3.6.113

open position

<of a mechanical switching device>

position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.114

shunt release

release energized by a source of voltage

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

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

3.6.115

anti-pumping device

device that prevents the reopening after an open-close operation as long as the device initiating opening is maintained in the position for opening

3.6.116

interlocking device

device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.6.117

by-pass switch with lock-out preventing opening

by-pass switch in which none of the moving contacts can insert the capacitor if the opening command is initiated while the conditions that cause the closing operation remain established

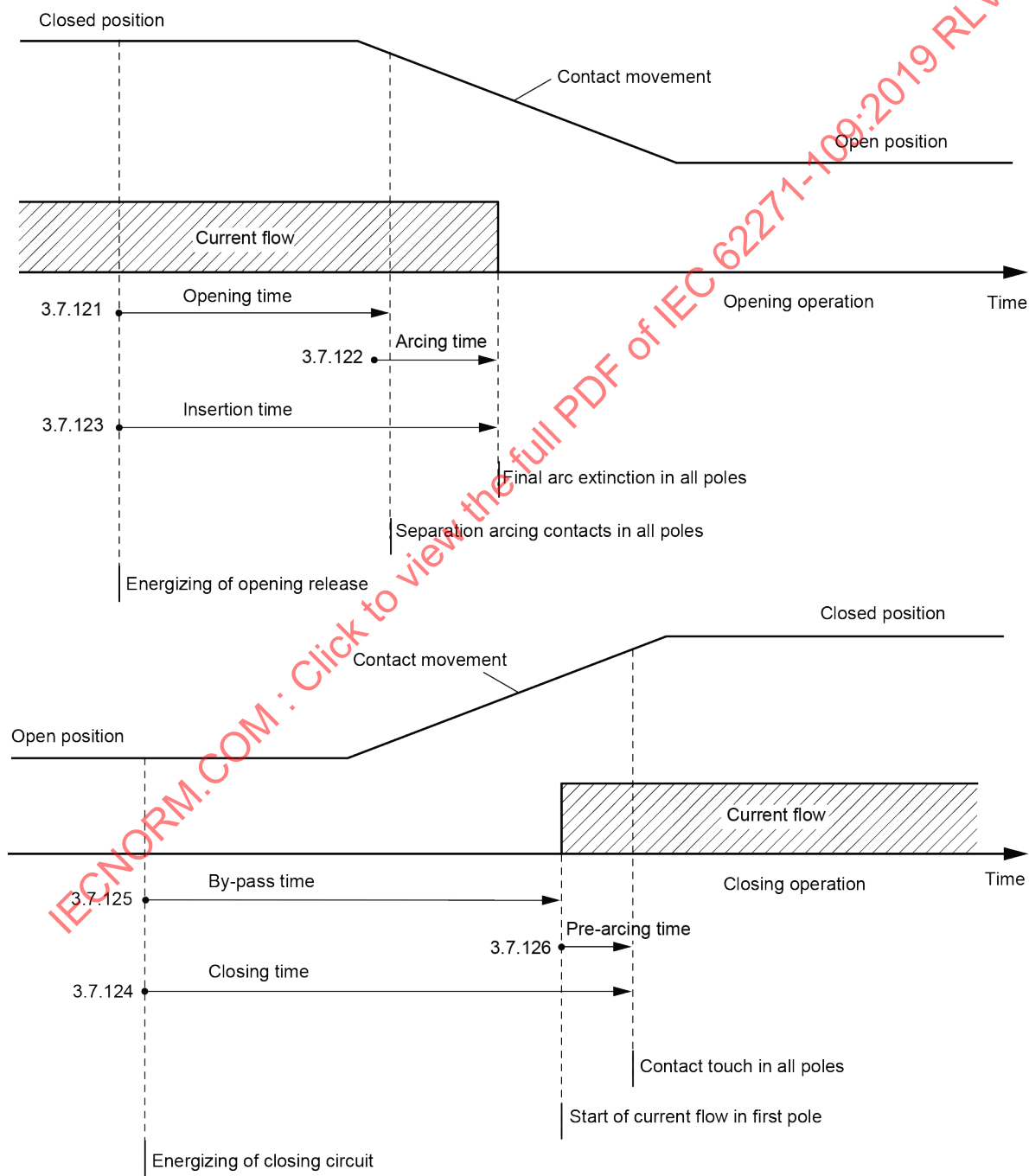
3.7 Characteristic quantities

Figures 2 to 4 illustrate some definitions of this subclause.

Time quantities (see definitions 3.7.120 to 3.7.130) are expressed in milliseconds or in cycles. When expressed in cycles, the power frequency shall be stated in brackets.

Concerning Figures 2 to 4:

- In practice, there will be a time spread between the travel of the contacts of the three poles. For clarity, the travel of the contacts in the figures is indicated by a single line for all three poles.
- In practice, there will be a time spread between both the start and end of current flow in the three poles. For clarity, both the start and end of current flow in the figures are indicated by a single line for all three poles.



IEC

Figure 2 – By-pass switch – Opening and closing operations

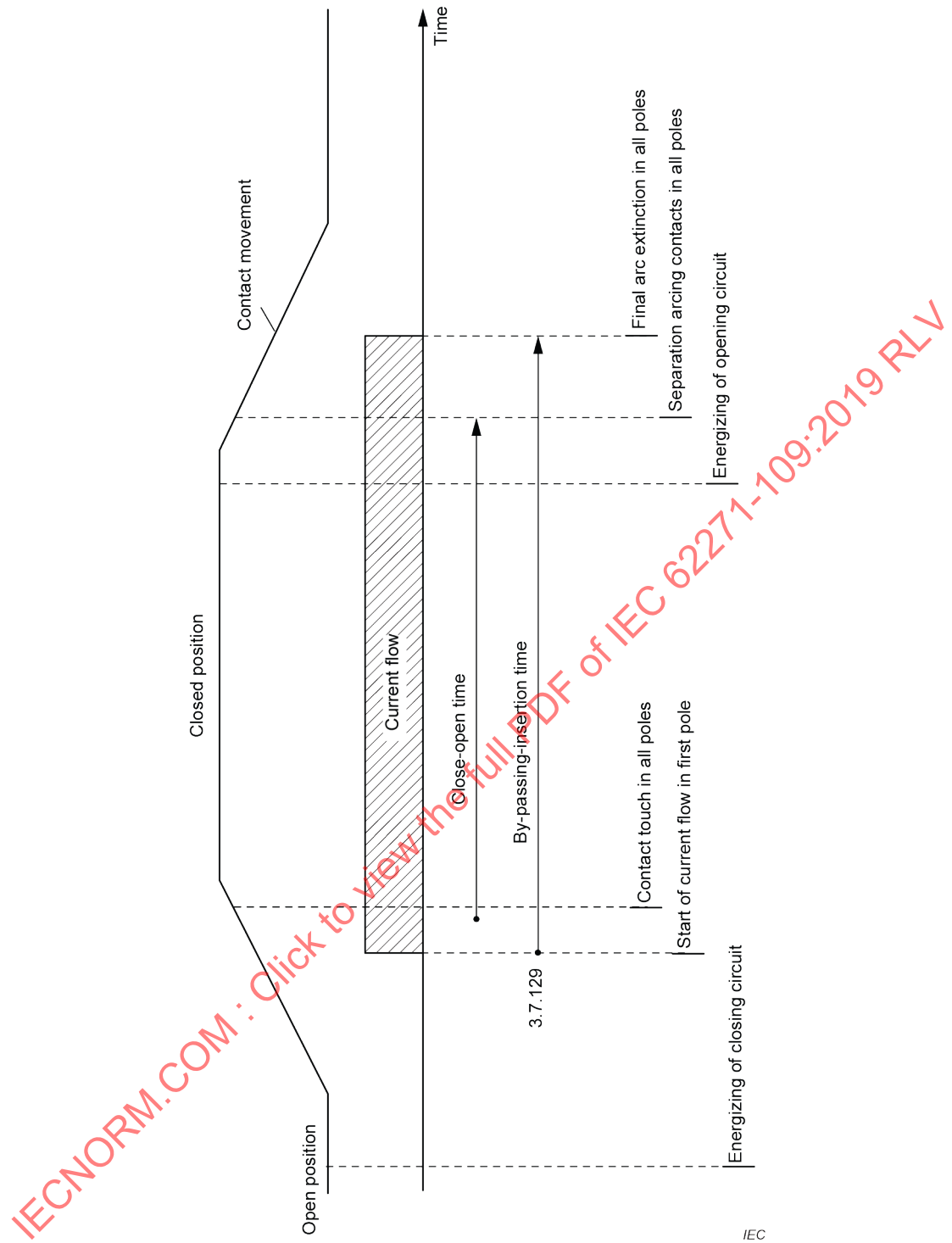
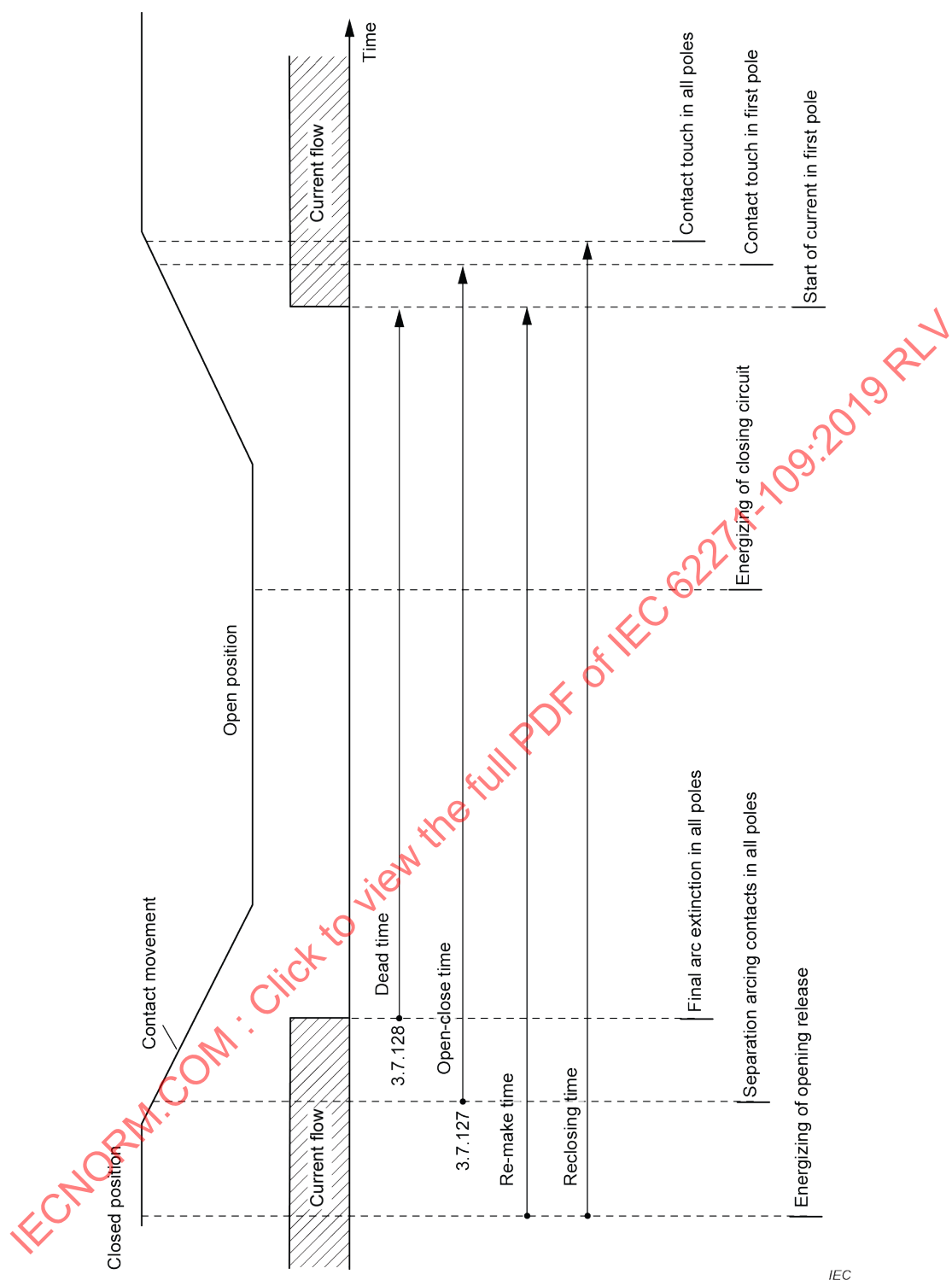


Figure 3 – By-pass switch – Close-open cycle



IEC

Figure 4 – By-pass switch – Open-close cycle

3.7.101**rated value**

quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

Note 1 to entry: Examples of rated value usually stated for fuses: voltage, current, breaking capacity.

3.7.102

prospective current

<of a circuit and with respect to a switching device or a fuse>

current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is to be specified in the relevant publications.

[SOURCE: IEC 60050-441:2000, 441-17-01]

3.7.103

prospective peak current

peak value of the first current loop of the prospective current during the transient period following initiation

Note 1 to entry: The definition assumes that the current is made by an ideal by-pass switch, i.e. with the instantaneous and simultaneous transition of its impedance across the terminals of each pole from infinity to zero. The peak value may differ from one pole to another; it depends on the instantaneous voltage across the capacitor prior to by-passing.

3.7.104

peak current

peak value of the first current loop during the transient period following initiation

3.7.105

transient by-pass current

superposition of capacitor bank discharge current and power-frequency current

3.7.106

by-pass making current

peak value of the by-pass current in a pole of a by-pass switch during the transient period following the initiation of current during a by-passing operation

Note 1 to entry: The value is the maximum instantaneous value of the sum of the capacitor bank discharge current component and the power-frequency current component. In case of system faults, the power-frequency fault current is equal to the maximum varistor coordinating current or for schemes without varistor, the actual maximum power-frequency fault current at the particular location.

Note 2 to entry: The peak value may differ from one pole to another and from one operation to another as it depends on the instantaneous capacitor voltage prior to by-passing.

Note 3 to entry: Where, for a three-phase circuit, a single value of peak value of by-pass making current is referred to, this is, unless otherwise stated, the highest value in any phase.

Note 4 to entry: The maximum power-frequency fault current at a particular location or the maximum varistor coordinating current is generally much lower than the rated peak withstand current of the by-pass switch.

3.7.107

insertion current

by-pass insertion current

steady state root-mean-square current that flows through the by-pass switch immediately prior to opening

3.7.108

insertion capacity

value of prospective current that a by-pass switch is capable of inserting at the stated voltage under prescribed conditions of use and behaviour

3.7.109

by-passing capacity

value of prospective current that a by-pass switch is capable of by-passing at a stated voltage under prescribed conditions of use and behaviour

3.7.110**short-circuit making capacity**

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

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

3.7.111**short-time withstand current**

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

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

3.7.112**peak withstand current**

value of peak current that a circuit or a switching device in the closed position can withstand under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.113**applied voltage**

<of a switching device>

voltage which exists across the terminals of a pole of a switching device just before the making of the current

[SOURCE: IEC 60050-441:2000, 441-17-24]

3.7.114**recovery voltage**

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

Note 1 to entry: This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency or the steady-state recovery voltage alone exists.

[SOURCE: IEC 60050-441:2000, 441-17-25]

3.7.115**power-frequency recovery voltage**

recovery voltage after the transient voltage phenomena have subsided

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

3.7.116**peak arc voltage**

<of a mechanical switching device>

maximum instantaneous value of voltage which under prescribed conditions appears across the terminals of a pole of a switching device during the arcing time

[SOURCE: IEC 60050-441:2000, 441-17-30]

3.7.117**clearance**

distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.118

clearance between poles

clearance between any conductive parts of adjacent poles

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.119

clearance to earth

clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.120

clearance between open contacts

total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position

[SOURCE: IEC 60050-441:2000, 441-17-34]

3.7.121

opening time

opening time of a by-pass switch defined according to the tripping method as stated below and with any time delay device forming an integral part of the by-pass switch adjusted to its minimum setting

Note 1 to entry: For a by-pass switch tripped by any form of auxiliary power, the opening time is the interval of time between the instant of energising the opening release, the by-pass switch being in the closed position, and the instant when the arcing contacts have separated in all poles.

Note 2 to entry: For by-pass switches with more than one insertion unit per pole, the instant when the arcing contacts have separated in all poles is determined as the instant of contact separation in the first unit of the last pole.

Note 3 to entry: The opening time includes the operating time of any auxiliary equipment necessary to open the by-pass switch and forming an integral part of the by-pass switch.

3.7.122

arcing time

<of a pole>

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

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

3.7.123

insertion time

interval of time between the beginning of the opening time of a by-pass switch and the end of the arcing time

3.7.124

closing time

interval of time between energizing the closing circuit, the by-pass switch being in the open position, and the instant when the contacts touch in all poles

Note 1 to entry: The closing time includes the operating time of any auxiliary equipment necessary to close the by-pass switch and forming an integral part of the by-pass switch.

3.7.125**by-pass time**

interval of time between energising the closing circuit, the by-pass switch being in the open position, and the instant when the current begins to flow in the first pole

Note 1 to entry: The by-pass time includes the operating time of any auxiliary equipment necessary to close the by-pass switch and forming an integral part of the by-pass switch.

Note 2 to entry: The by-pass time may vary, e.g. due to the variation of the pre-arcing time.

3.7.126**pre-arcing time**

interval of time between the initiation of current flow in the first pole during a by-passing operation and the instant when the contacts touch in all poles for three-phase conditions or the instant when the contacts touch in the arcing pole for single-phase conditions

Note 1 to entry: The pre-arcing time depends on the instantaneous value of the applied voltage during a specific by-passing operation and therefore may vary considerably.

3.7.127**open-close time**

interval of time between the instant when the arcing contacts have separated in all poles and the instant when the contacts touch in the first pole during a by-passing operation

Note 1 to entry: Unless otherwise stated, it is assumed that the closing release incorporated in the by-pass switch is energized at the instant when the contacts have separated in all poles during opening. This represents the minimum open-close time.

3.7.128**dead time**

<during auto-reclosing>

interval of time between final arc extinction in all poles in the insertion operation and the first re-establishment of current in any pole in the subsequent by-passing operation

Note 1 to entry: The dead time can vary, for example owing to the variation of the pre-arcing time.

3.7.129**by-passing-insertion time**

interval of time between the initiation of current flow in the first pole during a by-passing operation and the end of the arcing time during the subsequent insertion operation

Note 1 to entry: The by-pass insertion time may vary due to the variation of the pre-arcing and arcing times.

Note 2 to entry: The by-pass insertion time should be compatible with system requirements.

3.7.130**minimum trip duration**

minimum time the auxiliary power is applied to the opening release to ensure complete opening of the by-pass switch

3.7.131**minimum close duration**

minimum time the auxiliary power is applied to the closing device to ensure complete closing of the by-pass switch

3.7.132**insulation level**

for a by-pass switch, a characteristic defined by values indicating the insulation withstand voltages to earth and/or across the by-pass units

3.7.133

power-frequency withstand voltage

RMS value of sinusoidal power-frequency voltage that the by-pass switch can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22, modified, words "insulation of the given equipment" has been replaced by "by-pass switch"]

3.7.134

impulse withstand voltage

peak value of the standard impulse voltage wave which the insulation of the by-pass switch withstands under specified test conditions

Note 1 to entry: Depending on the shape of the wave, the term may be qualified as "switching impulse withstand voltage" or "lightning impulse withstand voltage".

3.7.135

minimum functional pressure p_{mm} for operation

pressure (in Pa), for operation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of a by-pass switch are maintained and at which a replenishment of the energy storage device becomes necessary

Note 1 to entry: This pressure is often designated as interlocking pressure (refer to 3.6.5.6 of IEC 62271-1:2017).

3.7.136

minimum functional pressure p_{me} for by-passing, insertion and insulation

pressure (in Pa), for by-passing, insertion and for insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of a by-pass switch are maintained and at which a replenishment of the by-passing, insertion and/or insulating fluid becomes necessary

Note 1 to entry: See also 3.6.5.5 of IEC 62271-1:2017.

Note 2 to entry: For by-pass switches with a sealed pressure system (also termed sealed-for-life), the minimum functional pressure for by-passing and insertion is the one at which the rated characteristics of the by-pass switch are maintained taking into account the pressure drop at the end of the expected operating life.

3.7.137

initiation of closing operation

instant of receipt of a command for a closing operation at the control circuit

3.7.138

initiation of opening operation

instant of receipt of a command for an opening operation at the control circuit

3.8 Terms and definitions related to series capacitor banks

3.8.1

capacitor

term used when it is not necessary to distinguish between the different meanings of the words "capacitor unit" and the assembly of capacitors associated with a segment

3.8.2

overvoltage protector

<of a series capacitor>

fast-acting device intended to limit the voltage across the capacitor to a permissible value when that value would otherwise be exceeded as a result of a circuit fault or other abnormal power system conditions

[SOURCE: IEC 60050-436:1990, 436-03-14, modified – words added: "when that value would otherwise be exceeded as a result of a circuit fault or other abnormal power system conditions"]

3.8.3

rated capacitance

C_N

<of a capacitor>

capacitance value for which the capacitor has been designed

3.8.4

rated current of a capacitor

I_N

RMS value of the alternating current for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-13]

3.8.5

rated reactance

X_N

<of a capacitor>

reactance of each phase of the series capacitor at rated frequency and 20 °C dielectric temperature

3.8.6

rated voltage

U_N

<of a capacitor>

RMS value of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$

[SOURCE: IEC 60050-436:1990, 436-01-15, modified – words "of the alternating voltage for which the capacitor has been designed." Have been replaced by " of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$ "]

3.8.7

limiting voltage

U_{LIM}

maximum peak of the power-frequency voltage occurring between capacitor unit terminals immediately before or during operation of the overvoltage protector, divided by $\sqrt{2}$

3.8.8

series capacitor bank

three phase assembly of capacitors with associated protection and insulated support structure

Note 1 to entry: The bank may include one or more modules.

3.8.9

segment

<of a series capacitor>

where each phase of a bank is divided into one or more series connected parts, of which each part contains its own assembly of capacitor units, overvoltage protector, protective functions and bypass switch, each such complete part is called segment

Note 1 to entry: Segments are not normally separated by isolating disconnectors. More than one segment can be on the same insulated platform.

3.8.10

bank protection

general term for all protective equipment for a capacitor bank, or part thereof

3.8.11

by-pass current

steady-state RMS current flowing through the by-pass switch in parallel with the capacitor

3.8.12

by-pass fault current

current flowing through the by-passed series capacitor bank caused by a fault on the line

3.8.13

by-pass gap (protective gap)

gap, or system of gaps, to protect either the capacitor (type K) against overvoltage or the non-linear resistor (type M) against overload by carrying the load or fault current around the protected parts for a specified time (see Figure 2 of IEC 60143-2:2012)

3.8.14

by-pass interlocking device

device that requires all three poles of the by-pass switch to be in the same open or closed position

3.8.15

current-limiting damping equipment

reactor or a reactor with a parallel connected resistor to limit the current magnitude and frequency and to provide a sufficient damping of the discharge of the capacitors upon operation of the by-pass gap or the by-pass switch

3.8.16

insertion

opening of the series capacitor by-pass switch to insert the series capacitor in series with the transmission line

3.8.17

insertion current

RMS current that flows through the series capacitor after the by-pass switch has opened. This current may be at the specified continuous or overload current magnitudes

3.8.18

insertion voltage

peak voltage appearing across the series capacitor upon transfer of the by-pass current with the opening of the by-pass switch

3.8.19

main gap

that part of the protective spark-gap intended to carry the fault current during a specified time, comprising two or more heavy-duty electrodes

3.8.20

module

<capacitor switching step>

three-phase function unit consisting of one capacitor segment (possibly several) per phase with provision for interlocked operation of the single-phase by-pass switches

3.8.21**non-linear resistor****varistor**

device to act as overvoltage protection of the capacitor consisting of resistors with a non-linear voltage-dependent resistance (normally metal-oxide varistors)

3.8.22**protective level**

U_{PL}

magnitude of the maximum peak of the power-frequency voltage appearing across the overvoltage protector during a power system fault ($U_{PL} = U_{LIM} \times \sqrt{2}$)

Note 1 to entry: The protective level may be expressed in terms of the actual peak voltage across a segment or in terms of per unit of the peak of the rated voltage across the capacitor.

3.8.23**reinsertion**

restoration of load current to the series capacitor from the by-pass path

3.8.24**reinsertion current**

transient current, power-frequency current, or both, flowing through the series capacitor during the opening of the by-pass path

3.8.25**reinsertion voltage**

recovery voltage appearing across the series capacitor during the opening of the by-pass path

3.8.26**temporary overvoltage**

temporary power-frequency voltage higher than the continuous rated voltage of the series capacitor

3.8.27**varistor coordinating current**

magnitude of the maximum varistor current associated with the protective level

3.8.28**capacitor bank discharge current**

$I_{DISCHARGE}$

current which flows during the discharging of the capacitor bank

Note 1 to entry: The maximum peak value of the capacitor discharge current occurs when the capacitor bank is charged to the protective level U_{PL} .

3.9 Index of definitions**A**

"a" contact, make contact	3.5.112
Alternative operating mechanism	3.5.126
Ambient air temperature	3.1.104
Anti-pumping device	3.6.115
Applied voltage <of a switching device>	3.7.113
Arcing contact	3.5.108
Arcing time <of a pole>	3.7.122
Arc control device	3.5.117

Auto-reopening	3.6.106
Assemblies	3.2
Auxiliary circuit <of a switching device>	3.5.104
Auxiliary contact	3.5.110
Auxiliary switch <of a mechanical switching device>	3.5.111

B

"b" contact, break contact	3.5.113
Bank protection	3.8.10
Break contact	3.5.113
By-pass current	3.8.11
By-pass fault current	3.8.12
By-pass gap (protective gap)	3.8.13
By-pass insertion current	3.7.107
By-passing-insertion time	3.7.129
By-pass interlocking device	3.8.14
By-pass making current	3.7.106
By-pass (or insertion) unit	3.5.121
By-pass switch	3.4.103
By-pass switch class M1	3.4.104
By-pass switch class M2	3.4.105
By-pass switch with lock-out preventing opening	3.6.117
By-pass time	3.7.125
By-passing capacity	3.7.109

C

Capacitor	3.8.1
Capacitor bank discharge current ($I_{DISCHARGE}$)	3.8.28
Clearance	3.7.117
Clearance between open contacts	3.7.120
Clearance between poles	3.7.118
Clearance to earth	3.7.119
Closed position <of a mechanical switching device>	3.6.112
Closing operation <of a mechanical switching device>	3.6.104
Closing time	3.7.124
Connection	3.5.119
Contact <of a mechanical switching device>	3.5.105
Contact piece	3.5.106
Control circuit <of a switching device>	3.5.103
Control contact	3.5.109
Current-limiting damping equipment	3.8.15

D

Dead time <during auto-reclosing>	3.7.128
Dependent power operation <of a mechanical switching device>	3.6.109
Disruptive discharge	3.1.112

E

Enclosure	3.5.123
External insulation	3.1.108

I

Impulse withstand voltage	3.7.134
Independent manual operation <of a mechanical switching device>	3.6.111
Initiation of closing operation	3.7.137
Initiation of opening operation	3.7.138
Insertion	3.8.16
Insertion current	3.8.17
Insertion capacity	3.7.108
Insertion time	3.7.123
Insertion voltage	3.8.18
Insulation level	3.7.132
Interlocking device	3.6.116
Internal insulation	3.1.109

L

Limiting voltage (U_{LIM})	3.8.7

M

Main circuit <of a switching device>	3.5.102
Main contact	3.5.107
Main gap	3.8.19
Make contact	3.5.112
Mechanical switching device	3.4.102
Minimum close duration	3.7.131
Minimum functional pressure ρ_{me} for by-passing, insertion and insulation	3.7.136
Minimum functional pressure ρ_{mm} for operation	3.7.135
Minimum trip duration	3.7.130
Module <of a by-pass switch>	3.5.122
Module <capacitor switching step>	3.8.20

N

Non-linear resistor (varistor)	3.8.21
Non-self-restoring insulation	3.1.111
Non-Sustained Disruptive Discharge (NSDD)	3.1.116

O

Open-close time	3.7.127
Opening operation <of a mechanical switching device>	3.6.105
Opening time	3.7.121
Open position <of a mechanical switching device>	3.6.113
Operating cycle <of a mechanical switching device>	3.6.102
Operating mechanism	3.5.124
Operating sequence <of a mechanical switching device>	3.6.103
Operation <of a mechanical switching device>	3.6.101
Outdoor switchgear and controlgear	3.1.102
Overvoltage <in an electric power system>	3.1.106
Overvoltage protector <of a series capacitor>	3.8.2

P

Parts of assemblies	3.3
Peak arc voltage <of a mechanical switching device>	3.7.116
Peak current	3.7.104
Peak withstand current	3.7.112
Pole <of a switching device>	3.5.101
Position indicating device	3.5.118
Positively driven operation	3.6.108
Positive opening operation <of a mechanical switching device>	3.6.107
Power-frequency recovery voltage	3.7.115
Power-frequency withstand voltage	3.7.133
Power kinematic chain	3.5.124
Pre-arcing time	3.7.126
Prospective current <of a circuit and with respect to a switching device or a fuse>	3.7.102
Prospective peak current	3.7.103
Protective level U_{PL}	3.8.22

R

Rated capacitance <of a capacitor> C_N	3.8.3
Rated current <of a capacitor> I_N	3.8.4
Rated reactance <of a capacitor> X_N	3.8.5
Rated voltage <of a capacitor> U_N	3.8.6
Rated value	3.7.101
Recovery voltage	3.7.114
Re-ignition <of an AC mechanical switching device>	3.1.114
Reinsertion	3.8.23
Reinsertion current	3.8.24
Reinsertion voltage	3.8.25
Release <of a mechanical switching device>	3.5.116
Restrike <of an AC mechanical switching device>	3.1.115
Restrike performance	3.1.113

Rolling contact	3.5.115
S	
Segment <of a series capacitor>	3.8.9
Self-restoring insulation	3.1.110
Series capacitor bank	3.8.8
Short-circuit current	3.1.103
Short-circuit making capacity	3.7.110
Short-time withstand current	3.7.111
Shunt release	3.6.114
Sliding contact	3.5.114
Stored energy operation	3.6.110
Switchgear and controlgear	3.1.101
Switching device	3.4.101
T	
Temperature rise <of a part of a by-pass switch>	3.1.105
Temporary overvoltage	3.8.26
Terminal	3.5.120
Transient by-pass current	3.7.105
U	
Unit test	3.1.107
V	
Varistor coordinating current	3.8.27

4 Normal and special service conditions

Clause 4 of IEC 62271-1:2017 is applicable.

5 Ratings

5.1 General

The characteristics of a by-pass switch, including its operating devices and auxiliary equipment, that shall be used to determine the ratings are the following.

Rated characteristics to be given for all by-pass switches

- rated voltage to earth (U_{re}) and across the by-pass switch (U_{rp});
- rated insulation level to earth (U_{pe} , U_{de} , U_{se}) and across the by-pass switch (U_{pp} , U_{dp} , U_{sp});
- rated frequency (f_r);
- rated continuous current (I_r);
- rated short-time withstand current (I_k);
- rated peak withstand current (I_p);
- rated duration of short-circuit (t_k);

- h) rated supply voltage of auxiliary circuits and control circuits (U_a);
- i) rated supply frequency of closing and opening devices and of auxiliary circuits;
- j) rated pressures of compressed gas supply and/or of hydraulic supply for operation, insertion, by-passing and insulation, as applicable;
- k) rated by-pass making current;
- l) rated by-pass insertion current;
- m) rated reinsertion voltage (peak value);
- n) rated operating sequence;
- o) rated mechanical endurance class

The rated characteristics of the by-pass switch are referred to the rated operating sequence.

5.2 Rated voltage (U_r)

5.2.1 General

Subclause 5.2.1 of IEC 62271-1:2017 is applicable with the following addition.

5.2.1.101 Rated voltage to earth (U_{re})

Subclauses 5.2.2 and 5.2.3 of IEC 62271-1:2017 are applicable. The rated voltage to earth is the power system phase-to-phase voltage for which the phase-to-ground insulation of the by-pass switch is designed.

5.2.1.102 Rated voltage across the by-pass switch (U_{rp})

The rated voltage across the by-pass switch shall be derived from its associated power frequency withstand voltage as determined in 5.3.102 and in 6.1.3 of IEC 60143-1:2015.

Tables 1 to 4 of IEC 62271-1:2017 shall be used for associating a rated voltage across the by-pass switch from a power frequency withstand voltage across the by-pass switch

5.2.2 Range I for rated voltage of 245 kV and below

Subclause 5.2.2 of IEC 62271-1:2017 is applicable.

5.2.3 Range II for rated voltage above 245 kV

Subclause 5.2.3 of IEC 62271-1:2017 is applicable.

5.3 Rated insulation level (U_p , U_d , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition.

5.3.101 Rated insulation level to earth (U_{pe} , U_{de} , U_{se})

The standard values of rated withstand voltages to earth are given in Tables 1, 2, 3 and 4 of IEC 62271-1:2017.

5.3.102 Rated insulation level across the by-pass switch (U_{pp} , U_{dp} , U_{sp})

The standard values of rated insulation voltages across the by-pass switch are given in Tables 1, 2, 3 and 4 of IEC 62271-1:2017 for the corresponding rated voltage across the by-pass switch. The rated insulation levels shall be determined in accordance with 6.1.3 of IEC 60143-1:2015.

The insulation levels for insulators and series capacitor equipment mounted on the supporting platform are in reference to the platform. For installations at altitudes exceeding 1 000 m, higher insulation levels can be required. The insulation level of the insulators and equipment on the platform should be selected based on the protective level established by the overvoltage protector using the equation below. The equation applies to the insulation across the entire segment using the protective level of that segment. It also applies to the insulation within the segment using the applicable protective level across that part of the segment.

$$U_{ipf} \geq 1,2 U_{PL} / \sqrt{2}$$

where

U_{ipf} is the power-frequency withstand voltage (RMS);

U_{PL} is the protective level.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 is not applicable.

The standard values for the rated frequency of high voltage by-pass switches are 50 Hz and 60 Hz.

5.5 Rated continuous current (I_r)

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

The rated continuous current of the by-pass switch (uncompensated line) may be lower than the series capacitor bank (compensated line).

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable.

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

Subclause 5.9 of IEC 62271-1:2017 is generally applicable. The tolerance given in 6.9.3 of IEC 62271-1:2017 for shunt opening releases shall be applied to shunt closing releases.

5.10 Rated supply frequency of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressures of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable.

5.101 Rated operating sequence

The rated characteristics of the by-pass switch are referred to the rated operating sequence.

$$C - t - OC - t' - OC$$

Unless otherwise specified:

- $t = 0,3$ s for by-pass switches intended for rapid auto-reopening (by-passing-insertion time);
- $t' = 3$ min.

where

- C represents a closing operation;
- OC represents an opening operation followed immediately (that is, without any intentional delay) by a closing operation;
- t and t' are time intervals between successive operations;
- t and t' should always be expressed in minutes or in seconds.

If the by-passing-insertion time is adjustable, the limits of adjustment should be specified.

Instead of $t = 0,3$ s, other value: $t = 0,2$ s may also be used for by-pass switches intended for rapid auto-reopening.

Instead of $t' = 3$ min, other values: $t' = 15$ s and $t' = 1$ min may also be used for by-pass switches intended for rapid auto-reopening.

Other operating sequences may be specified depending upon system requirements.

5.102 Rated by-pass making current (I_{BP})

The rated by-pass making current is the maximum value of the by-pass making current that the by-pass switch shall be capable of making under line fault condition when the capacitor bank is precharged to the limiting voltage of the overvoltage protector (U_{PL}) and with a frequency of the by-pass discharge current corresponding to the actual capacitance of the capacitor bank with its associated inductance of the damping circuit. The effective damping of the by-pass discharge current can be taken into consideration.

This current shall be the sum of the capacitor bank discharge current component and the power-frequency fault current component (see 3.7.106). In general, the power-frequency fault current component should be equal to the maximum varistor coordinating current.

The rated by-pass making current should be determined by system studies as the maximum sum of the instantaneous capacitor bank discharge current and the instantaneous fault current component during the pre-arcing period (see also IEC 60143-2:2012). A value of pre-arcing time of 5 ms is suggested in case no data is available.

The by-pass making performance is covered when the required peak value of the by-pass making current is equal to or lower than the peak current value used in the relevant type test. This rule is considered to be valid only when the frequency f_{BP} of the by-pass making current is equal to or lower than 130 % of the corresponding value used during type tests.

Specific ratings can generally not be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings. Nevertheless, preferred values for the rated by-pass making current and frequency are as follows:

I_{BP} : 63 kA – 100 kA and 125 kA

f_{BP} : 500 Hz and 1 000 Hz

5.103 Rated by-pass insertion current (I_{INS})

The rated by-pass insertion current is the RMS value of the power-frequency current that the by-pass switch shall be capable of transferring from the by-pass circuit path to the main series capacitor path under the rated reinsertion voltage. Specific ratings cannot be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings.

The rated by-pass insertion current should be taken from the R10 series and may be equal to or lower (uncompensated line) than the rated current of the capacitor bank (compensated line).

5.104 Rated reinsertion voltage (U_{INS})

The rated reinsertion voltage is the peak value of the recovery voltage that the by-pass switch shall be capable of withstanding, without restrike, during the transfer of the rated by-pass insertion current.

In general, the reinsertion voltage shall be equal to U_{PL} to take into account all emergency overload conditions and power swings that could result in insertion voltages up to the protective level of the overvoltage protector.

Several reinsertion voltage waveshapes can be obtained in service. The reinsertion voltage waveshape should be determined by systems studies. For standardization purposes, and in order to cover the greatest number of practical cases, this document recommends a "1-cos" waveshape having a preferred first time-to-peak of 5,6 ms. Other waveshapes may be required and should be clearly specified to the manufacturer at the time of enquiry.

Specific ratings cannot be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings. Annex F gives more information regarding recovery voltage during reinsertion.

NOTE 1 No specific recommended values can be given for the reinsertion voltage since this value is depending on the series capacitor design parameters (capacitive impedance, rated normal current of the capacitor bank, a protective level of the overvoltage protector, overload emergency current and power swing). See Annex F for more information.

NOTE 2 To cover most of the 50 Hz and 60 Hz applications with one single test-duty, the recovery voltage has been defined with a time-to-peak of 5,6 ms.

5.105 Number of mechanical operations

A by-pass switch shall be able to perform the number of operations given in Table 1 (as defined in 7.101.2.3 and Table 6 for type tests) taking into account the programme of maintenance specified by the manufacturer.

Table 1 – Number of mechanical operations

Standard by-pass switch (normal mechanical endurance) class M1	2 000 operating sequences
By-pass switch for special service requirements (extended mechanical endurance) class M2	10 000 operating sequences

6 Design and construction

6.1 Requirements for liquids in by-pass switches

Subclause 6.1 of IEC 62271-1:2017 is applicable.

6.2 Requirements for gases in by-pass switches

Subclause 6.2 of IEC 62271-1:2017 is applicable.

6.3 Earthing of by-pass switches

Subclause 6.3 of IEC 62271-1:2017 is applicable.

6.4 Auxiliary and control equipment and circuits

6.4.1 General

Subclause 6.4.1 of IEC 62271-1:2017 is applicable.

6.4.2 Protection against electrical shock

Subclause 6.4.2 of IEC 62271-1:2017 is applicable.

6.4.3 Components installed in enclosures

Subclause 6.4.3 of IEC 62271-1:2017 is applicable with the following modification:

- after the loss, of "suitable precautions" for a duration longer than 2 h, the functionality of the by-pass switch shall come back to its original characteristics when the service condition is recovered;
- where shunt opening and closing releases are used, appropriate measures shall be taken in order to avoid damage on the releases when permanent orders for closing or opening are applied. For example, those measures may be the use of series control contacts arranged so that when the by-pass switch is closed, the close release control contact ("b" contact or break contact) is open and the open release control contact ("a" contact or make contact) is closed, and when the by-pass switch is open, the open release control contact is open and the close release control contact is closed;
- systems other than contacts are possible and may be used;
- for shunt closing releases, the protective measures for the shunt closing releases (the "b" contact) as mentioned in the first indent above shall open no sooner than the minimum close duration (3.7.131) provided by the by-pass switch and no later than the specified closing time;
- if the current of the shunt closing release is interrupted by the control contact, the closing command should be positively longer than the specified closing time.
- for shunt opening releases, the protecting measures for the shunt opening releases (the "a" contact) as mentioned in the first indent above shall open no sooner than the minimum trip duration (3.7.130) required by the by-pass switch and no later than 20 ms after separation of the main contacts;
- for short open-close time requirements, the protective measures for the shunt closing releases (the "b" contact) as mentioned in the first indent above, shall close no sooner than when the "a" contact has opened;
- where auxiliary switches are used as position indicators, they shall indicate the end position of the by-pass switch at rest, open or closed. The signalling shall be sustained;
- connections shall withstand the stresses imposed by the by-pass switch, especially those due to mechanical forces during operations;
- all auxiliary equipment, including the wiring, shall be adequately protected against rain and humidity;
- where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, interrupting and/or insulating and operating fluids and be able to switch the loads which are stated by the by-pass switch manufacturer;

- special items of auxiliary equipment such as liquid indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts, shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of interrupting and/or insulating and operating fluids;
- the power consumption of heaters at rated voltage shall be within the tolerance of $\pm 10\%$ of the value stated by the manufacturer;
- where anti-pumping devices are part of the by-pass switch control scheme, they shall act on each control circuit, if more than one is installed;
- where a control scheme of pole discrepancy is part of the by-pass switch, the position of the poles shall be supervised, open or closed. The closing of one pole shall initiate closure of the remaining poles. Each by-pass switch shall be similarly interlocked for the opening operation.

6.5 Dependent power operation

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

A by-pass switch arranged for dependent power opening with external energy supply shall also be capable of closing immediately following an opening operation.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable with the following addition to subclause 6.6.1.

A by-pass switch arranged for stored energy operation shall also be capable of closing immediately following an opening operation.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is not applicable for by-pass switches.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is generally not applicable and shall be replaced by the following.

6.9.1 General

Subclause 6.9.1 of IEC 62271-1:2017 is applicable.

6.9.2 Shunt closing releases

A shunt closing release shall operate correctly under all operating conditions of switching device up to its rated by-pass making current, and between 70 % in case of DC – or 85 % in case of AC – and 110 % of the rated supply voltage of the closing device (see 5.9), the frequency in the case of AC being the rated supply frequency of the closing device (see 5.10).

6.9.3 Shunt opening releases

A shunt opening release shall operate correctly between 85 % and 110 % of the rated supply voltage of the opening device (see 5.9), the frequency in the case of AC being the rated supply frequency of the opening device (see 5.10).

6.9.4 Capacitor operation of shunt releases

Subclause 6.9.4 of IEC 62271-1:2017 is applicable.

6.9.5 Under-voltage release

Subclause 6.9.5 of IEC 62271-1:2017 is not applicable to by-pass switches.

6.9.101 Multiple releases

If a by-pass switch is fitted with more than one release for the same function, a defect in one release shall not disturb the function in the others. Releases used for the same function shall be physically separated, i.e. magnetically decoupled.

6.9.102 Operation limits of releases

For shunt-opening releases, the minimum trip duration, and for shunt-closing releases, the minimum command duration at rated supply voltage, shall not be less than 2 ms.

In order to prevent untimely operation due to parasitic voltages that may be present in control circuits, the minimum supply voltage for operation of shunt releases shall not be less than 20 % of the rated supply voltage.

6.9.103 Power consumption of releases

The power consumption of shunt closing or opening releases of a three-pole by-pass switch shall not exceed 1 200 VA. For certain by-pass switch designs, higher values may be necessary.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable.

6.10.101 Low- and high-pressure interlocking devices

All by-pass switches having an energy storage in gas receivers or hydraulic accumulators (see 6.6.2 of IEC 62271-1:2017) and all by-pass switches except sealed pressure devices, using compressed gas for by-passing and insertion (see 5.103) shall be fitted with a low-pressure interlocking device, and can also be fitted with a high-pressure interlocking device, set to operate at, or within, the appropriate limits of pressure stated by the manufacturer.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following additions: the nameplates of a by-pass switch and its operating devices shall be marked in accordance with Table 2.

Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer.

Releases shall bear the appropriate data.

Table 2 – Nameplate information

	Abbreviation	Unit	By-pass switch ^b	Operating device ^b	Condition: Marking only required if
1	2	3	4	5	6
Name of manufacturer			X	X	
Type designation and serial number			X	X	
Rated voltage to earth	U_{re}	kV	X		
Rated voltage across by-pass switch	U_{rp}	kV	X		
Rated lightning impulse withstand voltage to earth	U_{pe}	kV	X		
Rated lightning impulse withstand voltage across by-pass switch	U_{pp}	kV	X		
Rated switching impulse withstand voltage to earth	U_{se}	kV	Y		U_{re} 300 kV and above
Rated switching impulse withstand voltage across by-pass switch	U_{sp}	kV	Y		U_{rp} 300 kV and above
Rated frequency	f_r	Hz	X		rating is not applicable at both 50 Hz and 60 Hz
Rated continuous current	I_r	A	X		
Rated short-time withstand current	I_k	kA	X		
Rated peak withstand current	I_p	kA	X		
Rated duration of short circuit	t_k	s	Y		different from 1 s
Rated by-pass making current	I_{BP}	kA	X		
Frequency of the rated by-pass making current	f_{BP}	Hz	X		
Rated by-pass insertion current	I_{INS}	A	X		
Rated reinsertion voltage	U_{INS}	kV	X		
Filling pressure for operation ^a	P_{rm}	MPa		Y	If applicable
Filling pressure for insulation, by-passing and insertion ^a	P_{re}	MPa	Y		If applicable
Alarm pressure for operation ^a	P_{am}	MPa		Y	If applicable
Alarm pressure for insulation, by-passing and insertion ^a	P_{ae}	MPa	Y		If applicable
Minimum functional pressure for operation ^a	P_{mm}	MPa		Y	If applicable
Minimum functional pressure for insulation, by-passing and insertion ^a	P_{me}	MPa	Y		If applicable
Rated supply voltage(s) of auxiliary and control circuits. Specify DC/AC (with rated frequency)	U_a	V		X	
Type and mass of fluid (liquid or gas) for insulation	M_f	kg	X		
Mass of by-pass switch (including any fluid)	M	kg	Y	Y	more than 300 kg
Rated operating sequence			X		
Year of manufacture			X		
Minimum and maximum ambient temperature		°C	Y	Y	If different than –5 °C and 40 °C
Classification			Y		different from M1
Relevant standard with date of issue			X	X	
NOTE The abbreviations in column 2 can be used instead of the terms in column 1. When terms in column 1 are used, the word “rated” need not appear.					
^a Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate					
^b X = the marking of these values is mandatory; blanks indicate the value zero; Y = the marking of these values to the conditions in column 6.					

6.12 Locking devices

Subclause 6.12 of IEC 62271-1:2017 is applicable.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is applicable.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 is applicable.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable only to vacuum interrupters used as by-pass switches.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, by-passing, insertion and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable.

6.101 Requirements for simultaneity within a pole

If one pole consists of more than one by-pass unit connected in series, the maximum difference between the instants of contact separation or contact touch within these series connected units shall not exceed one-eighth of a cycle of rated frequency.

NOTE The time spread between poles is normally not considered unless the single-pole operation of the by-pass switch is restricted from system operation.

6.102 General requirement for operation

A by-pass switch, including its operating devices, shall be capable of completing its rated operating sequence (5.101) in accordance with the relevant provisions of 6.5 to 6.9 and 6.103 for the whole range of ambient temperatures within its temperature class as defined in Clause 4 of IEC 62271-1:2017.

This requirement is not applicable to auxiliary manual operating devices; where provided, these shall be used only for maintenance and for an emergency operation on a dead circuit.

By-pass switches provided with heaters shall be designed to permit a closing operation at the minimum ambient temperature defined by the temperature class when the heaters are not operational for a minimum time of 2 h.

6.103 Pressure limits of fluids for operation

The manufacturer shall state the maximum and minimum pressures of the fluid for operation at which the by-pass switch is capable of performing according to its ratings and at which the appropriate low- and high-pressure interlocking devices shall be set (see 6.10.101). The manufacturer shall state the minimum functional pressure for operation, by-passing and insertion (see 3.7.135 and 3.7.136).

The manufacturer may specify pressure limits at which the by-pass switch is capable for each of the following performances:

- a) making its rated by-pass making current, i.e. a "C" operation;
- b) reinserting its rated by-pass insertion current immediately followed by making its rated by-pass making current, i.e. an "OC" operating cycle;
- c) for by-pass switches intended for rapid auto-reinsertion: making its rated by-pass making current followed after a time interval t of the rated operating sequence (5.101) by reinserting its rated by-pass insertion current, immediately followed again by making its rated by-pass making current, i.e. an "C – t – OC" operating sequence.

The by-pass switches shall be provided with energy storage of sufficient capacity for satisfactory performance of the appropriate operations at the corresponding minimum pressures stated.

6.104 Vent outlets

Vent outlets are devices that allow a deliberate release of pressure in a by-pass switch during operation.

NOTE This is applicable to air-blast and oil by-pass switches.

Vent outlets of by-pass switches shall be so situated that a discharge of oil or gas or both will not cause electrical breakdown and is directed away from any location where persons may be present. The necessary safety distance shall be stated by the manufacturer.

The construction shall be such that gas cannot collect at any point where ignition can be caused, during or after the operation, by sparks arising from the normal operation of the by-pass switch or its auxiliary equipment.

6.105 Time quantities

Refer to Figures 2, 3 and 4.

Values may be assigned to the following time quantities:

- opening time (no-load);
- closing time (no-load);
- close-open time (no-load);
- open-close time (no-load).

Time quantities are based on

- rated supply voltages of closing and opening devices and of auxiliary and control circuits (see 5.9);
- rated supply frequency of closing and opening devices and of auxiliary circuits (see 5.10);
- rated pressure of compressed gas supply for controlled pressure systems (see 5.11);
- rated filling levels for insulation and/or operation (see 5.11);
- an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$.

NOTE It is not practical to assign a value of by-pass time or of by-pass- insertion time owing the variation of the arcing time and the pre-arcing time.

6.106 Static mechanical loads

By-pass switches 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 by-pass switch shall be in accordance with Clause 4 of IEC 62271-1:2017.

Some examples of static forces due to wind, ice and weight on flexible and tubular connected conductors are given as a guidance in Table 3.

The tensile force due to the connected conductors is assumed to act at the outermost end of the by-pass switch terminal.

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

Table 3 – Examples of static horizontal and vertical forces for static terminal load

Rated voltage range to earth	Rated current range	Static horizontal force F_{th}		Static vertical force (vertical axis-upward and downward) F_{tv} N
		Longitudinal F_{thA} N	Transversal F_{thB} N	
U_{re} kV	I_t A			
< 100	800 to 1 250	500	400	500
< 100	1 600 to 2 500	750	500	750
100 to 170	1 250 to 2 500	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

7 Type tests

7.1 General

7.1.1 Basics

Subclause 7.1.1 of IEC 62271-1:2017 is generally applicable with the following additions.

The type tests for by-pass switches are listed in Table 4.

For the type tests, the tolerances on test quantities are given in Annex A.

The individual type tests shall, in principle, be performed on a by-pass switch in a new and clean condition. In the case of by-pass switches using SF₆ for insulation, by-passing and insertion and/or operation, the quality of the gas shall at least comply with the acceptance levels of IEC 60480.

The responsibility of the manufacturer is limited to the declared rated values and not to those values achieved during the type tests.

The uncertainty of each measurement by oscillograph or equivalent equipment (for example transient recorder), including associated equipment, of the quantities that determine the ratings (for example by-pass current, applied voltage and recovery voltage) shall be within $\pm 5\%$ (equal to a coverage factor of 2,0).

NOTE For the meaning of coverage factor, refer to ISO/IEC Guide 98-1:2009.

Table 4 – Type tests

Mandatory type tests	Subclause
Dielectric tests	7.2
Measurement of the resistance of the main circuit	7.4
Temperature-rise tests	7.5
Short-time withstand current and peak withstand current tests	7.6
Tightness tests	7.8
Additional test on auxiliary and control circuits	7.10
Mechanical operation test at ambient air temperature	7.101.2
By-pass making current tests	7.103.2
Insertion current tests	7.103.3
Mandatory type tests, where applicable	Subclause
Radio interference voltage tests	7.3
Verification of the degree of protection	7.7
EMC tests	7.9
X-radiation test procedure for vacuum interrupters	7.11
Extended mechanical endurance tests on by-pass switches for special service conditions	7.101.2.4
Low and high temperature tests	7.101.3
Test to prove operation under severe ice conditions	7.101.5

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC 62271-1:2017 is applicable.

7.1.3 Information to be included in type test reports

Subclause 7.1.3 of IEC 62271-1:2017 is applicable with the following addition.

Further details relating to records and reports of type tests for by-pass current making and insertion tests are given in Annex B.

7.1.101 Invalid tests

In the case of an invalid test, it may become necessary to perform a greater number of tests than is required by this document. An invalid test is one where one or more of the test parameters demanded by the document is not met. This includes, for example, current, voltage and time factors as well as point-on-wave requirements (if specified) and the additional features in synthetic testing such as correct auxiliary switching device operation and correct injection time.

The deviation from the document could make the test less or more severe. Four different cases are considered in Table 5.

The invalid part of the test duty may be repeated without reconditioning of the by-pass switch. However, in the case of a failure of the by-pass switch during such additional tests, or at the discretion of the manufacturer, the by-pass switch may be reconditioned and the complete test-duties repeated. In those cases, the test report shall include reference to the invalid test.

If any record of an individual operation cannot be produced for technical reasons, this individual operation is not considered invalid, provided that evidence can be given in another manner that the by-pass switch did not fail and the required testing values were fulfilled.

Table 5 – Invalid tests

Test conditions related to document	By-pass switch	
	Passes	Fails
More severe	Test valid, result accepted	Test to be repeated with correct parameters Modification of the design of the by-pass switch not required
Less severe	Test to be repeated with correct parameters Modification of the design of the by-pass switch not required	By-pass switch failed the test. Modification of the design of the by-pass switch required, aiming for improvement of the performance Tests to be re-started on the modified by-pass switch

7.1.102 Type tests to repeat for by-pass switches with alternative operating mechanisms

The following type tests shall be repeated on by-pass switches with alternative operating mechanisms:

- mechanical operation tests at ambient temperature (according to 7.101.2);
- high and low temperature tests (according to 7.101.3);
- by-pass making current test (as defined in 7.102.7);
- short-time withstand current and peak withstand current tests on by-pass switches having main contacts of the butt type (according to 7.6).

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is applicable with the following note:

NOTE In the case of dead tank by-pass switches, when the bushings have been previously tested according to the relevant IEC standard, tests under wet conditions can be omitted.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable with the following modification.

The following test procedure B adapted for switching devices that have self-restoring and non-restoring insulation is the preferred test procedure for by-pass switches. The by-pass switch has passed the impulse tests if the following conditions are fulfilled:

- a) each series has at least 15 tests;
- b) no disruptive discharges on non-self-restoring insulation shall occur. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge;
- c) the number of disruptive discharges shall not exceed two for each complete series.

This procedure leads to a maximum possible number of 25 impulses per series.

Procedure C of IEC 60060-1:2010 may be used when all three poles are tested.

If disruptive discharges occur and evidence cannot be given during testing that the disruptive discharges were on self-restoring insulation, the by-pass switch shall be dismantled and inspected after the completion of the dielectric test series. If damage to non-self-restoring insulation is observed, the by-pass switch has failed the test.

If the atmospheric correction factor, K_t , is less than 1,00 but greater than 0,95, it is permissible to follow the criteria stated in 7.2.5 of IEC 62271-1:2017 if the correction factor is not applied during the tests. Then, if one or two disruptive discharges out of 15 impulses occur in the external insulation, the particular test series showing flashover(s) is repeated with the appropriate correction factor so that no external disruptive discharge occurs.

For by-pass switches of gas insulated switchgear tested with test bushings which are not part of the by-pass switch, flashover across the test bushings should be disregarded.

The determination of the location of the observed disruptive discharges should be done by the laboratory using sufficient detection means, for example, photographs, video recordings, internal inspection.

7.2.6 Application of test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is applicable with the following modifications:

- The allowance of preliminary impulses for vacuum interrupters is not applicable for by-pass switches;
- The number of reduced impulses before a test or before polarity reversal shall be limited to two impulses between 60 % and 80 % of the rated withstand voltage.

7.2.7 Tests of by-pass switches of $U_{re} \leq 245$ kV or $U_{rp} \leq 245$ kV

Subclause 7.2.7 of IEC 62271-1:2017 is applicable. These test series need to be performed only for the part of the insulation which fulfils the above criteria.

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-1:2017 is applicable.

7.2.7.2 Power-frequency voltage tests

Subclause 7.2.7.2 of IEC 62271-1:2017 is applicable with the following note:

NOTE In the case of dead tank by-pass switches, when the bushings have been previously tested according to the relevant IEC standard, tests under wet conditions can be omitted.

7.2.7.3 Lightning impulse voltage test

Subclause 7.2.7.3 of IEC 62271-1:2017 is applicable.

7.2.8 Tests of by-pass switches of $U_{re} > 245$ kV or $U_{rp} > 245$ kV

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-1:2017 is applicable. These test series need to be performed only for the part of the insulation which fulfils the above criteria.

7.2.8.2 Power-frequency voltage tests

Subclause 7.2.8.2 of IEC 62271-1:2017 is applicable with the following addition.

The test procedure following the alternative method is more severe than the test procedure following the preferred method.

7.2.8.3 Switching impulse voltage tests

Subclause 7.2.8.3 of IEC 62271-1:2017 is applicable with the following addition.

The dry tests shall be performed using voltage of positive polarity only. With the by-pass switch closed, the test voltage equal to the rated withstand voltage to earth, shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

With the by-pass switch open, the test voltage equal to the rated withstand voltage across the open by-pass switch shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

7.2.8.4 Lightning impulse voltage tests

Subclause 7.2.8.4 of IEC 62271-1:2017 is applicable with the following addition.

With the by-pass switch closed, the test voltage equal to the rated withstand voltage to earth, shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

With the by-pass switch open, the test voltage equal to the rated withstand voltage across the open by-pass switch shall be applied for each test condition of Table 10 of IEC 62271-1:2017.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is applicable.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition.

Partial discharge tests are not normally required to be performed on the complete by-pass switch. However, in the case of by-pass switches using components for which a relevant IEC standard exists, and if this relevant standard requires partial discharge measurements (for example, bushings, see IEC 60137), evidence shall be produced by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 is not applicable; the tests specified there are replaced with the following:

Where after mechanical or environmental tests (see 7.101.1.4) the insulating properties across open contacts of a by-pass switch cannot be verified by visual inspection with sufficient reliability, a power-frequency withstand voltage test in dry condition in accordance with 7.2.12 of IEC 62271-1:2017 across the open by-pass switch shall be applied as a condition check. For GIS and dead-tank by-pass switches for which the insulation to earth may be impaired, a power-frequency withstand voltage test in dry condition according to 7.2.12 of IEC 62271-1:2017 to earth with the by-pass switch in closed position shall also be performed as a condition check.

For multi-unit live tank by-pass switches with identical units according to 7.102.4.2.3, the voltage test as a condition check may be performed as a unit test.

For gas enclosed vacuum by-pass switches, the voltage test as a condition check may not be sufficient. For such cases, the vacuum integrity shall be demonstrated.

Where, after by-pass and insertion tests (see 7.102.9), a voltage test is performed as a condition check, the following conditions shall apply.

For by-pass switches with an asymmetrical current path, the connections shall be reversed. The complete tests shall be carried out once for each arrangement of the connections.

These test series need to be performed only for the part of the insulation which fulfils the criteria given below.

- By-pass switches with $U_{re} \leq 72,5 \text{ kV}$ or $U_{rp} \leq 72,5 \text{ kV}$

A 1 min power-frequency voltage test shall be performed. The test voltage shall be 80 % of the value in Table 1 or Table 2, column (2) of IEC 62271-1:2017.

- By-pass switches with $72,5 \text{ kV} < U_{re} \leq 245 \text{ kV}$ or $72,5 \text{ kV} < U_{rp} \leq 245 \text{ kV}$

An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 60 % of the highest relevant value in Table 1 or Table 2, column (4) of IEC 62271-1:2017.

- By-pass switches with $300 \text{ kV} \leq U_{re} \leq 420 \text{ kV}$ or $300 \text{ kV} \leq U_{rp} \leq 420 \text{ kV}$

An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 80 % of the rated switching impulse withstand voltage given in Table 3 or Table 4 of IEC 62271-1:2017. The rated switching impulse withstand voltage shall be taken from column (4). The reference value for the condition check shall be taken from the same column.

- By-pass switches with $550 \text{ kV} \leq U_{re} \leq 800 \text{ kV}$ or $550 \text{ kV} \leq U_{rp} \leq 800 \text{ kV}$

An impulse voltage test shall be performed. The crest value of the impulse voltage shall be 90 % of the rated switching impulse withstand voltage given in Table 3 or Table 4 of

IEC 62271-1:2017. The rated switching impulse withstand voltage shall be taken from column (4) of this table. The reference value for the condition check shall be taken from the same column.

Where an impulse voltage test shall be carried out, five impulses of each polarity shall be applied across the switching device and to earth (if required). The by-pass switch shall be considered to have passed the test if no disruptive discharge occurs.

For the impulse voltage test, the synthetic testing equipment of the power laboratory may be applied. The waveshape of the impulse voltage shall be either a standard switching impulse or a waveshape according to the TRV specified for terminal fault T10, as defined in IEC 62271-100. For the test with the waveshape according to T10, timing tolerances of -10 to $+200$ % on time t_3 are permitted.

Generally the insulation across the pole and to earth cannot be verified simultaneously since the insulation levels across pole are different from the insulation levels to earth. Additional condition check test can be necessary as outlined above.

For live tank by-pass switches, the phase-to-earth insulation is generally not influenced by by-pass and insertion operations and the phase-to-earth voltage test as a condition check is generally not required. For dead-tank bypass switches, the phase-earth insulation can be impaired by by-pass and insertion operations and the voltage test as a condition check, if required, should also be performed phase-to-earth. If the tests are performed using the TRV impulse with a T10 waveshape, equivalence is maintained to the standard switching impulse if the following rules are applied:

- the damping of the TRV should be such that the second peak of the TRV oscillation is not higher than 80 % of the first one;
- about 2,5 ms after the peak, the actual value of the recovery voltage should be in the range of 50 % of the peak value.

NOTE Comparative tests have shown that there are almost no differences in the behaviour of circuit-breakers, both in new and in worn conditions, when testing is performed with standard switching impulses or with TRV impulses with a waveshape in accordance with terminal fault T10, respectively.

7.3 Radio interference voltage (RIV) tests

Subclause 7.3 of IEC 62271-1:2017 is applicable with the following addition.

Tests may be performed on one pole of the by-pass switch in the closed position only. During the tests, the by-pass switch shall be equipped with all accessories such as grading capacitors, corona rings, HV connectors, etc., which may influence the radio interference voltage performance.

See also 7.9.1.1

NOTE If the by-pass switch forms an integral part of the series capacitor platform and RIV tests have been performed on the platform, the RIV test on the by-pass switch is considered to be covered.

7.4 Resistance measurement

Subclauses 7.4.1 to 7.4.3 of IEC 62271-1:2017 are applicable. Subclause 7.4.4 is replaced by the following.

7.4.4 Resistance measurement of contacts and connections in the main circuit as a condition check

7.4.4.101 Resistance measurement test procedure

When resistance measurements are called for as a condition check after a specific test, the following procedure shall be applied.

The resistance across the by-pass switch contacts shall be measured before the test. The measuring test points shall be the nearest accessible points to and on either side of the contacts. An average value of the resistance shall be calculated based on three measurements. If possible, one no-load open and close operation cycle should be made between each of the measurements. If no-load operations cannot be made, the 3 measurements shall be made without no-load operations of the by-pass switch.

NOTE 1 It is recognized that for some tests, it is not practical (e.g. if gas handling is required in between the measurements) nor possible (e.g. during continuous current test because of the presence of temperature sensors within the by-pass switch chamber(s)) to make any no-load operations between each of the three resistances measurements.

The measurements shall be made with DC at full rated continuous current (-20 % to 0 %) if less than or equal to 50 A or any convenient value of current between (and including) 50 A and the rated continuous current if it is higher than 50 A.

NOTE 2 In some designs, it can be only practical that several connections and/or contacts are measured in series in the main circuit or even the complete poles of a by-pass switch are measured during type testing.

After the completion of the test, the resistance shall be measured again using the identical procedure to that used for the resistance measurements made prior to the tests. Before this resistance measurement, some conditioning of the contacts is acceptable based on the manufacturer's recommendations such as no-load operation cycles or the application of rated continuous current for some time.

The resistance measurements before and after shall be performed at ambient temperature with a maximum difference of 10 K between the measurements. The resistance increase is calculated by the difference between the average value of the measurements before and after the test.

7.4.4.102 By-pass making and insertion tests

For by-pass switches having sealed-for-life interrupters, the resistance condition check of the test sample after completion of by-pass making and insertion tests is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.101 is not greater than 100 %. For other by-pass switch types, visual inspection of the contact system is usually sufficient as stated in 7.102.9.2.

7.5 Continuous current tests

7.5.1 Conditions of the test object

Subclause 7.5.1 of IEC 62271-1:2017 is applicable.

7.5.2 Arrangement of the equipment

Subclause 7.5.2 of IEC 62271-1:2017 is applicable.

7.5.3 Test current and duration

Subclause 7.5.3 of IEC 62271-1:2017 is applicable.

7.5.4 Temperature measurement during test

Subclause 7.5.4 of IEC 62271-1:2017 is applicable.

7.5.5 Resistance of the main circuit

Subclause 7.5.5 of IEC 62271-1:2017 is applicable.

7.5.6 Criteria to pass test

Subclause 7.5.6 of IEC 62271-1:2017 is applicable.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the by-pass switch and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is applicable.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

7.6.4 Condition of the by-pass switch after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable.

7.7 Verification of the protection

7.7.1 Verification of the IP coding

Subclause 7.7.1 of IEC 62271-1:2017 is applicable.

7.7.2 Verification of the IK coding

Subclause 7.7.2 of IEC 62271-1:2017 is applicable.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

7.9 Electromagnetic compatibility tests (EMC)

7.9.1 Emission tests

7.9.1.1 Emission tests from the main circuits (radio interference voltage test, RIV)

Subclause 7.9.1.1 of IEC 62271-1:2017 is applicable with the following modification:

Tests may be performed on one pole of the by-pass switch in the closed position only. During the tests, the by-pass switch shall be equipped with all accessories such as grading capacitors, corona rings and HV connectors, which may influence the radio interference voltage performance.

NOTE If the by-pass switch forms an integral part of the series capacitor platform and RIV tests have been performed on the platform, the RIV test on the by-pass switch is considered to be covered.

7.9.1.2 Emission tests from the auxiliary and control circuits

Subclause 7.9.1.2 of IEC 62271-1:2017 is applicable.

7.9.2 Immunity tests on auxiliary and control circuits

Subclause 7.9.2 of IEC 62271-1:2017 is applicable.

7.9.3 Additional EMC tests on auxiliary and control circuits

Subclause 7.9.3 of IEC 62271-1:2017 is applicable with the following note:

NOTE This clause is applicable to both, complete electronic boards (e.g. control modules) and devices containing at least one electronic component (e.g. electronic timing relays).

7.9.3.1 General

Subclause 7.9.3.1 of IEC 62271-1:2017 is applicable.

7.9.3.2 Ripple on DC input power port immunity test

If no electronic components are used in the control unit and the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete by-pass switch equipped with its entire control unit, the ripple on DC input power port immunity test is regarded as covered and additional tests shall be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

Where electronic components are used, tests according to subclause 7.9.2 of IEC 62271-1:2017 on the individual components are sufficient.

7.9.3.3 Voltage dips, short interruptions and voltage variations on input power port immunity tests

Subclause 7.9.3.3 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

7.10.1 General

Subclause 7.10.1 of IEC 62271-1:2017 is applicable.

7.10.2 Functional tests

Subclause 7.10.2 of IEC 62271-1:2017 is applicable with the following addition.

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete by-pass switch equipped with its entire control unit, the functional tests according to 7.10.2 of IEC 62271-1:2017 are regarded as covered and additional tests shall be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

7.10.3 Verification of the operational characteristics of auxiliary contacts

Subclause 7.10.3 of IEC 62271-1:2017 is applicable.

7.10.4 Environmental tests

Subclause 7.10.4 of IEC 62271-1:2017 is applicable with the following addition.

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 and the low and high temperature tests in accordance with 7.101.3 are performed on the complete by-pass switch equipped with its entire control unit, the environmental tests according to 7.10.4 of IEC 62271-1:2017 is regarded as covered and additional tests can be omitted. When testing of the complete by-pass switch is not practicable, component tests in accordance with 7.101.1.2 may be accepted.

Seismic tests are not covered. If a seismic test is requested, it should be performed by agreement between manufacturer and user.

7.10.5 Dielectric test

Subclause 7.10.5 of IEC 62271-1:2017 is applicable

7.11 X-Radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Mechanical and environmental tests

7.101.1 Miscellaneous provisions for mechanical and environmental tests

7.101.1.1 Mechanical characteristics

At the beginning of the type tests, the mechanical characteristics of the by-pass switch shall be established. The mechanical characteristics shall be measured similarly as circuit-breakers, 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 by-pass switch. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, by-pass making current and insertion 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 C operation and a single O 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 p_{me} for by-passing, insertion and insulation.

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

7.101.1.2 Component tests

When testing of a complete by-pass switch is not practicable, component tests may be accepted as type tests. The manufacturer shall determine the components that are suitable for testing.

Components are separate functional sub-assemblies that can be operated independently of the complete by-pass switch (for example, pole, by-pass unit, operating mechanism).

When component tests are made, the manufacturer shall prove that the mechanical and environmental stresses on the component during the tests are not less than those applied to the same component when the complete by-pass switch is tested. Component tests shall

cover all different types of components of the complete by-pass switch, provided that the particular test is applicable to the component. The conditions for the component type tests shall be the same as those which could be employed for the complete by-pass switch.

Parts of auxiliary and control equipment that have been manufactured in accordance with relevant standards shall comply with these standards. The proper function of such parts in connection with the function of the other parts of the by-pass switch shall be verified.

7.101.1.3 Characteristics and settings of the by-pass switch to be recorded before and after the tests

Before and after the tests, the following operating characteristics or settings shall be recorded and evaluated:

- a) closing time;
- b) opening time;
- c) time spread between units of one pole;
- d) time spread between poles (if multi-pole tested);
- e) recharging time of the operating device;
- f) consumption of the control circuit;
- g) consumption of the tripping devices, possible recording of the current of the releases;
- h) duration of opening and closing command impulse;
- i) tightness, if applicable;
- j) gas densities or pressures, if applicable;
- k) resistance of the main circuit;
- l) time-travel chart;
- m) other important characteristics or settings as specified by the manufacturer.

The above operating characteristics shall be recorded at

- rated supply voltage and filling pressure for operation,
- maximum supply voltage and maximum pressure for operation,
- maximum supply voltage and minimum functional pressure for operation,
- minimum supply voltage and minimum functional pressure for operation,
- minimum supply voltage and maximum pressure for operation.

7.101.1.4 Condition of the by-pass switch during and after the tests

During and after the tests, the by-pass switch shall be in a condition such that it is capable of operating normally, carrying its rated normal current, by-passing its rated by-pass making current and inserting its rated insertion current and withstanding the voltage values according to its rated insulation levels.

In general, these requirements are fulfilled if

- during the tests, the by-pass switch operates on command and does not operate without command;
- after the tests, the characteristics measured according to 7.101.1.3 are within the tolerances given by the manufacturer;
- after the tests, all parts, including contacts, do not show undue wear;
- after the tests, coated contacts are such that a layer of coating material remains at the contact area. If this is not the case, the contacts shall be regarded as bare and the test

requirements are fulfilled only if the temperature rise of the contacts during the continuous current test (according to 7.5) does not exceed the value permitted for bare contacts;

- during and after the tests, any distortion of mechanical parts is not such that it adversely affects the operation of the by-pass switch or prevents the proper fitting of any replacement part;
- after the tests, the insulating properties of the by-pass switch in the open position shall be in essentially the same condition as before the tests. Visual inspection of the by-pass switch after the tests is usually sufficient for verification of the insulating properties. In the case of by-pass switches with sealed-for-life by-pass units, a voltage test as a condition check in accordance with 7.2.12 may be necessary;
- 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 14 of IEC 62271-1:2017 by more than 10 K.

7.101.1.5 Condition of the auxiliary and control equipment during and after the tests

During and after the tests, the following conditions for the auxiliary and control equipment shall be fulfilled:

- during the tests, care shall be taken to prevent undue heating;
- during the tests, a set of contacts (both make and break auxiliary contacts) shall be arranged to switch the current of the circuits to be controlled (see 6.4);
- during and after the tests, the auxiliary and control equipment shall fulfil its functions;
- during and after the tests, the capability of the auxiliary circuits, the auxiliary switches and of the control equipment shall not be impaired. In case of doubt, the tests according to 7.10.3 of IEC 62271-1:2017 shall be performed;
- during and after the tests, the contact resistance of the auxiliary switches shall not be affected adversely. The temperature rise when carrying the rated current shall not exceed the specified values (see Table 14 of IEC 62271-1:2017).

7.101.2 Mechanical operation test at ambient air temperature

7.101.2.1 General

The mechanical operation test shall be made at the ambient air temperature of the test location. The ambient air temperature shall be recorded in the test report. Auxiliary equipment forming part of the operating devices shall be included.

The mechanical operation test shall consist of 2 000 operating sequences.

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 any other kind of maintenance is allowed.

NOTE A by-pass switch design can be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.9 and 5.10. These variants do not need to be tested if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

7.101.2.2 Condition of the by-pass switch before the test

The by-pass switch for test shall be mounted on its own support and its operating mechanism shall be operated in a specified manner. It shall be tested according to its type as follows.

A three-pole by-pass switch actuated by a single operating device and/or with all poles mounted on a common frame shall be tested as a complete unit.

Tests shall be conducted at the rated filling pressure for by-passing and insertion according to 7.101.1.3, item j).

A three-pole by-pass switch in which each pole or even each column is actuated by a separate operating device shall be tested preferably as a complete three-pole by-pass switch. However, for convenience, or owing to limitations of the dimensions of the test bay, one single-pole unit of the by-pass switch may be tested, provided that it is equivalent to, or not in a more favourable condition than, the complete three-pole by-pass switch over the range of tests, for example in respect of:

- reference mechanical travel characteristics,
- power and strength of closing and opening mechanism,
- the rigidity of the structure.

7.101.2.3 Description of the test on class M1 by-pass switches

The by-pass switch shall be tested in accordance with Table 6.

Table 6 – Number of operating sequences

Operating sequence	Supply voltage and operating pressure	Number of operating sequences
$O - t_a - C - t_a$	Minimum	500
	Rated	500
	Maximum	500
$C - t - OC - t_a - O - t_a$	Rated	250
O = opening; C = closing; OC = an opening operation followed immediately (i.e., without any intentional time-delay) by a closing operation; t_a = time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the by-pass switch (this time can be different according to the type of operation); t = 0,3 s for by-pass switches intended for rapid auto-reopening, if not otherwise specified.		

7.101.2.4 Extended mechanical endurance tests on class M2 by-pass switches for special service requirements (multi-segmented series capacitor banks)

For special service requirements in the case of frequently operated by-pass switches (for example in multi-segmented series capacitor banks), extended mechanical endurance tests may be carried out, as follows.

The tests shall be made according to 7.101.1, 7.101.2.1, 7.101.2.2 and 7.101.2.3 with the following addition:

- the tests shall consist of 10 000 operating sequences comprising five times the test series specified in Table 6;
- 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 the change of parts outside of the main circuit, which are not being part of the kinematic chain, and are listed in the programme of maintenance, is permitted;
- the programme of maintenance during the tests shall be defined by the manufacturer before the tests are recorded in the test report.

7.101.2.5 Acceptance criteria for the mechanical operation tests

The criteria given below apply for mechanical operation tests on class M1 and class M2 by-pass switches.

- a) Before and after the total test programme, the following operations shall be performed:
- five open-close operations at the rated supply voltage of closing and opening devices and of auxiliary and control circuits and the filling pressure for operation;
 - five open-close operations at the minimum supply voltage of closing and opening devices and of auxiliary and control circuits and the minimum pressure for operation;
 - five open-close operations at the maximum supply voltage of closing and opening devices and of auxiliary and control circuits and the maximum pressure for operation.

During these operations, the operating characteristics (see 7.101.1.3) shall be recorded and evaluated. It is not necessary to publish all the oscillograms recorded. However, at least one oscillogram for each set of conditions given above shall be included in the test report.

In addition, the following checks and measurements shall be performed (see 11.101.2):

- measurements of characteristic operating fluid pressures and consumption during operations, if applicable;
- verification of the rated operating sequence;
- checks of certain specific operations, if applicable.

The variation between the mean values of each parameter measured before and after the extended mechanical endurance tests shall be within the tolerances given by the manufacturer.

- b) After each series of 2 000 operating sequences, the operating characteristics a), b), c), d), e) and l) in 7.101.1.3 shall be recorded.
- c) After the total test programme, the condition of the by-pass switch shall be in accordance with 7.101.1.4.

7.101.3 Low and high temperature tests

7.101.3.1 General

The two tests need not be performed in succession, and the order in which they are made is arbitrary. For by-pass switches not subjected to a temperature lower than $-10\text{ }^{\circ}\text{C}$, no low temperature test is required.

For single enclosure by-pass switches or multi-enclosure by-pass switches with a common operating device, three-pole tests shall be made. For multi-enclosure by-pass switches with independent poles, testing of one complete pole is permitted.

Owing to limitations of the test facilities, multi-enclosure type by-pass switches may be tested using one or more of the following alternatives, provided that the by-pass switch, in its testing arrangement, is not in a more favourable condition than the normal condition for mechanical operation (see 7.101.2.2):

- a) reduced length of phase-to-earth insulation;
- b) reduced pole spacing;
- c) reduced number of modules.

If heat sources are required, they shall be in operation.

Liquid or gas supplies for by-pass switch operation shall be at the test air temperature unless the by-pass switch design requires a heat source for these supplies.

No maintenance, replacement of parts, lubrication or readjustment of the by-pass switch is permissible during the tests.

NOTE In order to determine the material temperature characteristics, ageing, etc., tests of longer duration than those specified in the following subclauses can be necessary.

As an alternative approach to the methods given in this document, a manufacturer may establish compliance with performance requirements for an established by-pass switch family by documenting satisfactory by-pass switch field experience in at least one location with ambient air temperatures frequently at, or above, the specified maximum ambient air temperature of 40 °C, and at least one location with satisfactory field experience in specified minimum ambient air temperature, depending on the ambient temperature range (see Clause 4 of IEC 62271-1:2017).

The by-pass switch has passed the test if the conditions stated in 7.101.1.4 and 7.101.1.5 are fulfilled. Furthermore, the conditions in 7.101.3.3 and 7.101.3.4 shall be fulfilled and the leakage rates recorded shall not exceed the limits given in Table 15 of IEC 62271-1:2017. In the test report, the testing conditions and the condition of the by-pass switch before, during and after the test shall be reported. The recorded quantities shall be presented in an appropriate way and the oscillograms taken shall be shown. To reduce the number of oscillograms in the test report, it is allowed to show a single representative oscillogram of every relevant type of operation under each specified testing condition.

Vacuum by-pass switches are excluded from the tightness verification tests during the high and low temperature tests. The integrity of the vacuum shall be verified by a power frequency voltage (or equivalent) test after the high and low temperature tests. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF₆, the tightness verification tests during the high and low temperature tests shall also be performed on this enclosure.

A by-pass switch design may be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.9 and 5.10. These variants do not need to be tested if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

For dead-tank by-pass switches equipped with tank heater(s) for the purpose of avoiding gas liquefaction during low ambient temperature conditions, the test sequence prescribed in 7.101.3.3 is not sufficient to demonstrate that the gas heating element is properly designed to avoid gas liquefaction during low ambient temperature conditions. For such by-pass switches, the test sequence prescribed in 7.101.3.3 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 by-pass switch. The wind shall be applied from step c) to j) of the test procedure described in 7.101.3.3.

The wind speed shall be measured by at least 5 positions along the longitudinal axis of the by-pass switch and at a distance of 0,5 m (±0,1 m) to the outer by-pass switch tank (see Figure 5). Each measurement shall be spaced by approximately 0,3 m. The number of measurements shall be such that the measurement length exceeds the by-pass switch 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.

Dimensions in metres

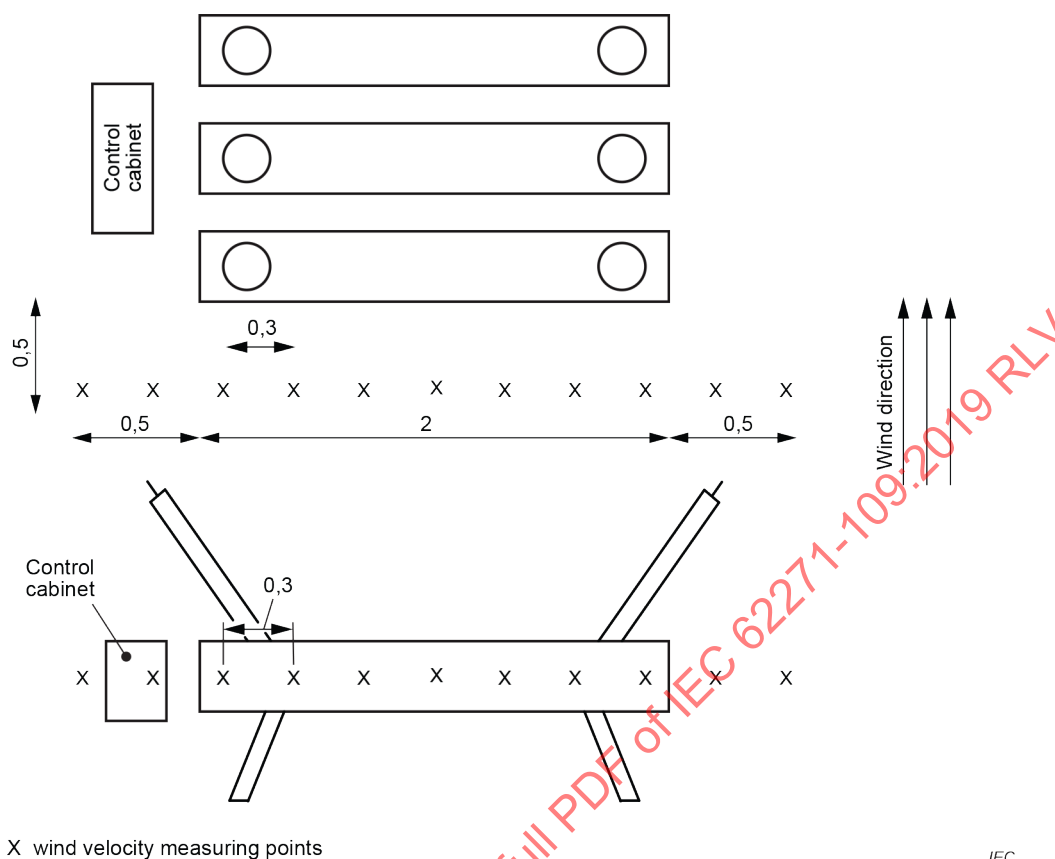


Figure 5 – Example of wind velocity measurement

It is recognised that the wind speed measurements in the relatively small climatic room (in relation to the by-pass switch 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 into 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 a gas heater, at low temperature T_L equal to or lower than the lowest temperature measured during the first test on the by-pass switch 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.

7.101.3.2 Measurement of ambient air temperature

The ambient air temperature of the immediate test environment shall be measured at half the height of the by-pass switch and at a distance of 1 m from the by-pass switch.

The maximum temperature deviation across the height of the by-pass switch shall not exceed 5 K.

7.101.3.3 Low temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 6a.

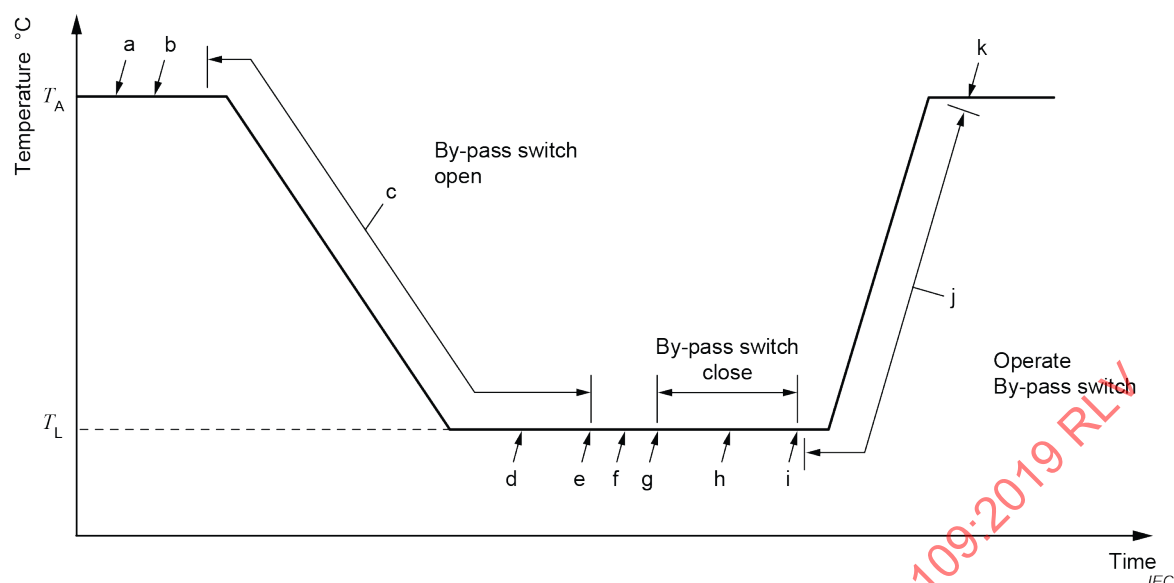


Figure 6a – Low temperature test

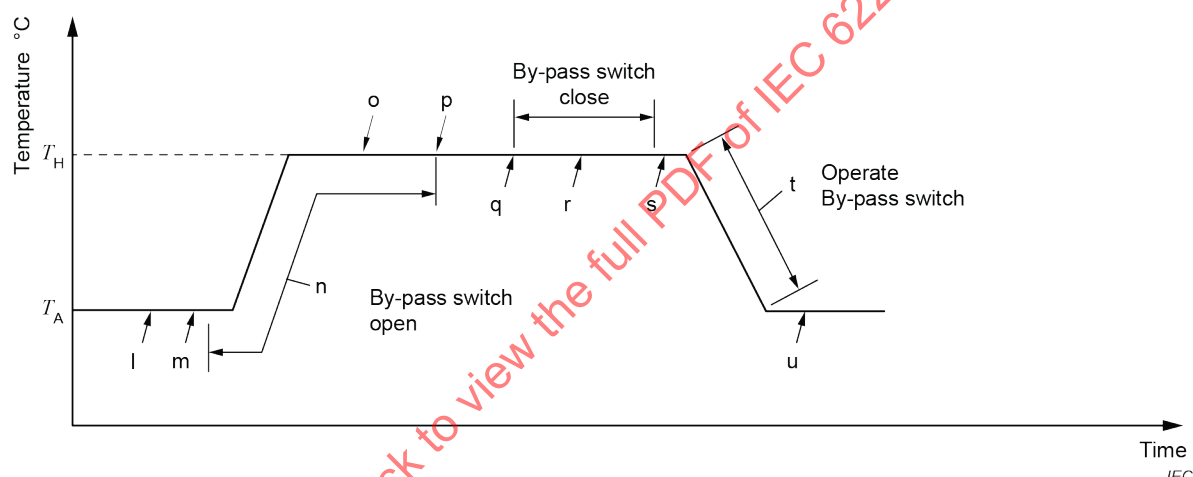


Figure 6b – High temperature test

NOTE Letters a to u identify application points of tests specified in 7.101.3.3 and 7.101.3.4.

Figure 6 – Test sequences for low and high temperature tests

If the low temperature test is performed immediately after the high temperature test, the low temperature test can proceed after completion of item u) of the high temperature test. In this case items a) and b) are omitted.

- The test by-pass switch shall be adjusted in accordance with the manufacturer's instructions.
- Characteristics and settings of the by-pass switch shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.8.
- With the by-pass switch in the open position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the specified minimum ambient temperature of the by-pass switch as given in Clause 4 of IEC 62271-1:2017. The by-pass switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_L .
- During the 24 h period with the by-pass switch in the open position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the

ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.

A tightness test is applicable if gases are used for operation, by-passing and insertion and/or insulation. In case of vacuum by-pass switch, no tightness test is required. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF_6 , the tightness verification tests have to be performed on this enclosure.

- e) After 24 h at temperature T_L , the by-pass switch shall be closed and opened at rated values of supply voltage and operating pressure. The closing time and the opening time shall be recorded to establish low temperature operating characteristics. Contact velocity shall be recorded if feasible.
- f) The low temperature behaviour of the by-pass switch and its alarms and lock-out systems shall be verified by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . During this interval, occurrence of the alarm is acceptable but lock-out is not. At the end of the interval t_x , a closing order, at rated values of supply voltage and operating pressure, shall be given. The by-pass switch shall then close. The closing time shall be recorded (and the mechanical travel characteristics measured, if feasible) to allow assessment of the by-passing capability.

The manufacturer shall state the value of t_x (not less than 2 h) up to which the by-pass switch is still operable without auxiliary power to the heaters. In the absence of such a statement, the default value shall be equal to 2 h.

NOTE The measurement of the mechanical characteristics is feasible if a location is accessible for the travel sensor to be used.

- g) The by-pass switch shall be left in the closed position for 24 h.
- h) During the 24 h period with the by-pass switch in the closed position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.
- i) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the by-pass switch at temperature T_L . At least a 3 min interval shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded to establish low temperature operating characteristics. Contact velocity shall be recorded, if feasible. Following the first opening operation (O) and the first closing operation (C), three OC operating cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing O – t_a – C – t_a operating sequences (t_a is defined in Table 5).
- j) After completing the 50 opening and 50 closing operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.

During the temperature transition period, the by-pass switch shall be subjected to alternate O – t_a – C – t_a – O and C – t_a – O – t_a – C operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences shall be made at 30 min intervals so that the by-pass switch will be in open and closed positions for 30 min periods between the operating sequences.

- k) After the by-pass switch has stabilized thermally at ambient air temperature T_A , a re-check shall be made of the by-pass switch settings, operating characteristics and tightness as in items a) and b) for comparison with the initial characteristics.

The accumulated leakage during the complete low temperature test sequence from item b) to item j) shall not be such that lock-out pressure is reached (reaching alarm pressure is allowed).

7.101.3.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 6b.

If the high temperature test is performed immediately after the low temperature test, the high temperature test can proceed after completion of item j) of the low temperature test. In this case, items l) and m) below are omitted.

- l) The test by-pass switch shall be adjusted in accordance with the manufacturer's instructions.
- m) Characteristics and settings of the by-pass switch shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.8.
- n) With the by-pass switch in the open position, the air temperature shall be increased to the appropriate, maximum ambient air temperature (T_H), according to the specified upper limit of ambient air temperature as given in Clause 4 of IEC 62271-1:2017. The by-pass switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_H .

NOTE 1 The influence of solar radiation is not considered.

- o) During the 24 h period with the by-pass switch in the open position at the temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.

A tightness test is applicable if gases are used for operation, by-passing and insertion and/or insulation. In case of vacuum by-pass switches, no tightness test is required. However, if the vacuum by-pass switch is used in an enclosure filled with an insulating gas, for example, SF_6 , the tightness verification tests have to be performed on this enclosure.

- p) After 24 h at the temperature T_H , the by-pass switch shall be closed and opened at rated values of supply voltage and operating pressure. The closing time and the opening time shall be recorded to establish high temperature operating characteristics. Contact velocity shall be recorded if feasible.

NOTE 2 The measurement of the mechanical characteristics is feasible if a location is accessible for the travel sensor to be used.

- q) The by-pass switch shall be closed and left closed for 24 h at the temperature T_H .
- r) During the 24 h period with the by-pass switch in the closed position at the temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the by-pass switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC 62271-1:2017.
- s) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the by-pass switch at the temperature T_H . An interval of at least 3 min shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded to establish high temperature operating characteristics. Contact velocity shall be recorded if feasible.

Following the first opening operation (O) and the first closing operation (C), three OC operation cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing $O - t_a - C - t_a$ operating sequences (t_a is defined in Table 5).

- t) After completing the 50 opening and 50 closing operations, the air temperature shall be decreased to ambient air temperature T_A , at a rate of change of approximately 10 K/h.

During the temperature transition period, the by-pass switch shall be subjected to alternate $O - t_a - C - t_a - O$ and $C - t_a - O - t_a - C$ operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences shall be made at 30 min intervals so that the by-pass switch will be in the closed and open positions for 30 min periods between the operating sequences.

- u) After the by-pass switch has stabilized thermally at ambient air temperature T_A , a re-check shall be made of the by-pass switch settings, operating characteristics and tightness as in items l) and m) for comparison with the initial characteristics.

The accumulated leakage during the complete high temperature test sequence from item l) to item u) shall not be such that lock-out pressure is reached (reaching alarm pressure is allowed).

7.101.4 Humidity test

The humidity test does not apply to by-pass switches.

7.101.5 Test to prove the operation under severe ice conditions

The test under severe ice conditions is applicable only to by-pass switches having moving external parts and for which a class of 10 mm or 20 mm of ice thickness is specified. The test shall be performed under the conditions described in IEC 62271-102:2018.

7.102 Miscellaneous provisions for by-pass making and insertion tests

7.102.1 General

The following subclauses are applicable to all by-pass making and insertion tests.

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 by-pass (or insertion) unit guaranteeing the rated operating sequence (for example the minimum functional pressure for by-passing and insertion in case of a gas by-pass switch).

By-pass switches shall be capable of by-passing all currents up to and including the rated by-pass making current. In addition, by-pass switches shall be capable of inserting all currents up to and including the rated by-pass insertion current.

This is demonstrated when the by-pass switch is subjected to the particular by-pass making current and insertion current tests outlined in this document.

By-pass making current and insertion current tests are normally performed in single-phase on a complete pole, see also 7.102.4.1.

The by-pass making current test is normally performed with a single power source (pre-charged capacitor bank) while the insertion current test may be performed with several sources where all of the current, or a major part of it, is obtained from one source and the recovery voltage is obtained only, or in part, from a separate source (synthetic tests).

During testing of a metal enclosed by-pass switch, the insulation to earth is not stressed with the full voltage phase-to-earth voltage occurring during a by-pass or insertion operation. It may be necessary to prove that the insulation to earth is capable of withstanding this full voltage after the required test duties. The influence of exhaust gases shall also be taken into account.

Where the by-pass switch consists of three poles in one enclosure, the test procedure should be modified as suggested in IEC 62271-100 and IEC 62271-101 for capacitive current switching tests.

If due to limitations of the testing facilities, the overall performance of the by-pass switch cannot be proved in the above way, several methods employing either direct or synthetic test methods may be used either singly or in combination, unit testing, depending on the by-pass switch type.

7.102.2 Number of test specimens

For the performance of by-pass making current and insertion current tests, a unique test specimen shall be used without any maintenance permitted between the test duties.

7.102.3 Arrangement of by-pass switch for tests

7.102.3.1 General

The by-pass switch under test shall be mounted on its own support or on an equivalent support. A by-pass switch supplied as an integral part of an enclosed unit shall be assembled on its own supporting structure and enclosure, complete with any disconnecting features, with vent outlets forming part of the unit and, where practicable, with main connections and busbars.

To facilitate consistent control of the closing and opening operation, the closing and/or opening releases can be supplied at their maximum supply voltage, provided that the contact speed is not affected.

If the contact speed is dependent on the supply voltage, the operating device shall be operated in the manner specified and in particular, if it is electrically or spring operated, closing solenoid or shunt-closing releases and shunt opening releases shall be supplied at their respective minimum voltages (see Table 7) guaranteeing successful operation.

Table 7 – Limits of supply voltage for closing and opening releases

	AC		DC	
	Minimum %	Maximum %	Minimum %	Maximum %
Closing	85	110	70	110
Opening	85	110	85	110

When it is required that pneumatically or hydraulically operated devices be operated at the minimum functional pressure for operation the following procedure applies. This procedure is based on the fact that the by-pass making and insertion test duties call for separate C and O operations:

- before performing by-pass making current and insertion current tests and starting from the minimum functional pressure for operation as per 3.7.135, all the pressures during the rated operating sequence carried out at no-load shall be recorded;
- the recorded values shall be compared with the minimum values declared by the manufacturer as guaranteeing successful operations as separate C and O;
- when required, tests shall be carried out at the pressure for operation set at the minimum functional value resulting from a) and b) above, whatever is the lower, for the corresponding operation in the test-duty; the pressure values shall be reported in the test report.

Interlocking devices associated with pressure interlocks shall be made inoperative during the tests if they interfere with the intent of the test.

It shall be shown that the by-pass switch will operate satisfactorily under the above conditions at no-load as specified in 7.102.6. When required, the pressure of the compressed gas for by-

passing, insertion and/or insulation, if any, shall be set at its minimum functional value according to 3.7.136.

The by-pass switch shall be tested according to its type as specified in 7.102.3.2 and 7.102.3.3.

7.102.3.2 Common enclosure type

Generally not applicable for by-pass switches, see 7.102.1.

7.102.3.3 Multi-enclosure type

A three-pole, by-pass switch consisting of three independent single-pole switching devices is normally tested single-phase according to 7.102.4.1. The manufacturer shall give testing evidence to show compliance with 6.101.

A three-pole by-pass switch not having completely independent switching devices shall also be tested single-phase. However, the mechanical and electrical conditions applied during the tests shall be equivalent to, or not in a more favourable condition than, the complete three-pole by-pass switch over the range of tests in respect of

- mechanical travel characteristics in a by-pass making current operation (for the evaluation method, see 7.102.4 and 7.102.7),
- mechanical travel characteristics in an insertion current operation (for the evaluation method, see 7.102.4 and 7.102.7),
- availability of arc-extinguishing medium,
- power and strength of closing and opening devices,
- the rigidity of the structure.

If these conditions cannot be fulfilled, the manufacturer and user shall agree upon a suitable test procedure.

7.102.4 General considerations concerning testing methods

7.102.4.1 Single-phase testing of a single pole of a three-pole by-pass switch

According to this method, a single pole of a three-pole by-pass switch is tested single-phase, applying to the pole the same test currents and the same voltage that would be impressed upon the most highly stressed pole during three-phase by-pass making current and insertion current tests by the complete three-pole by-pass switch under corresponding conditions.

A three-pole operated by-pass switch can be tested single-pole provided that a three-pole assembly is provided for the tests.

7.102.4.2 Unit testing

7.102.4.2.1 General

Certain by-pass switches are constructed by assembling identical by-pass and/or insertion units in series, the voltage distribution between the units of each pole often being improved by the use of parallel impedances.

This type of design enables the by-pass making and insertion performance of a by-pass switch to be tested by carrying out tests on one or more units. The requirements of 7.101.1.1, 7.102.3 and 7.102.4.1 also apply for unit testing. Since therefore at least a complete pole assembly has to be made available for the verification tests on one or more units, the test results relate only to this specific pole design.

The following situations can be distinguished.

- a) The by-pass switch pole consists of units (or assemblies of units) which are separately operated and which have no mutual connections for the arc extinguishing medium.

In this case, unit testing is acceptable. However, the mutual influence through the electrodynamic forces of the current on the units and the arc in the units shall be taken into account (see Figure 7). This may be done by substitution of the second unit by a conductor of equivalent shape.

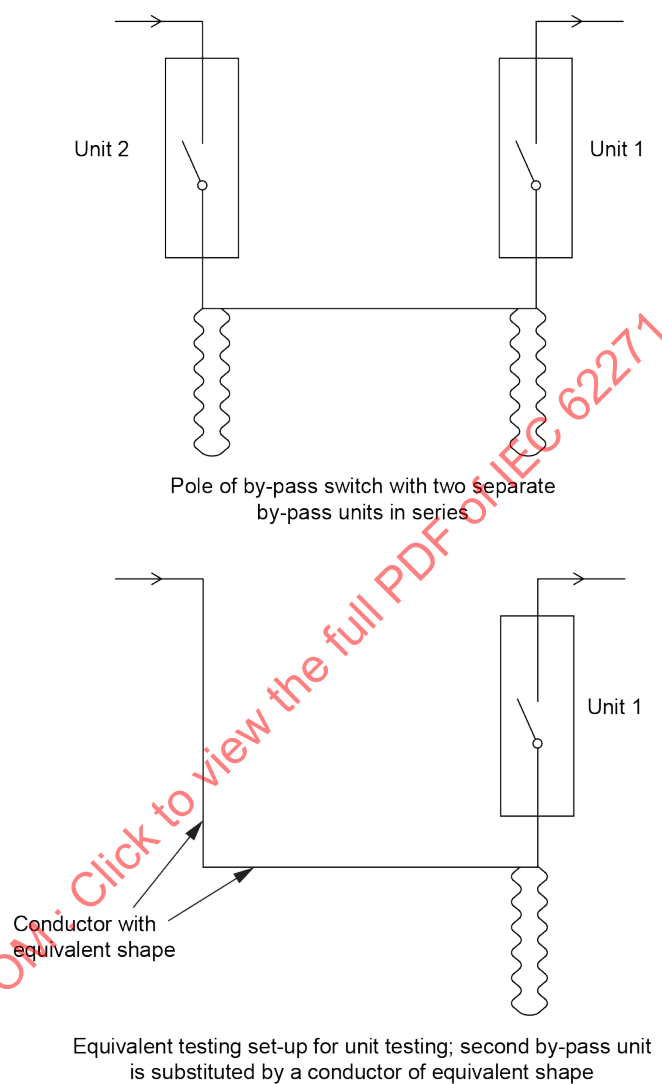


Figure 7 – Equivalent testing set-up for unit testing of by-pass switches with more than one separate by-pass units

- b) The by-pass switch pole consists of units (or assemblies of units) which are separately operated but which have a mutual connection for the arc extinguishing medium.

In this case, unit testing is acceptable and the influence of electrodynamic forces (see also item a) above) shall be covered.

- c) The by-pass switch pole consists of units (or assemblies of units) which are not separately operated.

In this case, unit testing is acceptable for the insertion current test-duty only. Moreover, the influence of electrodynamic forces (see also item a) above) shall be covered.

The by-pass making current test-duty is generally performed on a full pole. Nevertheless, because of test plant limitations, unit testing can be also acceptable if it is demonstrated that this is not influencing the contact travel characteristics as stated in 7.101.1.1.

The demonstration method should be agreed upon user and manufacturer.

The mechanical no-load travel characteristics for single-unit testing and for full-pole testing shall be the same.

When carrying out unit tests, it is essential that the units are identical and that the static voltage distribution for the type of test is known.

7.102.4.2.2 Identical nature of the units

The units of the by-pass switch shall be identical in their shape, in their dimensions and in their operating conditions; only the devices for controlling the voltage distribution among units may be different. In particular, the following conditions shall be fulfilled.

a) Operation of contacts

The opening, in insertion current tests, or the closing, in by-pass making current tests, of the contacts of one pole, shall be such that the time interval between the opening or closing of the contacts of the unit which is first to operate and the contacts of the unit which is last to operate is not more than one-eighth of a cycle of rated frequency. Rated operating pressures and voltages shall be used to determine this time interval.

b) Supply of the arc-extinguishing medium

For a by-pass switch using a supply of arc-extinguishing medium from a source external to the units, the supply to each unit shall, be independent of the supply to the other units, and the arrangement of the supply pipes shall be such as to ensure that all units are fed essentially together and in an identical manner.

7.102.4.2.3 Voltage distribution

The test voltage is determined by analysing the voltage distribution between the units of the pole.

The voltage distribution between units of a pole, as affected by the influence of earth, shall be determined for the relevant test conditions.

Where the units are not symmetrically arranged, the voltage distribution shall be determined also with reverse connections.

The voltage distribution is determined either by measurements or by calculations. Values used in the calculations shall be supported by measurements of the stray capacitances of the by-pass switch. Such calculations and supporting measurements verifying the assumptions used in the calculations are the responsibility of the manufacturer.

The voltage distribution may be calculated or measured at power frequency only.

The manufacturing tolerances for resistors and capacitors shall be taken into account. The manufacturer shall state the value of these tolerances.

NOTE The influence of pollution is not considered in determining voltage distribution. In some cases, pollution can affect this voltage distribution.

7.102.4.2.4 Requirements for unit testing

When testing a single unit, the test voltage shall be the voltage of the most highly stressed unit of the complete pole of the by-pass switch, determined in accordance with 7.102.4.2.3.

When testing a group of units, the voltage appearing at the terminals of the most highly stressed unit of the group shall be equal to the voltage of the most highly stressed unit of the pole, both determined in accordance with 7.102.4.2.3.

7.102.4.3 Multi-part testing

Multi-part testing is generally not applicable to by-pass switches.

7.102.5 Synthetic tests

Synthetic testing methods can be applied for insertion current tests. Synthetic testing techniques and methods proposed for capacitive current switching as described in IEC 62271-101 shall be used as a reference.

7.102.6 No-load operations before tests

Before commencing by-pass making current and insertion current tests, no-load operations and no-load operating sequences (C, OC and C – t – OC) shall be made and details of the operating characteristics of the by-pass switch recorded. Details such as closing time and opening time shall be recorded.

In addition, it shall be demonstrated that the mechanical behaviour of the by-pass switch, or sample under test, conforms to that of the reference mechanical travel characteristics required in 7.101.1.1. For this test, the operational conditions stated in 7.101.1.1 apply.

The pressure of the fluid for by-passing and insertion shall be set at its minimum functional value according to 3.7.136.

For electrically or spring-operated by-pass switches, operations shall be made with the closing solenoid or shunt-closing releases energized at 100 % and 85 % in the case of AC or 70 % in the case of DC of the rated supply voltage of the closing device and with the shunt-opening release(s) energized at 100 % and 85 % of the rated supply voltage.

For pneumatic or hydraulic operating devices, the operations shall be made under the following conditions:

- a) pressure of the fluid for operation set at its minimum functional value as per 3.7.135 with the shunt opening releases energized at 85 % and with the shunt closing releases energized at 85 % in case of AC, 70 % in case of DC of the rated supply voltage.
- b) pressure of the fluid for operation set at its rated value as per 5.11 with the shunt releases energized at the rated supply voltage.

7.102.7 Alternative operating mechanisms

If it can be shown that the use of an alternative operating mechanism (see 3.5.126) does not affect the performance of the common portion, particularly with regard to the closing and opening characteristics of the by-pass switch, a repetition of the type tests under by-pass making and insertion test duties is not necessary.

NOTE In this subclause, it is considered that one version of the by-pass switch using a certain operating mechanism, is completely type-tested in accordance with this document; this version is referred to as the completely tested by-pass switch. The other versions, differing only in the operating mechanisms (see definition in 3.5.124) are referred to as by-pass switch with alternative operating mechanisms.

The tests to be performed are limited to the following.

- a) On each of the by-pass switches (the completely tested by-pass switch and the by-pass switches with alternative operating mechanisms), the mechanical characteristics shall be recorded at no-load (single O and single C operations) and compared in accordance with 7.101.1.1 (the use of mechanical characteristics and related requirements are described in Annex G).
- b) On each of the by-pass switches (the completely tested by-pass switch and the by-pass switches with alternative operating mechanisms), a by-pass making current operation

shall be performed. The test results shall be evaluated according to the method prescribed under a) above.

If requirements a) or b) or both of them are not met, then the new mechanism is not considered to be an alternative operating mechanism.

If the above-given requirements are met, the reference mechanical characteristics of the completely tested by-pass switch should apply also to the by-pass switches with alternative operating mechanisms.

7.102.8 Behaviour of by-pass switch during tests

During by-pass and insertion tests, the by-pass switch shall not

- show signs of distress,
- exhibit behaviour which could endanger an operator.

For by-pass switches which are designed to have discharge of interrupting medium into the atmosphere during the by-passing and insertion tests, the above requirements are considered to have been met, provided that

- for oil by-pass switches, there is no outward emission of flame, and the gases produced, together with the oil carried with the gases, shall be conducted away from the by-pass switch and directed away from all live conductors and locations where persons may be present,
- for other types of by-pass switches, such as air blast or air break, there is an outward emission of flame, gas and/or metallic particles. If such emissions are appreciable, it may be required that the tests shall be made with metallic screens placed in the vicinity of the live parts and separated from them by a safety clearance distance which the manufacturer shall specify. The screens shall be insulated from earth but connected thereto by a suitable device to indicate any significant leakage current to earth. There shall be no indication of significant leakage currents to the by-pass switch earthed structure, or screens when fitted, during the tests.

If no other devices are available, the earthed parts, etc. should be connected to earth through a fuse consisting of a copper wire of 0,1 mm diameter and 5 cm long. No significant leakage is assumed to have occurred if this fuse wire is intact after the test.

If faults occur which are not persistent or due to defect in design, but rather are due to errors in assembly, the faults can be rectified and the by-pass switch subjected to a repetition of all test duties. In those cases, the test report shall include reference to the invalid tests.

For by-switch comprising vacuum interrupters, NSDDs may occur during the recovery voltage period following an insertion operation. However, their occurrence is not a sign of distress of the by-pass switch under test. Therefore, their number is of no significance to interpreting the performance of the device under test. They shall be reported in the test report in order to differentiate them from restrikes.

It is not the intent to require the installation of special measuring circuits to detect NSDDs. They should only be reported when seen on an oscillogram.

7.102.9 Condition of by-pass switch after tests

7.102.9.1 General

The by-pass switch shall be inspected after completion of all test duties. Its mechanical parts and insulators shall be in essentially the same condition as before the test duties. Visual inspection is usually sufficient for verification of the insulating properties. In case of doubt, the condition checking test according to 7.2.12 is sufficient to prove the insulation properties.

For by-pass switches with sealed-for-life units, the condition checking test is mandatory, except as stated in 7.102.9.2.

7.102.9.2 Condition after the by-pass current making and insertion test duties

The by-pass switch shall, after performing the by-pass making current and insertion current test duties specified in 7.103.2 and 7.103.4, be capable of operating satisfactorily at any by-pass making current and insertion current up to its rated by-pass making current and insertion current.

In addition, the by-pass switch shall be capable of carrying its rated normal current with a temperature rise, not in excess of the temperature rise permitted by Table 14 of IEC 62271-1:2017.

For other than sealed for life by-pass and insertion units, visual inspection is usually sufficient for verification of the capability of the by-pass switch to carry the rated normal current and to by-pass and insert at any current up to its rated by-pass making current and insertion current.

There shall be no evidence of puncture, flashover or tracking of the internal insulating materials, except that moderate wear of the parts of arc control devices exposed to the arc is permissible.

Degradation of the components in the current carrying path shall not reduce the integrity of the normal current carrying path.

If during the insertion current tests, one restrike occurred, the dielectric condition checking test according to 7.2.12 shall be performed before visual inspection, provided that the tested peak recovery voltage during the insertion current tests is lower than the peak voltage of the specified dielectric condition checking test. The subsequent visual inspection shall demonstrate that the restrike occurred between the arcing contacts only. There shall be no evidence of puncture, flashover or permanent tracking of internal insulating materials. Wear of the parts of arc control devices exposed to the arc is permissible as long as it does not impair the by-pass making and insertion capability. Moreover, the inspection of the insulating gap between the main contacts, if they are different from the arcing contacts, shall not show any trace of a restrike.

If no restrike occurred during the insertion current tests visual inspection is sufficient. The dielectric condition checking test according to 7.2.12 is not necessary.

For by-pass switches with sealed-for-life by-pass units, the dielectric condition checking test according to 7.2.12 shall be performed, whether a restrike occurs during testing or not, provided that the tested peak recovery voltage during the insertion current tests is lower than the peak voltage of the specified dielectric condition checking test.

7.102.9.3 Reconditioning after a test-duty

The by-pass switch shall not be reconditioned during and between the by-pass making current and insertion current test duties.

If local safety rules require depressurising to enter the test cell, it is allowed to decrease the pressure in the by-pass switch provided that the gas is reused when refilling the by-pass switch.

When refilling is necessary, the used gas cannot be reused totally due to vacuum pump limitations. For such cases, new gas can be used for topping up and the quantity of new gas should not exceed 10 % of the total gas quantity.

7.103 By-pass making current test-duty and insertion current test-duty, sequence of tests

7.103.1 General

The by-pass making current test-duty and the insertion current test-duty shall be performed in the following order:

- a) half of the required making operations at minimum functional pressures for operation and/or by-passing, insertion and insulation;

These making operations are including two of the making operations at rated by-pass making current and 10 making operations at capacitor bank discharge current.

- b) half of the required insertion operations at minimum functional pressures for operation and/or by-passing, insertion and insulation;

- c) half of the required making operations at filling functional pressures for operation and/or by-passing, insertion and insulation;

These making operations include two of the making operations at rated by-pass making current and 10 making operations at capacitor bank discharge current.

- d) half of the required insertion operations at filling functional pressures for operation and/or by-passing, insertion and insulation.

Maintenance is not permitted between the test duties.

If the by-pass switch has a non-symmetrical current path, the terminal connections shall be reversed for half of the number of required operations. This reversal should be carried out between the test series required at minimum functional pressures and the test series required at filling functional pressures (between test series b) and c) above).

It is also acceptable to perform the tests in the order a), c), b), d). This procedure requires more gas handling operations and more terminal reversals. This should not be done without the consent of the manufacturer.

It is also acceptable to perform all tests at minimum functional pressures for operation and/or by-passing, insertion and insulation. This should not be done without the consent of the manufacturer.

7.103.2 By-pass making current test-duty

7.103.2.1 General

This test-duty is valid for both rated frequencies, i.e. for 50 Hz or 60 Hz systems.

7.103.2.2 Characteristics of supply circuit

It is recommended to use an oscillatory circuit (LC circuit, see Figures 8 and 9). The test circuit shall fulfil the following requirements.

- a) The characteristics of the test circuit shall be such that the instantaneous applied voltage, just before the making operation, be equal to the limiting peak voltage of the overvoltage protector (U_{PL}). A DC voltage can be applied.
- b) The components of the oscillatory circuit (series inductance and precharged capacitor bank) shall be selected in order to obtain the required by-pass current (first peak, I_{BP}) at the frequency of the by-pass making current (f_{BP}).

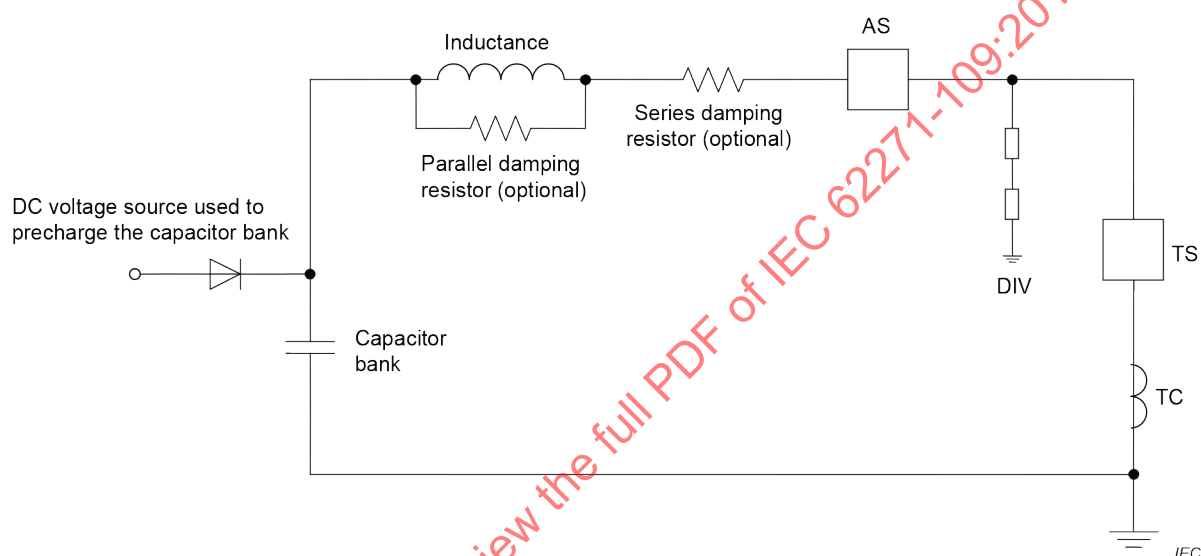
The by-pass making performance is covered when the required peak by-pass making current is equal to or lower than the actual value used in the test-duty. This equivalency rule is considered to be valid only when the frequency of the by-pass making current f_{BP} is equal to or lower than 130 % of the value used during type tests.

- c) The damping ratio of the by-pass current (sinusoidal exponential decaying current) may be adjusted to the service condition damping ratio by inserting an additional resistor in the oscillatory circuit. The damping ratio is defined as the ratio between the second peak and the first peak of the same polarity of the by-pass discharge current.

The damping ratio obtained during tests shall be indicated in the test report.

In order to be a valid test-duty for a specific series capacitor installation, the damping ratio obtained during tests shall not be less than 10 % of than the actual damping ratio at the site.

A test performed without intentional damping automatically covers applications where a damping resistor is used and when the condition given in b) above and in 5.102 are covered. Specific damping ratings can generally not be assigned because they are specific to each project parameters. Annex D gives examples of by-pass switch ratings.



Key

DIV	voltage divider
AS	auxiliary switch
TS	tested by-pass switch
TC	current measuring device

Figure 8 – Typical test circuit for the by-pass making current test-duty

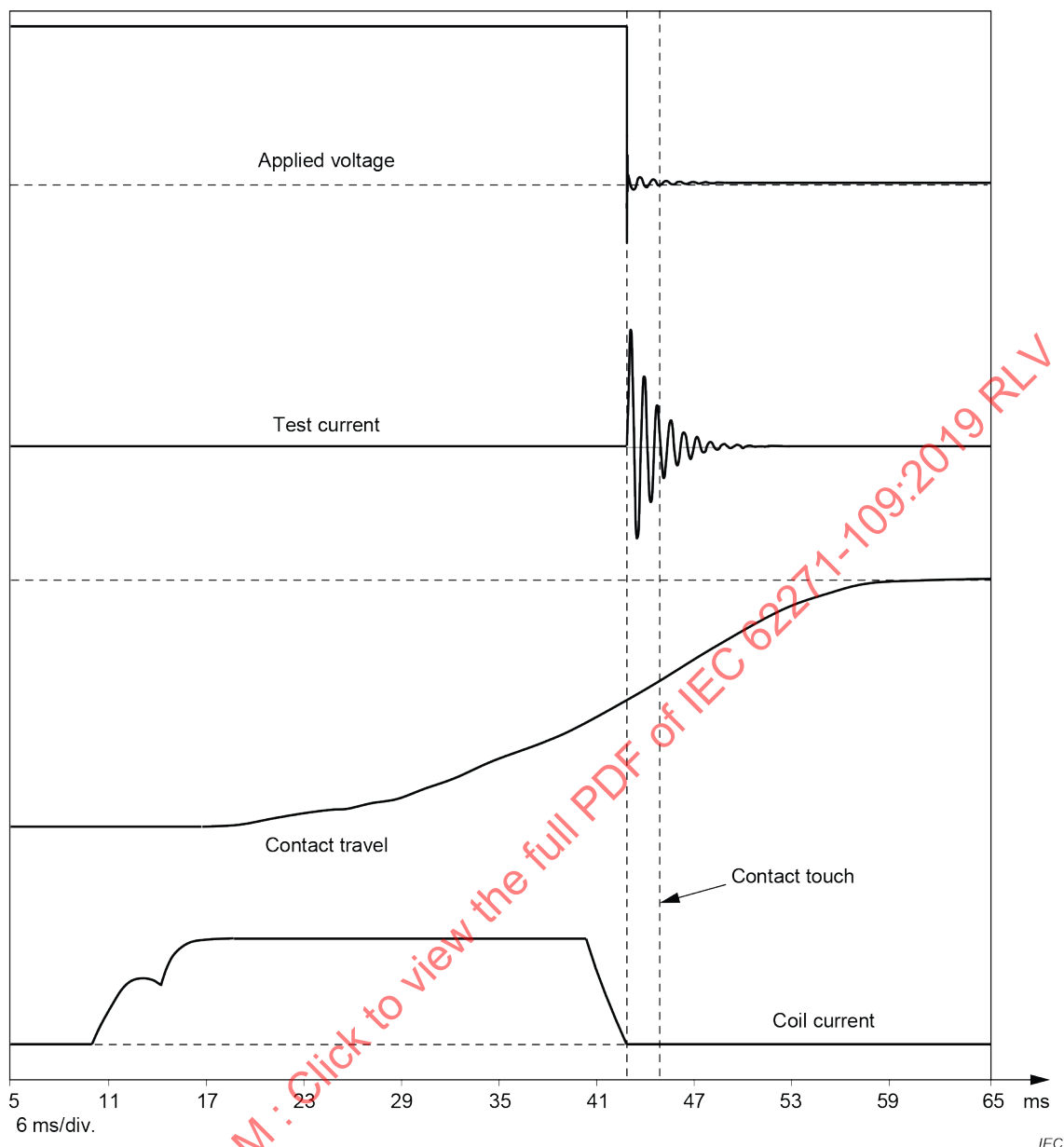


Figure 9 – Oscillogram obtained from the typical test circuit for the by-pass making current test-duty

7.103.2.3 Test voltage

The instantaneous test voltage to be applied across the by-pass switch, prior to the by-pass making tests, shall be the limiting peak voltage of the overvoltage protector (U_{PL} ; $+5\%$).

7.103.2.4 Test current

For four making operations, the first peak of the test current shall be the rated by-pass making current I_{BP} at the frequency of the by-pass making current f_{BP} . The tolerance on the by-pass making current shall be within ($+5\%$) of the by-pass making current I_{BP} . The effective damping of the making current component should be taken into consideration.

If because of laboratory limitations, the rated peak by-pass making current cannot be obtained, then it is permissible to perform the test differently. For such cases, the frequency

f_{BP} should be as close as possible to the rated value. Deviations from rated values may affect the applicability range (see 5.102).

For the remaining 20 making operations, the first peak of the test current shall be limited to the capacitor bank discharge current $I_{DISCHARGE}$ (without considering the power-frequency fault current component) when the bank is precharged to the limiting voltage of the overvoltage protector (U_{PL}) ($+5_0$ %) at by-pass making frequency f_{BP} . The effective damping of the capacitor bank discharge current should also be taken into consideration.

If because of laboratory limitations, the capacitor bank discharge current at by-pass making current frequency cannot be obtained, then it is permissible to perform the test differently. For such cases, f_{BP} should be as close as possible to the rated value. Deviations from rated values may affect the applicability range (see 5.102).

If, because of laboratory limitations, the rated peak by-pass making current and/or the capacitor bank discharge current at by-pass making current frequency cannot be obtained, then it is permissible to perform the test series with test currents higher than the tolerance stated above. This should not be performed without the consent of the manufacturer.

7.103.2.5 Number of making operations

The by-pass making current test can be performed using one of the two alternatives given in Table 8. The by-pass switch conditions shall be in accordance with 7.102.3.1.

Table 8 – Test procedures for by-pass making current tests

Alternative	Number of making operations	Test current
Alternative 1	20	I_{BP}
Alternative 2	4	I_{BP}
	20	$I_{DISCHARGE}$

7.103.3 Insertion current test-duty

7.103.3.1 General

Re-ignitions during the insertion current test-duty are permitted but restrikes are not permitted unless otherwise indicated (a low expected probability of restrike is required).

NOTE 1 The restrike probability is related to the performance during the series of type tests.

NOTE 2 Phenomena occurring after a restrike or a re-ignition event are not representative of service conditions as the test circuit does not adequately reproduce the post-event voltage and current conditions.

NOTE 3 Since the quantity of energy trapped in the capacitor bank used during tests is generally much lower than the energy trapped in the service series capacitor bank, it is important to have a low probability of restrike to limit possible damages to the internal components of by-pass units.

Several reinsertion voltage waveshapes can be obtained in service. The reinsertion voltage waveshape should be determined by systems studies. For standardization purposes, in order to cover most of the practical cases, this document recommends a "1-cos" waveshape having a preferred first time-to-peak of 5,6 ms to cover 50 Hz and 60 Hz applications with one single test-duty. Other waveshapes may be required and should be clearly specified to the manufacturer at the time of enquiry. The tolerance on the time-to-peak of the recovery voltage shall be ± 5 %.

For by-pass switches exclusively rated for 50 Hz systems, the recovery voltage time-to-peak may be increased to 6,7 ms.

The border delimiting a re-ignition and a restrike shall be set to half of the time to peak of the recovery voltage.

NOTE 4 The border delimiting re-ignition and restrike has been set to half of the time-to-peak of the recovery voltage for limiting the amount of energy released during restrike which can affect internal components of the by-pass switch as well as other equipment on the series capacitor platform.

The test circuit branch supplying the power-frequency test current shall have a frequency ranging from 49 Hz to 61 Hz.

NOTE 5 Tests performed with a current source frequency ranging from 49 Hz to 61 Hz are considered to prove the insertion capability for both system frequencies i.e. 50 Hz or 60 Hz.

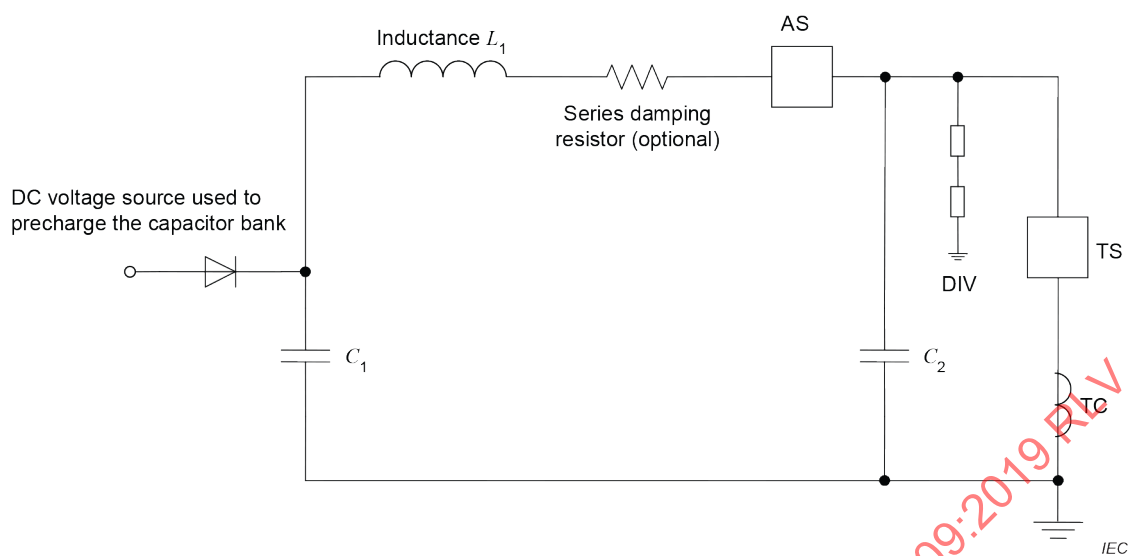
7.103.3.2 Characteristics of supply circuit

An oscillatory circuit (double frequency LC circuit, see Figures 10 and 11 with one oscillatory circuit branch feeding the power-frequency current and another circuit branch producing the recovery voltage is suggested. Other test circuits as proposed by IEC 62271-101 for synthetic capacitive current switching tests may also be used. Other examples of synthetic and direct test circuits are shown in Figures 12, 13, 14 and 15. The test circuit shall fulfil the following requirements.

- a) The characteristics of the test circuit current branch shall be such that the instantaneous peak current, just before the interruption, is the peak value of the rated insertion current. The current circuit shall produce, as nearly as possible, a sinusoidal current waveshape (with the proposed synthetic test circuit, it will be a sinusoidal exponential decaying current). This condition is considered to be met if the ratio of the RMS value to the RMS value of the fundamental component does not exceed 1,2.

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

- b) Unless otherwise specified, the characteristics of the test circuit voltage branch should be such that a recovery voltage having "1-cos" waveshape is generated across the by-pass switch terminals. The time-to-peak of the voltage waveshape should be 5,6 ms unless otherwise specified. The initial voltage jump that can appear at the beginning of the "1-cos" waveshape should be as small as possible and should never exceed 5 % of the recovery voltage peak.

**Key**

DIV voltage divider

AS auxiliary switch

TS tested by-pass switch

TC current measuring device

 C_1 and L_1 set to the rated frequency (current source components) C_1 , C_2 , and L_1 set to obtain the required time-to-peak of the recovery voltage (voltage source components)**Figure 10 – Typical LC test circuit for the insertion current test-duty**

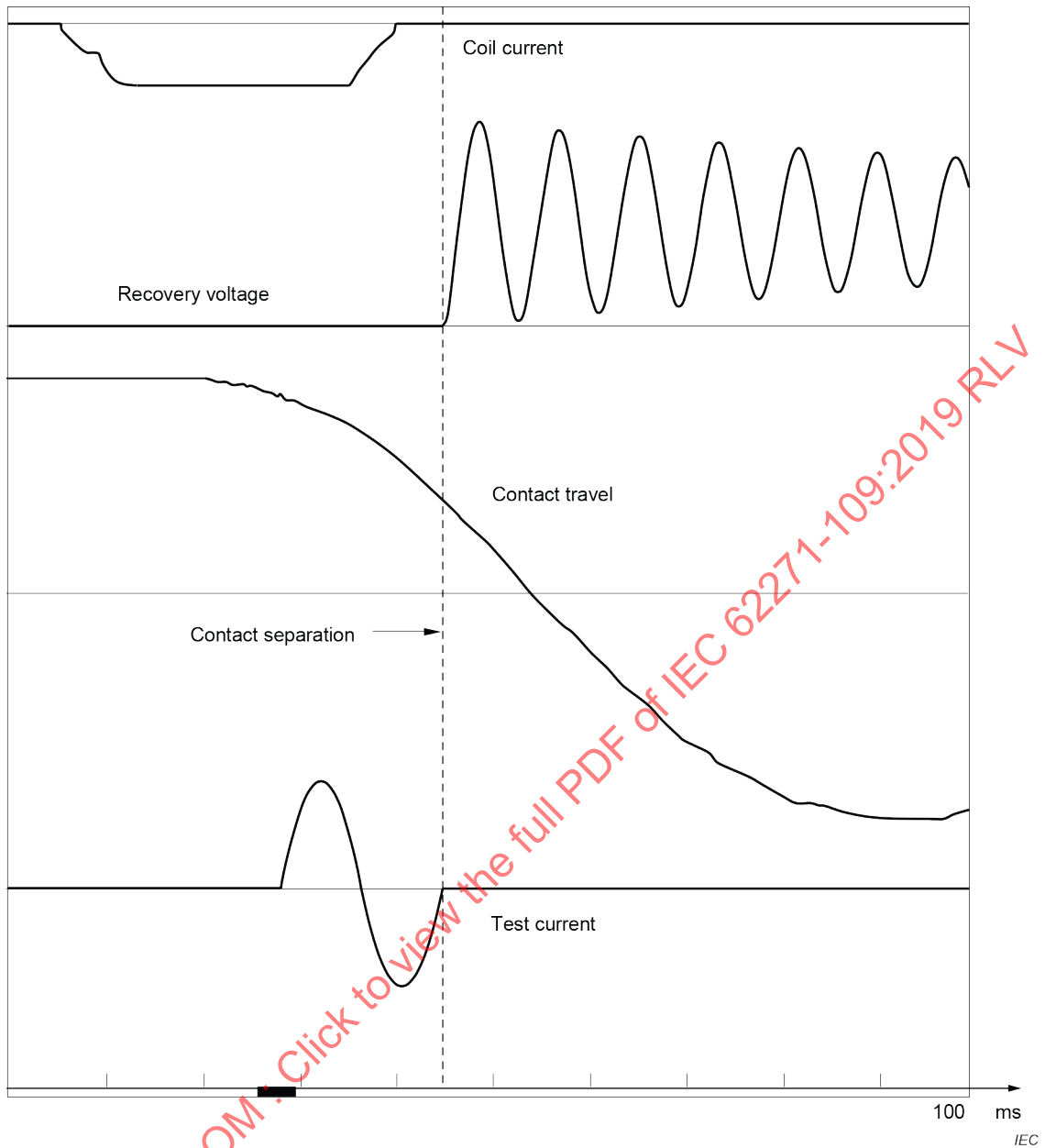
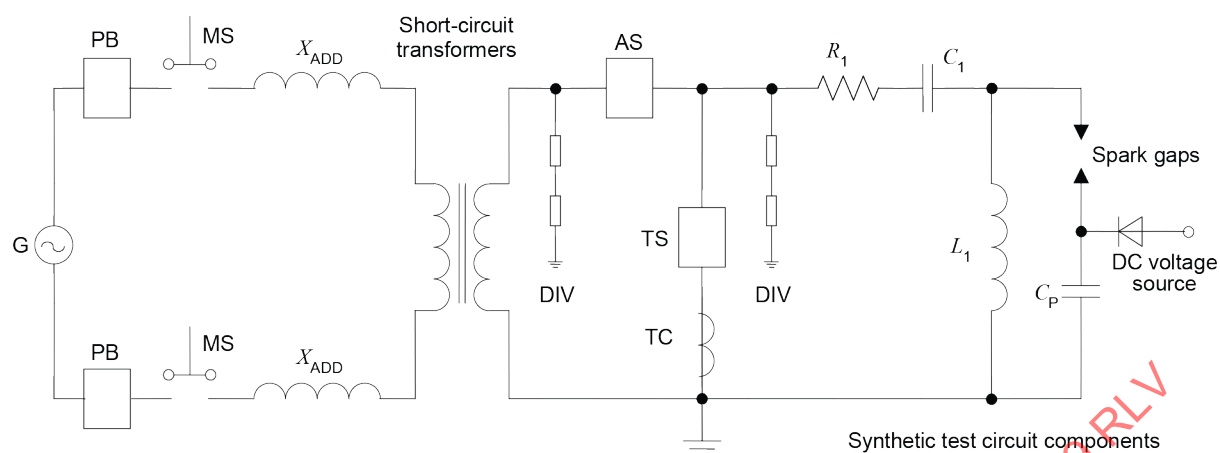


Figure 11 – Oscillogram obtained from the typical LC test circuit for the insertion current test-duty



IEC

Key

G	short-circuit generator supplying the power-frequency current
PB	protection circuit-breakers (back-up)
MS	making switches
X_{ADD}	reactances added to adjust the test current to the required insertion current value
DIV	voltage divider
AS	auxiliary switch
TS	tested by-pass switch
TC	current measuring device
R_1, C_1, L_1, C_p	element of the voltage source (synthetic circuit)

Figure 12 – Typical test circuit for the insertion current test-duty (mainly for high rated insertion current)

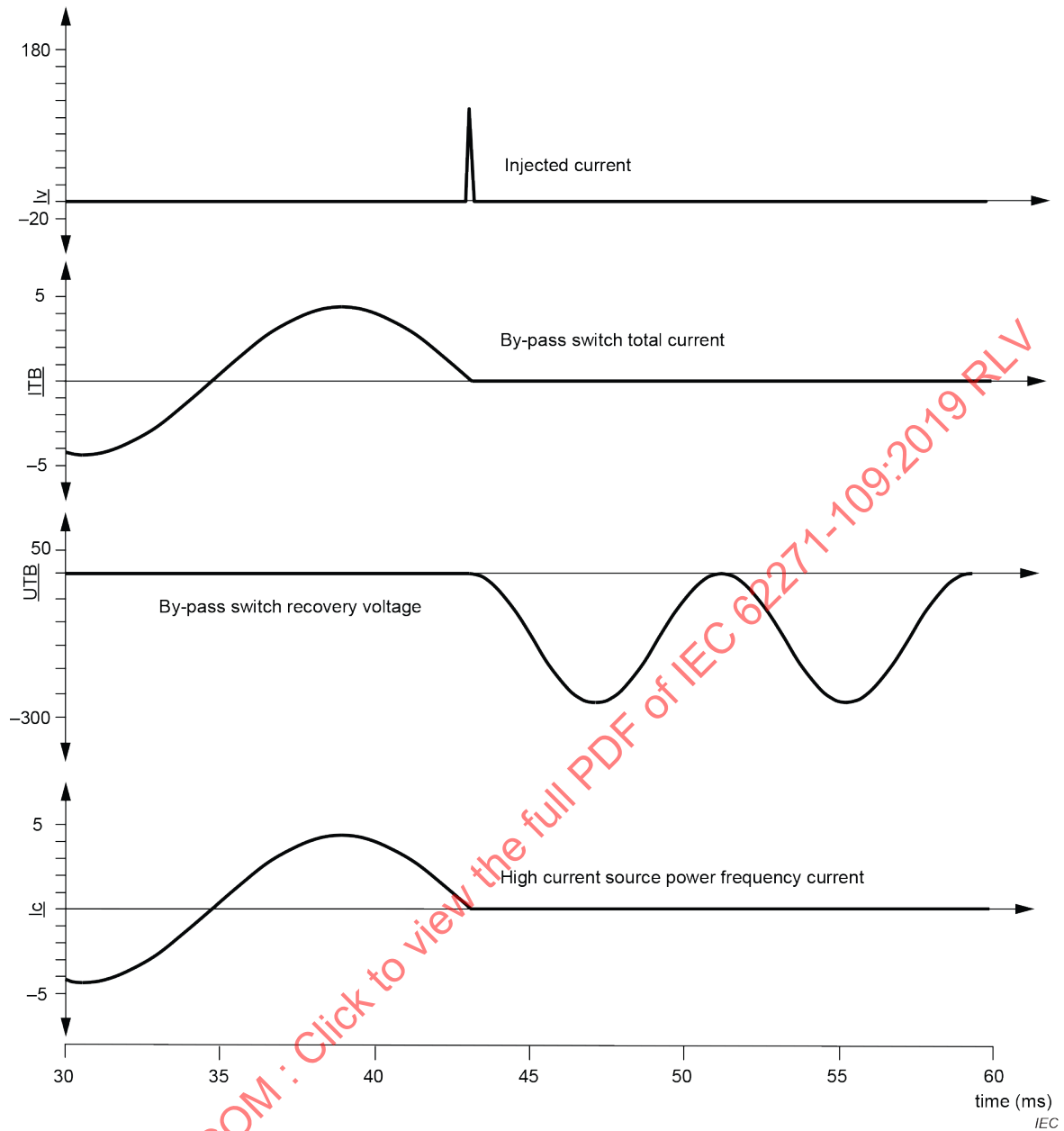
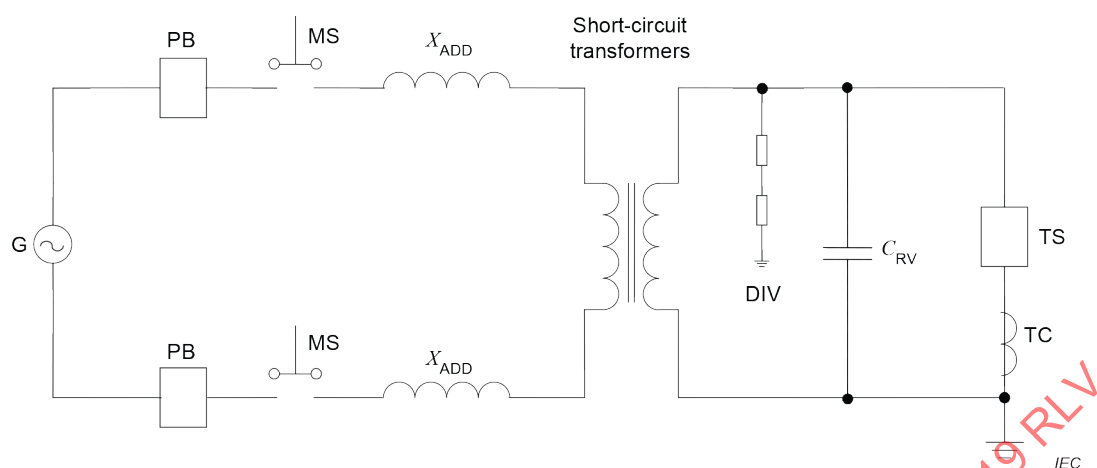


Figure 13 – Oscillogram obtained from the typical test circuit shown in Figure 12 for the insertion current test-duty

**Key**

- G short-circuit generator supplying the power-frequency current
- PB protection circuit-breakers (back-up)
- MS making switches
- X_{ADD} reactances added to adjust the test current to the required insertion current value
- DIV voltage dividers
- TS tested by-pass switch
- TC current measuring device
- C_{RV} capacitor used to adjust the "1-cos" waveshape for to the required recovery voltage. The value of " C_{RV} " should be chosen to obtain a peak value of the recovery voltage of 5,6 ms or 6,7 ms for by-pass switches exclusively rated for 50 Hz).

Because this circuit produces a second recovery voltage peak which is significantly higher than the first recovery voltage peak, it may be necessary to add some voltage-limiting devices (e.g. ZnO arresters) across the tested by-pass switch.

Figure 14 – Typical direct test circuit for the insertion current test-duty

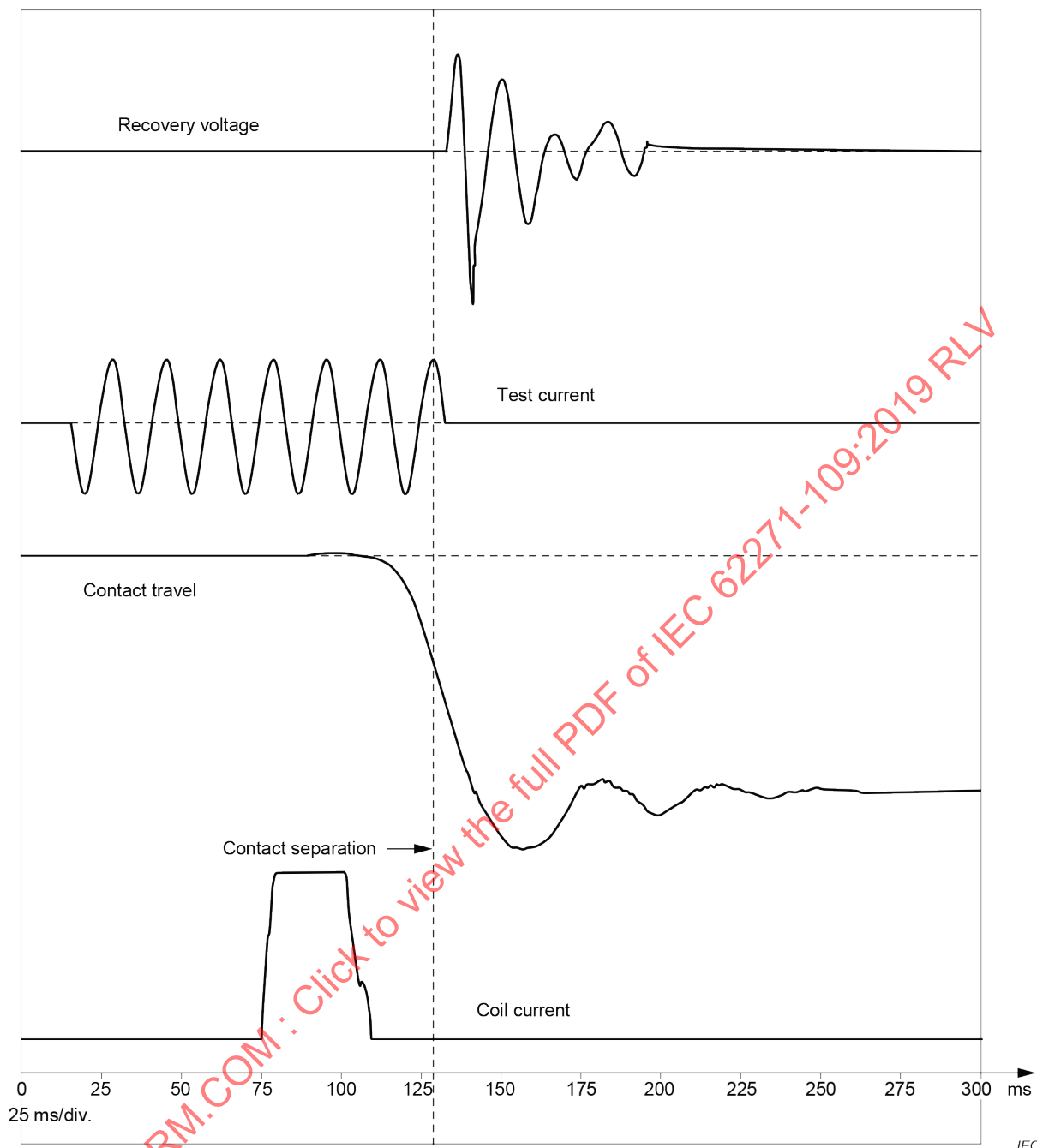


Figure 15 – Oscillogram obtained from the typical direct test circuit for the insertion current test-duty

7.103.3.3 Test voltage

The recovery voltage peak to be applied across the by-pass switch shall be the limiting peak voltage of the overvoltage protector (U_{PL} ; $+5$ $\%$ $_0$ %).

7.103.3.4 Test current

The test current shall be the rated by-pass insertion current (± 20 %).

7.103.3.5 Number of operations

The insertion current test-duty comprises a total of two test duties of 24 opening operations (2×24 O).

The opening operations should be performed in the following manner:

- O operations for finding the minimum arcing time on one polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on one polarity;
- O operations for finding the minimum arcing time on the other polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on the other polarity;
- additional tests to achieve 24 O, distributed in both polarities (step: 30°)
- reversal of the connections for the second set if the current path is not symmetrical;
- O operations for finding the minimum arcing time on one polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on one polarity;
- O operations for finding the minimum arcing time on the other polarity (step: 6°);
- additional operations to achieve a total of 6 O at minimum arcing on the other polarity;
- additional tests to achieve 24 O, distributed in both polarities (step: 30°).

It is understood that to comply with this requirement, a search for the minimum arcing time should be done before doing the required tests with minimum arcing time. These test shots are included in the total of 24 O for each individual set.

NOTE It is understood that when following this procedure, the number of shots distributed at 30° steps at each polarity may not be equal. This is acceptable.

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

In order to obtain more consistent opening time of the by-pass switch, by agreement of the manufacturer, voltages even higher than the relevant upper tolerance limit of the supply voltages of the operating devices may be applied during these tests.

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

- advance the setting of the control of the tripping impulse by 6° and repeat the test. The new setting should be kept for other tests at minimum arcing time. If with this new setting, another maximum arcing time is obtained instead of an expected minimum arcing time, the setting shall be further advanced by a step of 6° and this procedure repeated until a minimum arcing time is achieved;
- make one less opening operation for each of the above operations resulting in a maximum arcing time to retain the overall total count of tests.

For relatively high rated insertion current, it may appear that two minimum arcing times are found, one in the thermal reignition zone (typically around 1 ms before current zero) and one in the dielectric reignition zone (typically less than 0,5 ms before current zero). In order to have a consistent test procedure, the minimum arcing time search should start from a contact separation point as close as possible to current zero.

The number of operations at minimum arcing time as stated above shall be achieved, even if the specified total number of operations is exceeded.

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

For tests using the test circuit given in Figure 12, the result will become invalid when the arcing time becomes maximum instead of an expected minimum arcing time. This test cannot be included in the count for the total number of tests.

The by-pass switch conditions shall be in accordance with 7.102.3.1. If the by-pass switch has a non-symmetrical current path, the terminal connections shall be reversed for the second test-duty as shown above.

7.103.4 Criteria to pass the test duties

The by-pass switches shall have successfully passed the tests if the following conditions are fulfilled:

- the behaviour of the by-pass switch during by-pass making current and insertion current test duties fulfils the conditions given in 7.102.8;
- either no restrikes occurred during the insertion current test-duty, or, if only one restrike occurs in one of the two sets, then the set shall be completed and repeated on the same test sample without any maintenance. No restrike shall occur during the further tests. External flashover and phase-to-ground flashover shall not occur;
- the condition of the by-pass switch after the test series corresponds to the conditions given in 7.102.9.2. If no restrike occurred during the insertion test-duty, visual inspection is sufficient.

8 Routine tests

8.1 General

Subclause 8.1 of IEC 62271-1:2017 is applicable.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable with the following addition.

In the case of by-pass switches constructed by assembling identical by-pass units in series, the test voltage to be applied across each single unit, when open, shall be the higher fraction of the total withstand voltage resulting from actual power-frequency voltage distribution with the by-pass switch fully open and one terminal earthed.

With reference to Figure 2 of IEC 62271-1:2017, which shows a diagram of a three-pole operated by-pass switch, the test voltage shall be applied, according to Table 9. For single pole operated by-pass switches, the required tests are limited to two tests, one with the by-pass switch in the closed position and one with the by-pass switch in the open position. The required test levels for both positions can be different.

Table 9 – Application of voltage for dielectric test on the main circuit

Test condition No.	By-pass switch	Voltage applied to	Earth connected to
1	Closed	AaCc	BbF
2	Closed	Bb	AaCcF
3	Open	ABC	abcF

NOTE If the insulation between poles is air at atmospheric pressure, test conditions nos. 1 and 2 can be combined, the test voltage being applied between all parts of the main circuit, connected together, and the base.

In the case of by-pass switches using a gas mixture such as SF₆/CF₄ or SF₆/N₂, the test can be performed using the declared gas mixture at the minimum functional pressure for by-passing, inserting and insulation or pure SF₆ at a total absolute pressure not exceeding the equivalent gas pressure (P_{test}) as calculated by the following equations (see Figure 4.1 of CIGRE TB 163):

- for circuit-breakers using a SF₆/N₂ mixture: $P_{\text{test}} = P_{\text{SF6}} + 0,7 \times P_{\text{add N2}}$. The equation is valid for mixtures having at least 30 % of SF₆ gas volume; (see Note);
- for circuit-breakers using a SF₆/CF₄ mixture: $P_{\text{test}} = P_{\text{SF6}} + 0,45 \times P_{\text{add CF4}}$.

where

P_{test} is the total absolute SF₆ pressure at $T = 20\text{ °C}$ during routine dielectric test on the main circuit;

P_{SF6} is the partial pressure of SF₆ at $T = 20\text{ °C}$ at the minimum functional pressure for by-passing, inserting and insulation according to the declared gas mixture;

P_{add} is the partial pressure of CF₄ or N₂ at $T = 20\text{ °C}$ at the minimum functional pressure for by-passing, inserting and insulation according to the declared gas mixture.

NOTE See CIGRE TB 163 for mixtures having less than 30 % of SF₆.

8.2.101 Partial discharge test

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

The measurement of partial discharges should be preferably performed on the complete by-pass switch. In this case, the measurement of partial discharges shall be performed during the dielectric test (8.2) and preferably after mechanical operating routine tests (8.101).

If a test on the complete by-pass switch is impractical, it is allowed to replace the test on the complete by-pass switch by partial discharge measurements on individual components, before assembly, such as bushings, insulators, partitions, insulated operating rods, etc. For partial discharge tests on bushings, 9.5 of IEC 60137:2017 is applicable.

Partial discharge test on bushings is required for all types of bushings with the exception of gas-insulated bushings and ceramic, glass or analogous inorganic material bushings as defined respectively in 3.6 and 3.13 of IEC 60137:2017.

The measurement shall be made in accordance with IEC 60270.

The applied power-frequency voltage shall be raised to a pre-stress value which is identical to the power-frequency withstand voltage test and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage shall be decreased to the value defined in Table 10.

The extinction voltage shall be recorded during the reduction of the applied test voltage specified in Table 10.

Table 10 – Test voltage for partial discharge test

	System with effectively earthed neutral		System with non-effectively earthed neutral	
	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min.)	Test voltage for PD measurement $U_{\text{pd-test}}$ (> 1 min.)	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min.)	Test voltage for PD measurement $U_{\text{pd-test}}$ (> 1 min.)
Single-phase enclosure designs (phase-to-earth voltage)	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test}} = 1,2 \times U_{\text{re}} / \sqrt{3}$	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test}} = 1,2 \times U_{\text{re}}$
Three-phase enclosure designs	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test, ph-ea}} = 1,2 \times U_{\text{re}} / \sqrt{3}$ $U_{\text{pd-test, ph-ph}} = 1,2 \times U_{\text{re}}$	$U_{\text{pre-stress}} = U_{\text{de}}$	$U_{\text{pd-test, ph-ea}} = 1,2 \times U_{\text{re}}$
Key U_{re} : rated voltage to earth for equipment. U_{de} : power-frequency withstand test voltage to earth as per Tables 1, 2, 3 and 4 of IEC 62271-1:2017. $U_{\text{pre-stress}}$: pre-stress voltage. $U_{\text{pd-test}}$: test voltage for PD measurement. $U_{\text{pd-test, ph-ea}}$: test voltage for PD measurement, phase-to-earth. $U_{\text{pd-test, ph-ph}}$: test voltage for PD measurement, phase-to-phase.				

8.3 Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to circuit diagrams and wiring diagrams

Subclause 8.3.1 of IEC 62271-1:2017 is applicable.

8.3.2 Functional tests

Subclause 8.3.2 of IEC 62271-1:2017 is applicable.

8.3.3 Verification of protection against electrical shock

Subclause 8.3.3 of IEC 62271-1:2017 is applicable.

8.3.4 Dielectric tests

Subclause 8.3.4 of IEC 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 is applicable.

8.5 Tightness test

8.5.1 General

Subclause 8.5.1 of IEC 62271-1:2017 is applicable.

8.5.2 Controlled pressure systems for gas

Subclause 8.5.2 of IEC 62271-1:2017 is applicable.

8.5.3 Closed pressure systems for gas

Subclause 8.5.3 of IEC 62271-1:2017 is applicable.

8.5.4 Sealed pressure systems

Subclause 8.5.4 of IEC 62271-1:2017 is applicable.

8.5.5 Liquid tightness tests

Subclause 8.5.5 of IEC 62271-1:2017 is applicable.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable with the following addition.

The by-pass switch shall be checked to verify its compliance with the order specification.

The following items shall be checked as applicable:

- the language and data on the nameplates;
- identification of any auxiliary equipment;
- the colour and quality of paint and corrosion protection of metallic surfaces;
- the values of the resistors and capacitors connected to the main circuit.

8.101 Mechanical operating tests

Mechanical operating tests shall include the following:

- a) at maximum supply voltage of operating devices and of auxiliary and control circuits and maximum pressure for operation (if applicable)
 - five closing operations;
 - five opening operations.
- b) at specified minimum supply voltage of operating devices and of auxiliary and control circuits and minimum functional pressure for operation (if applicable)
 - five closing operations;
 - five opening operations.
- c) at rated supply voltage of operating devices and of auxiliary and control circuits and rated pressure for operation (if applicable)
 - five open-close operating cycles with the closing mechanism energized by the opening of the main contacts through the auxiliary switch.

Mechanical operating tests shall be made on the complete by-pass switch. However, when by-pass switches are assembled and shipped as separate units, routine tests may be performed on components according to 7.101.1.2. In such cases, the manufacturer shall produce a programme of commissioning tests for use at site to confirm the compatibility of such separate units and components when assembled as a by-pass switch. A guide for commissioning tests is given in 11.101.2.

For all required operating sequences, the following shall be performed and records made of the closing and opening operations:

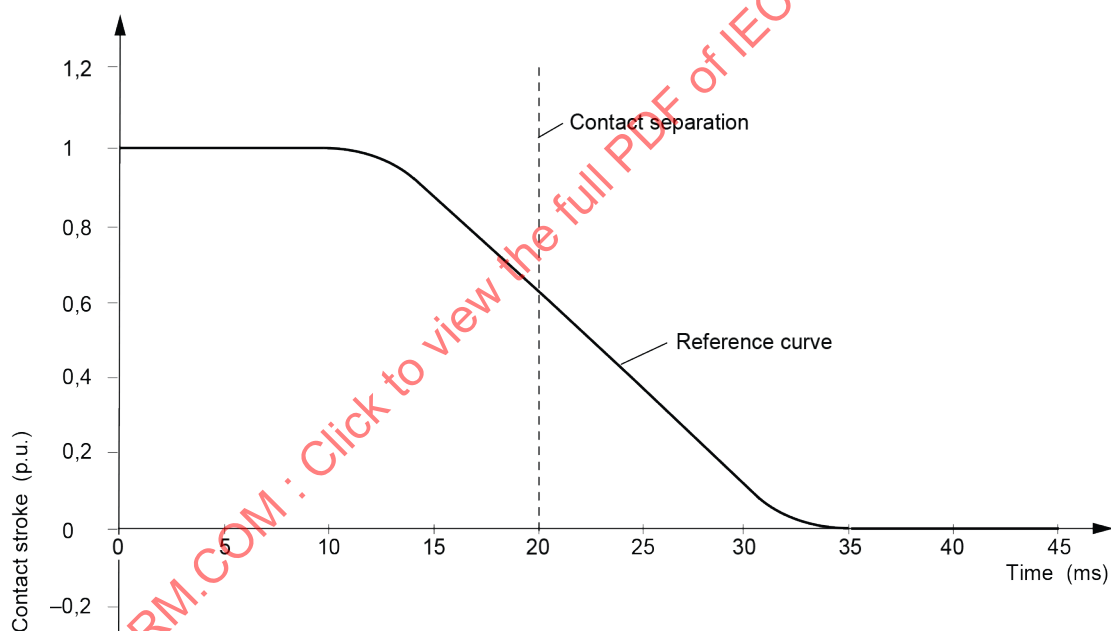
- measurement of operating times;
- where applicable, measurement of fluid consumption during operations, for example, the pressure difference.

Proof shall be given that the mechanical behaviour conforms to that of the test specimen used for type testing. For example, a no-load operating cycle, as described in 7.101.1.1, can be performed to record the no-load travel curves at the end of the routine tests. Where this is done, the curve shall be within the prescribed envelope of the reference mechanical travel characteristic, as defined in 7.101.1.1, from the instant of contact separation to the end of contact travel or from the start of contact travel to the instant of contact touch.

Where the mechanical routine tests are performed on sub-assemblies, the reference mechanical travel characteristics shall be confirmed to be correct, as above, at the end of the commissioning tests on site.

If the measurement is performed on site, the manufacturer shall state the preferred measuring procedure. If other procedures are used, the results may be different and the comparison of the instantaneous contact stroke may be impossible to achieve.

The mechanical travel characteristics can be recorded directly, using a travel transducer or similar device on the by-pass switch contact system or at other convenient locations on the drive to the contact system where there is a direct connection, and a representative image of the contact stroke can be achieved. The mechanical travel characteristics shall be preferably a continuous curve as shown in Figure 16. Where the measurements are taken on site, other methods may be applied which record points of travel during the operating period.



IEC

Figure 16 – Reference mechanical travel characteristics (idealized curve)

In these circumstances, the number of points recorded shall be sufficient to derive the time to, and contact speed at, contact touch and contact separation, together with the total travel time.

After completion of the required operating sequences, the following tests and inspections shall be performed (if applicable):

- connections shall be checked;
- the control and/or auxiliary switches shall correctly indicate the open and closed positions of the by-pass switch;
- all auxiliary equipment shall operate correctly at the limits of the supply voltage of operating devices and of auxiliary and control circuits and/or pressures for operation.

Furthermore, the following tests and inspections shall be made (if applicable):

- measurement of the resistance of heaters (if fitted) and of the control coils;
- inspection of the wiring of the control, heater and auxiliary equipment circuits and checking of the number of auxiliary contacts, in accordance with the order specification;
- inspection of control cubicle (electrical, mechanical, pneumatic and hydraulic systems);
- recharging duration(s);
- functional performance of pressure relief valve;
- the operation of electrical, mechanical, pneumatic or hydraulic interlocks and signalling devices;
- the operation of the anti-pumping device;
- general performance of equipment within the required tolerance of the supply voltage;
- inspection of earthing terminals of the by-pass switch.

9 Guide to the selection of by-pass switches (informative)

For more information refer to IEC 60143-1, IEC 60143-2 and Annexes E and F of this document.

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

10.1 General

Subclause 10.1 of IEC 62271-1:2017 is applicable.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC 62271-1:2017 is generally applicable with the following additions:

- a) Particularities of the systems:
Nominal and highest voltages to earth and across the by-pass unit, frequency;
- b) Service conditions if different than normal (refer to Clause 4):
Minimum and maximum ambient air temperatures, altitude if over 1 000 m and any special condition likely to exist or arise, for example, unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air;
- c) Particulars of the installation and its components
- d) Characteristics of the by-pass switch.
The following information shall be given:

Type of information	Reference
1) number of poles	
2) environmental conditions (temperature, wind, ice, etc.)	4
3) rated voltage to earth and across poles	5.2
4) rated insulation level to earth and across poles where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, the desired insulation levels	5.3
5) rated frequency	5.4
6) rated continuous current	5.5
7) rated short-time withstand current	5.6
8) rated peak withstand current	5.7
9) duration of short-circuit	5.8
10) rated operating sequence	5.101
11) rated by-pass making current	5.102
12) frequency of the rated by-pass making current	5.102
13) capacitor bank discharge current	3.8.28
14) damping of the by-pass making current	5.102
15) rated by-pass insertion current	5.103
16) rated reinsertion voltage	5.104
17) maximum limiting peak voltage of the overvoltage protector	5.104
18) minimum time-to-peak voltage during insertion	5.104
19) compensation factor	Annex F
20) amplitude of power swing	Annex F
21) the type tests specified on special request (for example artificial pollution and radio interference, etc.)	7.1.1
22) the number of mechanical operating sequences (class M1 or M2)	5.105
23) if applicable, any test exceeding the standardised type, routine and commissioning tests	

e) characteristics of the operating mechanism of the by-pass switch and associated equipment, in particular:

- 1) number and type of spare auxiliary switches;
- 2) rated supply voltage and rated supply frequency;
- 3) number of releases for closing, if more than one;
- 4) a number of releases for opening, if more than one.

f) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels.

The enquirer should give information of any special conditions, not included above, that might influence the tender or order.

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 is generally applicable with the following additions:

When the enquirer requests technical particulars of a by-pass switch, the following information (those which are applicable) shall be given by the manufacturer, with the descriptive matter and drawings:

a) rated values and characteristics:

Type of information	Reference
1) number of poles	
2) class: environmental conditions (temperature, wind, ice-coating)	4
3) rated voltage to earth and across the pole	5.2
4) rated insulation level to earth and across the pole	5.3
5) rated frequency	5.4
6) rated continuous current	5.5
7) rated short-time withstand current	5.6
8) rated peak withstand current	5.7
9) rated duration of short-circuit	5.8
10) rated operating sequence	5.101
11) rated by-pass making current	5.102
12) frequency of the rated by-pass making current	5.102
13) capacitor bank discharge current	3.8.28
14) damping of the by-pass making current	5.102
15) rated by-pass insertion current	5.103
16) maximum limiting peak voltage of the overvoltage protector	3.8.22
17) minimum time-to-peak voltage during insertion	5.104
18) maximum closing time and maximum open-close time	6.105
19) the type tests specified on special request (for example, artificial pollution and radio interference, etc.)	7.1.1
20) class M1 or class M2 for mechanical endurance	5.105

b) type tests:

certificate or report on request;

c) constructional features:

The following details are required where they are applicable to the design:

- 1) mass of complete by-pass switch without fluids for insulation, by-passing, insertion and operation;
- 2) mass/volume of fluid for insulation, its quality and operating range, including the minimum functional value;
- 3) mass/volume of fluid for by-passing and insertion (where different fluid to items 2) and/or 4)), its quality and operating range, including the minimum functional value;
- 4) mass/volume of fluid for operation (where different fluid to items 2) and/or 3)), its quality and operating range, including the minimum functional value;
- 5) tightness qualification;
- 6) mass/volume of fluids per pole to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
- 7) number of units in series per pole;
- 8) minimum clearances in air:
 - between poles;
 - to earth;
 - the safety boundaries during a by-passing operation, for by-pass switches with an external exhaust for ionised gasses or flame;
- 9) any special arrangements (for example, heating or cooling) to maintain the rated characteristics of the by-pass switch at the required temperatures of the ambient air;

d) operating mechanism of the by-pass switch and associated equipment:

- 1) type of operating mechanism;
- 2) rated supply voltage and/or pressure of closing mechanism, pressure limits were different to or expanding data required in c) 4) of 10.3;
- 3) the current required at rated supply voltage to close the by-pass switch;
- 4) energy expended to close the by-pass switch, for example, measured as a fall in pressure;
- 5) rated supply voltage of shunt opening release;
- 6) the current required at rated supply voltage for shunt opening release;
- 7) number and type of spare auxiliary switches;
- 8) the current required at rated supply voltage by other auxiliaries;
- 9) the setting of high and low pressure interlocking devices;
- 10) number of releases for closing, if more than one;
- 11) number of releases for opening, if more than one;

e) overall dimensions and other information.

The manufacturer shall give the necessary information as regards the overall dimensions of the by-pass switch and details necessary for the design of the foundation.

General information regarding maintenance of the by-pass switch and its connections shall be given.

11 Transport, storage, installation, operating instructions and maintenance

11.1 General

Subclause 11.1 of IEC 62271-1:2017 is applicable.

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC 62271-1:2017 is applicable.

11.3 Installation

Subclause 11.3 of IEC 62271-1:2017 is applicable.

11.4 Operating instruction

Subclause 11.4 of IEC 62271-1:2017 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC 62271-1:2017 is applicable.

11.101 Guide for commissioning tests

11.101.1 General

After a by-pass switch has been installed and all connections have been completed, commissioning tests are recommended to be performed. The purpose of these tests is to confirm that transportation and storage have not damaged the by-pass switch. In addition, when a large part of the assembly and/or of the adjustment is performed on site, as identified in 8.101, the tests are required to confirm compatibility of the subcomponents and the satisfactory nature of both the site work and the functional characteristics dependent upon it.

In addition to the requirements of 11.101.2, a minimum of 50 no-load operations shall be performed at commissioning, on site, on the by-pass switch where major sub-assemblies are combined at the site without previous routine tests on the complete by-pass switch. These operations shall be performed after assembly, all connections and checks having been made and the programme of commissioning tests having been completed. These operations may include deferred routine test operations forming part of the commissioning programme only where they are made after all site adjustments and tightness checks are complete. The purpose of these tests is to reduce occurrences of maloperation and failure early in the operational life of the by-pass switch.

The manufacturer shall produce a programme of site commissioning checks and tests. Repetition of the full programme of routine tests, already performed in the factory, shall be avoided as the purpose of commissioning tests is for confirmation of:

- the absence of damage;
- compatibility of separate units;
- correct assembly;
- correct performance of the assembled by-pass switch.

In general, this is achieved when the commissioning tests include, but are not limited to, the programme given in 11.101.2. The results of the tests shall be recorded in a test report.

11.101.2 Commissioning checks and test programme

11.101.2.1 Checks after installation

11.101.2.1.1 General

Subclause 11.101.1 requires the manufacturer to produce a programme of commissioning checks and tests. This should be based on but is not limited to, the programme of checks and tests given here.

11.101.2.1.2 General checks

These shall include the following:

- assembly conforms to manufacturer's drawings and instructions;
- the tightness of by-pass switch, its fastenings, fluid systems and control devices;
- external insulation and, where applicable, internal insulation are undamaged and clean;
- paint and other corrosion protection are sound;
- operating devices, especially operating releases, are free from contamination;
- adequacy and integrity of the earth connection up to and including the interface with the substation earthing system;

and, where applicable:

- record the number on the operations counter(s) at delivery;
- record the number on the operations counter(s) at the completion of all site testing;
- record the number on the operations counter(s) at first energisation.

11.101.2.1.3 Checks of electrical circuits

This shall include:

- conformity to the wiring diagram;
- correct operation of signalling (position, alarms, lockouts, etc.);
- correct operation of heating and lighting.

11.101.2.1.4 Checks of the insulation and/or extinguishing fluid(s)

Oil	Type, dielectric strength (IEC 60296), level
SF ₆	Filling pressure/density, and quality checks, to confirm the acceptance levels of IEC 60376, IEC 60480 and IEC 62271-4. These quality checks are not required on sealed equipment and new gas used from sealed bottles. A dew point check and a check of the total impurities shall be carried out to confirm the manufacturer's acceptance levels
Gas mixtures	Quality to be confirmed prior to energisation
Compressed air	Quality (if applicable) and pressure

11.101.2.1.5 Checks on operating fluid(s), where filled or added to on site

Hydraulic oil	Level and, unless otherwise agreed, confirmation that the moisture content is sufficiently low to prevent internal corrosion or other damage to the hydraulic system
Nitrogen	Filling pressure and purity (for example oxygen free or 1 % tracer gas)

11.101.2.1.6 Site operations

Confirmation shall be given that the programme of commissioning checks and tests required by 8.101 has been completed and, where applicable, extended by the additional 50 operations required by 11.101.1.

11.101.2.2 Mechanical tests and measurements

11.101.2.2.1 Measurements of the characteristic insulating and/or by-passing and insertion fluid pressures (where applicable)

11.101.2.2.1.1 General

The following measurements shall be taken in order to compare them with the values both recorded during the routine tests and guaranteed by the manufacturer. These values serve as the reference for future maintenance and other checks and will enable any drift in operating characteristics to be detected.

These measurements involve a check of the operation of the alarm and lockout devices (pressure switches, relays, transducers, etc.) where applicable.

11.101.2.2.1.2 Measurements to be taken

- a) Where applicable, on rising pressure:
 - the reset value of the closing lockout;
 - the reset value of the opening lockout;
 - the reset value of the auto-reopening lockout;
 - the disappearance of the low-pressure alarm.
- b) Where applicable, on dropping pressure:
 - the appearance of low-pressure alarm;
 - the operating value of lockout of the auto-reopening feature;

- the operating value of lockout of the opening;
- the operating value of lockout of the closing.

11.101.2.2.2 Measurements of characteristic operating fluid pressures (if applicable)

11.101.2.2.2.1 General

The following measurements (list to be adapted as necessary) shall be taken, in order to compare them with the values both recorded during routine tests and guaranteed by the manufacturer. These values may serve as a reference during later checks (maintenance) and will enable any drift in operating characteristics to be detected.

The measurements involve a check of the operation of the lockout or alarm devices (pressure switches, relays, etc.).

11.101.2.2.2.2 Measurements to be taken

a) On a rise in pressure with the pumping device (pump, compressor, controlled valve, etc.) in service:

- the reset value of the closing lockout;
- the reset value of the opening lockout;
- the reset value of the auto-reopening lockout (if applicable);
- the disappearance of the low-pressure alarm;
- the cut-off of the pumping device;
- the opening of the safety valve (if applicable).

The measurements may be combined with the measurements of the recharging time of the operating mechanism (see 11.101.2.2.5.2).

b) On a drop in pressure with the pumping device switched off:

- the closing of the safety valve (if applicable);
- starting of the pumping device;
- the appearance of the low-pressure alarm;
- lockout of the auto-reopening (if applicable);
- lockout of the opening;
- lockout of the closing.

In the case of a hydraulic control, the pre-inflation pressure of the accumulators should be indicated together with the ambient air temperature before the tests are performed.

11.101.2.2.3 Measurement of consumption during operations (if applicable)

With the pumping device switched off and the individual reservoir at the cut-in pressure of the pumping device, the consumption during each of the following operations or operating sequence should be evaluated:

- O;
- C;
- OC.

The steady-state pressure after each operation or operating sequence should be noted.

11.101.2.2.4 Verification of the rated operating sequence

The ability of the by-pass switch to perform its specified rated operating sequence should be verified. The tests should be performed with the recharging device in service, with site supply voltage and, if applicable, starting with the cut-in pressure of the pumping device, as in 11.101.2.2.3.

Evidence should be given to demonstrate the coordination between the interlocking device intervention levels and the minimum pressures for operation measured during the rated operating sequence.

The site supply voltage is the on-load voltage available at the by-pass switch from the normal site supply and should be compatible with the rated supply voltage of auxiliary and control circuits.

11.101.2.2.5 Measurement of time quantities

11.101.2.2.5.1 Characteristic time quantities of the by-pass switch

a) Closing and opening times, time spread

The following measurements should be made at maximum pressure (cut-off of pumping device) and at the supply voltage of the auxiliary and control circuits, measured at the terminals of the equipment and under typical load conditions of the supply voltage source:

- closing time of each pole, time spread of the poles and, when possible, time spread of the by-passing units or groups of units of each pole,
- opening time of each pole, time spread of the poles and, when possible, time spread of the by-passing units or groups of units of each pole.

These measurements should be carried out for separate opening and closing operations and for the individual opening and closing operations of a OC operating cycle, in case of a by-pass switch with a rated operating sequence C – t – OC – t' – OC.

In the case of multiple close and trip coils, all should be tested and the times recorded for each.

The supply voltage before and during the operations should be recorded.

b) Operation of control and auxiliary contacts

The timing of the operation of one of each kind (by-pass and insertion) of control and auxiliary contacts should be determined in relation to the operation of the main contacts, on closing and on opening of the by-pass switch.

11.101.2.2.5.2 Recharging time of the operating mechanism

a) Fluid-operated mechanism

The operation time of the pumping device (pump, compressor, control valve, etc.) should be measured:

- between minimum and maximum pressure (cut-in and cut-off of the pumping device);
- during the following operations or operating sequence, starting each time with minimum pressure (cut-in of the pumping device):
 - C;
 - O;
 - OC.

b) Spring-operated mechanism

The recharging time of the motor after an opening operation should be measured at the site supply voltage.

11.101.2.2.6 Record of mechanical travel characteristics

As required by 8.101, a record can be made of the mechanical travel characteristics where the by-pass switch has been assembled as a complete by-pass switch for the first time on site or where all or part of the routine tests are performed on site. The record shall confirm satisfactory performance by comparison with the reference mechanical travel characteristics obtained during the reference no-load tests detailed in 7.101.1.1.

11.101.2.2.7 Checks of certain specific operations

11.101.2.2.7.1 Auto-reopening at the minimum functional pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered to the lockout value for auto-reopening and an auto-reopening operating sequence be carried out (under site conditions, it may be necessary to use a separate timing device to initiate reopening). The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted and it should be ensured that there is sufficient safety margin to the minimum functional pressure for operation for closing, as a guard against pressure switch deviation and pressure transients.

In case of doubt, an alternative test to the one described above may be performed, starting with a lower pressure than the minimum functional pressure for operation for auto-reopening (short-circuited contact). It should then be verified that a closing operation is still possible.

11.101.2.2.7.2 Closing at the minimum functional pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for closing and a closing operation be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted.

11.101.2.2.7.3 Opening at the minimum functional pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for opening and an opening operation be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted and a sufficient safety margin is ensured to the minimum functional pressure for closing.

In case of doubt, an alternative test to the one described above may be performed, starting with a lower pressure than the minimum functional pressure for opening (short-circuited contact). It should then be verified that a closing operation is still possible.

11.101.2.2.7.4 Simulation of fault-making operation and check of anti-pumping device

Measurement should be taken of the time during which the by-pass switch remains open during an OC operating cycle with the close circuit energized by the closing of the auxiliary contact.

The test also allows checking of the anti-pumping device operation and the absence of malfunction for any mechanical, hydraulic or pneumatic reasons, caused by the rapid application of the closing command.

The opening command should be maintained for 1 s to 2 s in order that the anti-pumping device can be checked for effective operation.

A simplified anti-pumping test may also be executed, using the local control. In this case, an opening command is applied and maintained, while a consecutive closing command is applied.

11.101.2.2.7.5 Behaviour of the by-pass switch on an opening command while a closing command is already present

It should be verified that the by-pass switch meets the technical specifications in the presence of an opening command when previously a closing command is applied and maintained.

11.101.2.2.7.6 Application of a closing command on both releases simultaneously (if applicable)

It may happen that both releases (normal and emergency) are energized simultaneously (or virtually simultaneously).

It should be ensured that the operations are not subject to any mechanical, hydraulic or pneumatic interference, particularly if the releases do not operate at the same level.

11.101.2.2.7.7 Protection against pole discrepancy (if applicable)

Protection against pole discrepancy should be checked by either of the following tests:

- with the by-pass switch open, the closing release of one of the poles shall be energized and a check carried out to see that all poles close;
- with the by-pass switch closed, the opening release of one of the poles shall be energized and a check carried out to see that it opens and then closes.

11.101.2.3 Electrical tests and measurements

11.101.2.3.1 Dielectric tests

Dielectric tests on auxiliary circuits shall be performed to confirm that transportation and storage of the by-pass switch have not damaged these circuits. However, it is recognized that such circuits contain vulnerable sub-components and the application of the full testing voltage for the full duration can cause damage. In order to avoid this, and to avoid the temporary removal of proven connections, the supplier shall detail the test process that demonstrates that damage has not occurred as well as the method of recording the results from this test process.

For dielectric tests on the main circuit of metal-enclosed switchgear and controlgear, IEC 62271-200 and IEC 62271-203 are applicable (see Bibliography).

11.101.2.3.2 Measurement of the resistance of the main circuit

Measurement of the resistance of the main circuit need only be made if by-passing units have been assembled on site. The measurement shall be made with a direct current in accordance with 8.4 of IEC 62271-1:2017.

11.101.3 Resistors and capacitors (if applicable)

When checking resistors and capacitors, allowed variations of the values should be given.

12 Safety

12.1 General

Subclause 12.1 of IEC 62271-1:2017 is applicable with the following addition.

Any known chemical and environmental impact hazards should be identified in the by-pass switch handbook/manual.

12.2 Precautions by manufacturers

Subclause 12.2 of IEC 62271-1:2017 is applicable.

12.3 Precautions by users

Subclause 12.3 of IEC 62271-1:2017 is applicable.

13 Influence of the product on environment

Clause 13 of IEC 62271-1:2017 is applicable.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex A (normative)

Tolerances on test quantities during type tests

During type tests, the following types of tolerances may normally be distinguished:

- tolerances on test quantities which directly determine the stress of the test object;
- tolerances concerning features or the behaviour of the test object before and after the test;
- tolerances on test conditions;
- tolerances concerning parameters of measurement devices to be applied.

In the following Table A.1, only tolerances on test quantities are considered.

A tolerance is defined as the range of the test value specified in this document within which the measured test value should lie for a test to be valid. In certain cases (see 7.1.101 and Table 5) the test may remain valid even if the measured value falls outside the tolerance.

Any deviation of the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

The basic rules for the application of tolerances on test quantities during type tests are as follows:

- a) testing stations shall aim wherever possible for the test values specified;
- b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses of the by-pass switch exceeding those tolerances are permitted only with the consent of the manufacturer. Lower stresses render the test invalid;
- c) where, for any test quantity, no tolerance is given within this document, or the document to be applied, the type test shall be performed at values not less severe than specified. The upper-stress limits are subject to the consent of the manufacturer;
- d) if for any test quantity, only one limit is given, the other limit shall be considered to be as close as possible to the specified value.

Table A.1 – Tolerances on test quantities for type tests (1 of 3)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerances/ limits of test values	Reference to
7.2	Dielectric tests				
7.2.7.2 and 7.2.8.2	Power-frequency voltage tests	Test voltage (RMS value)	Rated short-duration power-frequency withstand voltage	$\pm 1\%$	IEC 62271-1, IEC 60060 (all parts)
7.2.7.3 and 7.2.8.4	Lightning impulse voltage tests	Frequency	--	45 Hz to 65 Hz	IEC 60060 (all parts)
		Wave shape	Peak value / RMS value = $\sqrt{2}$	$\pm 5\%$	
		Peak value	Rated lightning impulse withstand voltage	$\pm 3\%$	
		Front time	1,2 μs	$\pm 30\%$	
		Time to half-value	50 μs	$\pm 20\%$	
7.2.8.3	Switching impulse voltage tests	Peak value	Rated switch impulse withstand voltage	$\pm 3\%$	
		Time to peak	250 μs	$\pm 20\%$	
		Time to half-value	2 500 μs	$\pm 60\%$	
7.2.12	Voltage tests as condition check using standard switching impulse voltage	Peak value of switching impulse voltage	See 7.2.12	$\pm 3\%$	IEC 60060 (all parts)
		Time to peak	250 μs	$\pm 20\%$	
		Time to half-value	2 500 μs	$\pm 60\%$	
	Using TRV circuit of T10	Peak value of switching impulse voltage	See 7.2.12	$\pm 3\%$	
		Time to peak	Standard value for T10 (see IEC 62271-100)	+200 % -10	
7.3	Radio interference voltage tests	Test voltage	See 7.3 of IEC 62271-1:2017	$\pm 1\%$	IEC 60060 (all parts)
7.4	Measurement of the resistance of the main circuit	DC test current I_{DC}	--	$50 \text{ A} \leq I_{\text{DC}} \leq \text{rated normal current}$	IEC 62271-1

Table A.1 (2 of 3)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerances/ limits of test values	Reference to
7.5	Continuous current tests	Ambient air velocity	--	$\leq 0,5$ m/s	IEC 62271-1
		Test current frequency	Rated frequency	$+2$ -5 %	
		Test current	Rated normal current	$+2$ 0 %	
				These limits shall be kept only for the last two hours of the testing period	
7.6	Short-time withstand current and peak withstand current tests	Ambient air temperature T	--	$+10$ °C < T < 40 °C	IEC 62271-1
		Test frequency	Rated frequency	± 10 %	
		Peak current (in one of the outer phases)	Rated peak withstand current	$+5$ 0 %	
		Average of AC component of the three-phase test current	Rated short-time withstand current	± 5 %	
		AC component of test current in any phase/average	1	± 10 %	
		Short-circuit current duration	Rated short-circuit duration	See tolerances for I^2t	
		Value of I^2t	Rated value I^2t	$+10$ 0 %	
7.101.3	Low and high temperature tests	Deviation of ambient air temperature over height of test object	--	≤ 5 K	
		Ambient air temperature for recording characteristics before test	20 °C	± 5 K	
		Minimum and maximum ambient air temperature during tests	According to class of by-pass switch (see IEC 62271-1)	± 3 K	
		Maximum temperature of a cycle	40 °C	± 2 K	

Table A.1 (3 of 3)

Subclause	Designation of the test	Test quantity	Specified test value	Test tolerances/ limits of test values	Reference to
7.103.2	By-pass making current test-duty	Applied voltage before making	U_{PL}	+5 % 0	7.103.2.3
		Rated by-pass making current	I_{BP}	+5 % 0	7.103.2.4
		Capacitor bank discharge current	$I_{DISCHARGE}$	+5 % 0	7.103.2.4
		Frequency of the rated by-pass making current	f_{BP}	As close as possible to the required value. Shall not be lower than 77 % of the service condition and not higher than 6 000 Hz	7.103.2.4
		Damping factor of the rated by-pass making current	I_2 / I_1	not less than 10 % of service condition	7.103.2.2
		Test current at power frequency	I_{INS}	±20 %	7.103.3.4
7.103.3	Insertion current test-duty	Frequency of the test current	From 49 Hz to 61 Hz		7.103.3.1
		Recovery voltage, peak value	U_{PL}	0 %, +5 %	7.103.3.3
		Time to peak of the recovery voltage	Specified value	±5 %	7.103.3.1
		Amplitude of the initial voltage jump of the "1-cos" waveshape		≤ 5 % of the peak of the recovery voltage	7.103.3.2
		RMS current value/RMS current value of fundamental	≤ 1,2		7.103.3.3
		Waveshape of the recovery voltage	Maximum instantaneous deviation over theoretical test voltage waveshape of the corresponding "1-cos curve" with the exception of the initial voltage jump	+3 % of the peak -0 recovery voltage u_c	7.103.3.1

Annex B (normative)

Records and reports of type tests

B.1 Information and results to be recorded

All relevant information and results of type tests shall be included in the type test report.

Oscillographic records, in accordance with B.2, shall be made for all by-pass making current operations and insertion current operations and no-load operations included in the type test report.

The type test report shall include a statement concerning the uncertainty of the measurement systems used for the tests. This statement shall refer to internal procedures of the laboratory through which traceability of the measuring uncertainty is established.

The type test report shall include a statement of the performance of the by-pass switch during the test duties and of the condition of the by-pass switch at the end of the series of test duties. The statement shall include the following particulars:

- a) the condition of the by-pass switch, giving details of any replacements or adjustments made and condition of contacts, arc control devices, oil (including any quantity loss), statement of any damage to arc shields, enclosures, insulators and bushings;
- b) description of performance during test duties, including observations regarding emission of oil, gas or flame.

B.2 Information to be included in type test reports

B.2.1 General

- a) date of tests;
- b) reference of report number;
- c) test numbers;
- d) oscillogram numbers.

B.2.2 Apparatus tested

Clause 7 of IEC 62271-1:2017 is applicable.

Reference drawing numbers given in the test report shall indicate the manufacturer's reference number, revision number and corresponding contents.

The reference mechanical characteristic, if applicable, shall be included or reference shall be made in the test report by the use of a drawing number or in an equivalent way.

B.2.3 Rated characteristics of by-pass switch, including its operating devices and auxiliary equipment

The values of rated characteristics specified in Clause 5 shall be given by the manufacturer.

B.2.4 Test conditions (for each series of tests; if applicable)

- a) number of poles;
- b) power factor;

- c) frequency, in Hz;
- d) generator neutral (earthed or isolated);
- e) transformer neutral (earthed or isolated);
- f) diagram of test circuit including connection(s) to earth;
- g) details of the connection of the by-pass switch to the test circuit (e.g. orientation);
- h) pressure of fluid for insulation and/or by-passing and insertion;
- i) pressure of fluid for operation.

B.2.5 Short-time withstand current and peak withstand current test

- a) current
 - 1) RMS value in kA,
 - 2) peak value in kA;
- b) duration, in s;
- c) behaviour of the by-pass switch during tests;
- d) condition after tests;
- e) resistance of the main circuit before and after tests, in $\mu\Omega$.

B.2.6 No-load operation

- a) before each by-passing and insertion test set (see 7.102.6);
- b) after the last insertion test set (see 7.102.9.2);
- c) before and after the short-time withstand current and peak withstand current test.

B.2.7 By-pass making current test-duty

- a) applied voltage, in kV;
- b) peak making current, in kA;
- c) frequency in Hz;
- d) damping ratio;
- e) closing time, in ms;
- f) pre-arcing time, in ms;
- g) by-pass time, in ms;
- h) behaviour of the by-pass switch during tests;
- i) condition after tests.

B.2.8 Insertion current test-duty

- a) breaking current, in A;
- b) recovery voltage, peak value, in kV;
- c) time to recovery voltage peak value, in ms;
- d) details on point-of-wave setting;
- e) arcing time, in ms;
- f) number of restrikes (if any), the occurrence of NSDDs (if any) shall be noted for vacuum by-pass and insertion units;
- g) behaviour of the by-pass switch during tests;
- h) condition after tests.

B.2.9 Oscillographic and other records

Oscillograms shall record the whole of the operations. The following quantities shall be recorded. Certain of these quantities may be recorded separately from the oscillograms, and several oscillographs with different time scales may be necessary:

- a) applied voltage;
- b) current in each pole;
- c) recovery voltage (voltage across the by-pass switch);
- d) current in closing coil;
- e) current in opening coil;
- f) amplitude and timing scale appropriate for the required accuracy;
- g) mechanical travel characteristics (where applicable).

All cases in which the requirements of this document are not strictly complied with and all deviations shall be explicitly mentioned at the beginning of the test report.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex C
(informative)

(Void)

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex D (informative)

Examples of by-pass switch ratings

Tables D.1 to D.3 illustrate case studies of typical series capacitor bank ratings used in recent projects. The tables also illustrate the corresponding by-pass switch ratings. The values given in the tables should be used as a guideline for assigning rated values to by-pass switches since specific ratings cannot be standardized because they are project specific. It should be noted that some insulation levels were specified according to IEEE standards and are given solely as examples. Values given in these tables correspond to the same nomenclature and abbreviation of the various ratings that are outlined in Clause 5.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Table D.1 – Typical ratings for a series capacitor bank by-pass switch – Cases 1 to 6

Rating	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Rated voltage to earth U_{re}	kV RMS	500	500	500	500	500	500
Line maximum system voltage	kV RMS	560	560	560	560	560	560
Capacitor bank rated voltage U_N	kV RMS	101,3	63,9	63,5	70,4	69,9	94,8
Overload voltage	kV RMS	136,8	86,3	81,3	87,3	86,7	117,5
Protective level U_{PL}	kV	310,9	225,9	195,7	204	197,7	268,1
Rated frequency f_r	Hz	60	60	60	60	60	60
Rated normal current I_r	A RMS	4 000	4 000	3 000	3 000	3 000	3 000
Rated 30 min current	A RMS	5 400	5 400	4 050	4 050	4 050	4 050
Swing current (max. 30 s)	A RMS						
Insulation levels to earth							
– Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	710	710	710	710	860	860
– Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
– Rated lightning impulse withstand voltage, U_{pe}	kV	1 550	1 550	1 550	1 550	1 800	1 800
– Rated switching impulse withstand voltage, U_{se}	kV	1 050	1 050	1 050	1 050	1 175	1 175
Insulation levels between terminals							
– Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	425	260	310	310	310	365
– Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS	350	230	275	275	275	315
– Rated lightning impulse withstand voltage, U_{pp}	kV	900	550	650	650	650	750
Short time current withstand							
– Rated short-time withstand current I_k	kA RMS	63	40	40	40	40	40
– Rated duration of short-circuit t_k	s	3	3	3	3	3	3
– Rated peak withstand current I_p	kA	164	128	128	128	128	128
Rated operating sequence		O-C-t-OC-t-O- O-t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC	C-t-OC-t-O- t'-C-t-OC
– t	s	0,3	0,3	0,3	0,3	0,3	0,3
– t'	s	30	30	30	30	30	30

Rating	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Maximum closing time	ms	34	34	34	34	34	34
Maximum opening time	ms	50	50	50	50	50	50
Insertion current							
– Rated by-pass insertion current I_{INS}	A RMS	5 400	4 050	3 240	3 240	3 240	4 250
– Rated reininsertion voltage U_{INS}	kV	310,9	225,9	195,7	204	197,7	268,1
– Reininsertion voltage, first time-to-peak	ms	8	8	8	8	8	8
By-pass making current under normal operating condition							
– Capacitor bank discharge current component $I_{\text{DISCHARGE}}$	kA	37	28	21	23	23	25
– Power-frequency current	kA	5,7	4,5	4,2	4,1	4,0	4,0
– By-pass making current	kA	42,7	32,5	25,2	27,1	27,0	29,0
– Frequency of the by-pass making current f_{BP}	Hz	385,2	509,4	408,1	470,5	471,2	530,2
– Applied voltage	kV	143,3	90,4	89,8	99,6	98,9	134,1
By-pass making current under fault condition							
– Capacitor bank discharge current component $I_{\text{DISCHARGE}}$	kA	80	71	52	56	57	67
– Power-frequency fault current	kA	65	34	27	21	24	24
– By-pass making current	kA	139	105	79	77	81	91
– Frequency of the by-pass making current f_{BP}	Hz	385,2	509,4	408,1	470,5	471,2	530,2
– Applied voltage	kV	310,9	225,9	195,7	204	197,7	268,1
– Damping factor							
Specified electrical and mechanical endurance							
– No-load operations	CO						
– Number of operations/year at rated current	CO	20	20	20	20	20	20
– Number of operations/year under fault condition	CO	1	1	1	1	1	1
– Operations under fault condition (lifetime)	CO						

Table D.2 – Typical series capacitor bank by-pass switch ratings – Cases 7 to 12

Rating	Unit	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Rated voltage to earth U_{re}	kV RMS	500	500	735	245	345	345
Line maximum system voltage	kV RMS	550	550	800	245	362	362
Capacitor bank rated voltage U_N	kV RMS	19,9	19,9	80	46	42,6	55,6
Overload voltage	kV RMS	29,9	29,9	140	68/105		
Protective level U_{PL}	kV	81,6	81,6	270	148	144,4	188,6
Rated frequency f_r	Hz	60	60	60	60	60	60
Rated normal current I_r	A RMS	3 150	3 150	4 000	630	2 000	2 000
Rated 30 min. current	A RMS			6 000	945		
Swing current (max. 30 s)	A RMS			7 000	1 103	2 700	2 700
Insulation levels to earth							
– Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	650	650	830	450	710	710
– Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
– Rated lightning impulse withstand voltage, U_{pe}	kV	1 550	1 550	1 550	850	1 550	1 550
– Rated switching impulse withstand voltage, U_{se}	kV	1 175	1 175	2 100	1 175	1 050	1 050
Insulation levels between terminals							
– Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	110	110	230	140	145	185
– Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS	69,3	69,3		185 (1 s)		
– Rated lightning impulse withstand voltage, U_{pp}	kV	200	200	550	325	350	450
Short time current withstand							
– Rated short-time withstand current I_k	kA RMS	40	40	40	25	40	40
– Rated duration of short-circuit t_k	s	1	1	1	1	1	1
– Rated peak withstand current I_p	kA	128	128	108	65		
Rated operating sequence		O-C-t-OC-t'-O- O-t'-C-t-OC	C-t-OC-t'-O- t'-C-t-OC	C-t-OC-t'- OC	C-t-OC-t'- OC	C-O-C-t'-O- C	C-O-C-t'-O- C
– t	s	0,3	0,3	0,3	0,3		
– t'	s	30	30	15	15	30	30

Rating	Unit	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Maximum closing time	ms	34	34	100	50	30	30
Maximum opening time	ms						
Insertion current							
– Rated insertion current I_{INS}	A RMS	4 800	4 800	4 000	400	3 000	3 000
– Rated reinsertion voltage U_{INS}	kV	81,6	81,6	270	148		
– Reinsertion voltage, first time-to-peak	ms	4	4	4	4		
By-pass making current under normal operating condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA	18,3	18,3	30	23	37	37
– Power-frequency current	kA			4	0,6		
– By-pass making current	kA			34	24	37	37
– Frequency of the by-pass making current f_{BP}	Hz	708	744	1 000	840	900	900
– Applied voltage	kV	28,1	28,1	115	65,1	60,2	78,6
By-pass making current under fault condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA	75	75	70	52	85	85
– Power-frequency fault current	kA	65	65	5,6	8	15	15
– By-pass making current	kA	140	140	75,6	60	100	100
– Frequency of the by-pass making current f_{BP}	Hz	708	744	1 000	840	900	900
– Applied voltage	kV	81,6	81,6	270	148	144,4	188,6
– Damping factor				0,5	0,5		
Specified electrical and mechanical endurance							
– No-load operations	CO			2 000	2 000		
– Number of operations/year at rated current	CO	5	5	15	20		
– Number of operations/year under fault condition	CO			5	10		
– Operations under fault condition (lifetime)	CO	1	1	150	300		

Table D.3 – Typical series capacitor bank by-pass switch ratings – Cases 13 to 18

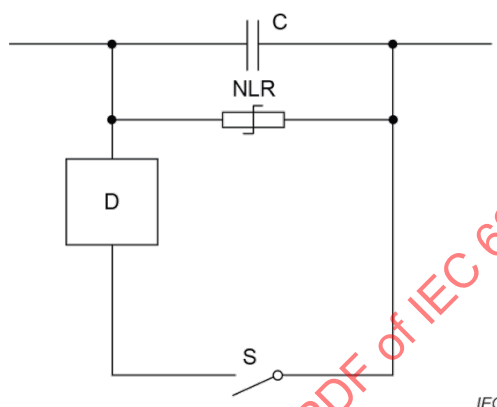
Rating	Unit	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18
Rated voltage to earth U_{re}	kV RMS	500	500	400	400	500	500
Line Maximum system voltage	kV RMS	550	550	460	460	550	550
Capacitor bank rated voltage U_N	kV RMS	65,4		33,8	33,8	61,7	170
Overload voltage	kV RMS			45,6	45,6		
Protective level U_{PL}	kV	212,7		110	110	200,6	383
Rated frequency f_r	Hz	60	50	60	60	50	60
Rated normal current I_r	A RMS	3 000	3 150	2 000	2 000	2 500	3 000
Rated 30 min. current	A RMS	4 500					
Swing current (max. 30 s)	A RMS	5 700					
Insulation levels to earth							
– Rated power-frequency withstand voltage, dry, 1 min U_{de}	kV RMS	710		860	860	680	860
– Rated power-frequency withstand voltage, wet, 10 s U_{de}	kV RMS						
– Rated lightning impulse withstand voltage, U_{pe}	kV					1 175	1 175
– Rated switching impulse withstand voltage, U_{se}	kV	1 800	1 500	1 550	1 550	1 550	1 550
Insulation levels between terminals							
– Rated power-frequency withstand voltage, dry, 1 min. U_{dp}	kV RMS	185					325
– Rated power-frequency withstand voltage, wet, 10 s U_{dp}	kV RMS						
– Rated lightning impulse withstand voltage, U_{pp}	kV	450					750
Short time current withstand							
– Rated short-time withstand current I_k	kA RMS	40	50	40	40	50	40
– Rated duration of short-circuit t_k	s	1	3	3	3	3	1
– Rated peak withstand current I_p	kA		125	100	100	125	108
Rated operating sequence		(O)-C-O-C	C-O-C- t' -O-C	O- t' -CO- t' -CO	O- t' -CO- t' -CO	C-O-C- t' -O-C	C-O-C- t' -O-C
– t	s			0,3	0,3		
– t'	s		30	30	30	30	30

Rating	Unit	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18
Maximum closing time	ms	< 35	< 50	36	36		< 50
Maximum opening time	ms		< 50				< 50
Insertion current							
– Rated insertion current I_{INS}	A RMS	4 500	3 150			3 600	3 650
– Rated reinsertion voltage U_{INS}	kV					200,6	383
– Reinsertion voltage, first time-to-peak	ms					6,7	8,3
By-pass making current under normal operating condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA	40				52,8	
– Power-frequency current	kA	15					
– By-pass making current	kA	55				52,8	
– Frequency of the by-pass making current f_{BP}	Hz	430				620	680
– Applied voltage	kV	92,5				123,3	240,4
By-pass making current under fault condition							
– Capacitor bank discharge current $I_{DISCHARGE}$	kA	70		68	68	80,9	91
– Power-frequency fault current	kA	30		40	40	24,7	
– By-pass making current	kA	100		108	108	105,6	108
– Frequency of the by-pass making current f_{BP}	Hz	430		1 048	1 048	620	680
– Applied voltage	kV	150,4		110	110	200,6	383
– Damping factor						0,3	
Specified electrical and mechanical endurance							
– No-load operations	CO		5 000			6 000	
– Number of operations/year at rated current	CO						
– Number of operations/year under fault condition	CO						
– Operations under fault condition (lifetime)	CO						

Annex E (normative)

By-pass switches used as the primary by-passing devices

By-pass switches are sometimes used as the primary protection of the overvoltage protector of the series capacitor bank (e.g. without the use of a fast by-passing device such as a spark-gap) for cases where the power-frequency fault current is relatively low (capacitor banks generally located in the middle of the line length) or where the use of a spark-gap could result in non-reliable operation of the spark-gap. For such series capacitor schemes, the varistor bank is designed to absorb the resulting energy produced by a line fault until the by-pass switch is closed. Figure E.1 illustrates the typical components layout.



Key

C	series capacitor
NLR	non-linear resistor (varistor)
D	damping circuit
S	by-pass switch

**Figure E.1 – Typical component layout for by-pass switches
used as the primary by-passing device**

For this particular application, the requirements stated in this document also apply with the following addition.

The by-pass switch will be subjected, for all line faults, to the capacitor bank discharge current component ($I_{\text{DISCHARGE}}$) and to the power-frequency fault current. For schemes using fast by-passing devices (for example spark-gap), these types of stresses are not frequent since they are almost always seen by the fast by-passing device and not by the by-pass switch.

Test parameters of already performed by-pass making current tests can be used to qualify a by-pass switch for this specific application as follows:

- A by-pass switch has been tested following alternative 1 (see 7.103.2.5) at a by-pass making current I_{BP} . This by-pass switch can be used as a primary by-passing device in an installation having a by-pass making current of up to the tested I_{BP} .
- A by-pass switch has been tested following alternative 2 (see 7.103.2.5) at a by-pass making current I_{BP} and a discharge current $I_{\text{DISCHARGE}}$. The tested parameters result in an equivalent I_{BPE} for gapless application as follows:

$$(I_{\text{BP}})^2 \times 4 + (I_{\text{DISCHARGE}})^2 \times 20 = (I_{\text{BPE}})^2 \times 20 \rightarrow I_{\text{BPE}} = \sqrt{\frac{(I_{\text{BP}})^2}{5} + (I_{\text{DISCHARGE}})^2}$$

Example: A by-pass switch has been tested following alternative 2 (see 7.103.2.5) at a by-pass making current of 120 kA and a discharge current of 70 kA. The tested parameters give an equivalent I_{BPE} for gapless application as follows:

$$(120)^2 \times 4 + (70)^2 \times 20 = (I_{BPE})^2 \times 20 \rightarrow I_{BPE} = 88,2 \text{ kA.}$$

This by-pass switch can be used as the primary by-passing device in an installation having a by-pass making current of up to 88,2 kA.

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

Annex F (informative)

Explanatory note regarding recovery voltage during reinsertion

When a by-pass switch reinserts a series capacitor bank, the reinsertion voltage appearing across the open contacts of the by-pass switch is function of the load current at power frequency, including any power swing and emergency load current, if applicable, and the transient damped oscillatory current produced by the resonance of the capacitive impedance and line impedance. This reinsertion voltage across the by-pass switch can be determined the following equation:

$$u(t) = U_N \times \sqrt{2} \times (\cos \omega_1 t - e^{-\beta t} \cos \omega_2 t) \times I_{\text{load}} / I_N$$

where

- $u(t)$ is the reinsertion voltage across the by-pass switch;
- U_N is the rated voltage of the series capacitor bank (RMS value);
- ω_1 is the angular frequency derived from the rated power frequency;
- t is the time, in s;
- β is the damping of the oscillation between the capacitance of the series capacitor bank and the line inductance, usually between 0,8 and 0,9;
- ω_2 is the angular frequency of the undertone caused by the oscillation between the capacitance of the series capacitor bank and the line inductance

$$\omega_2 = \omega_1 \times \sqrt{k}$$

and

$$k = X_C / X_L$$

- k is the compensation factor;
- I_{load} is the actual insertion current of the series capacitor bank (RMS value);
- I_N is the rated current of the series capacitor bank (RMS value).
- X_C is the capacitive reactance in Ω of the series capacitor bank ($X_C = 1/\omega_1 C$);
- X_L is the inductive reactance in Ω of the series compensated line ($X_L = \omega_1 L$);
- C is the capacitance of the series capacitor bank;
- L is the inductance of the series compensated line.

In IEC 60143-1, typical emergency overload currents range from 1,2 p.u. to 1,6 p.u. and power swings range from 1,7 p.u. to 2,5 p.u. According to IEC 60143-1, typical compensation factors range from 0,2 p.u. to 0,8 p.u. and protective levels U_{PL} range from between 2,0 p.u. and 2,5 p.u.

The combined effect of the undertone frequency, load current, including emergency and power swing currents and the operation level (U_{PL}) of the non-linear, voltage-limiting device (varistors) may cause the first voltage peak of the reinsertion voltage across the by-pass switch to be earlier than half of the power-frequency period e.g. 10 ms for 50 Hz systems or 8,3 ms for 60 Hz systems.

The protective level in p.u. is defined as $U_{PL} / (U_N / \sqrt{2})$ with U_{PL} being a peak value and U_N being an RMS value.

Therefore, the reinsertion voltage given in p.u. of the rated capacitor peak voltage is given by:

$$u(t) \text{ p.u.} = (\cos \omega_1 t - e^{-\beta t} \cos \omega_2 t) \times I_{\text{load}} / I_N$$

Tables F.1 to F.16 illustrate some examples.

**Table F.1 – Typical examples of reinsertion voltages for systems not having power swing nor emergency overload,
 $I_{\text{load}} = 1,0$ p.u.; $U_{\text{PL}} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,26	8,6	No
0,3	1,00	8,2	No
0,4	0,79	7,8	No
0,5	0,61	7,5	No
0,6	0,46	7,3	No
0,7	0,32	7,1	No
0,8	0,20	6,9	No

**Table F.2 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{\text{load}} = 1,2$ p.u.; $U_{\text{PL}} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,51	8,6	No
0,3	1,20	8,2	No
0,4	0,95	7,8	No
0,5	0,74	7,5	No
0,6	0,55	7,3	No
0,7	0,39	7,1	No
0,8	0,25	6,9	No

**Table F.3 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,76	8,6	No
0,3	1,40	8,2	No
0,4	1,11	7,8	No
0,5	0,86	7,5	No
0,6	0,64	7,3	No
0,7	0,45	7,1	No
0,8	0,29	6,9	No

**Table F.4 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,01	8,6	No
0,3	1,60	8,2	No
0,4	1,27	7,8	No
0,5	0,98	7,5	No
0,6	0,73	7,3	No
0,7	0,52	7,1	No
0,8	0,33	6,9	No

Table F.5 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	7,8	Yes
0,3	1,80	8,2	No
0,4	1,43	7,8	No
0,5	1,10	7,5	No
0,6	0,83	7,3	No
0,7	0,58	7,1	No
0,8	0,37	6,9	No

**Table F.6 – Typical examples of reinsertion voltages for systems
having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	6,7	Yes
0,3	2,01	8,2	No
0,4	1,58	7,8	No
0,5	1,23	7,5	No
0,6	0,92	7,3	No
0,7	0,65	7,1	No
0,8	0,41	6,9	No

**Table F.7 – Typical examples of reinsertion voltages for systems
having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,9	Yes
0,3	2,20	7,2	Yes
0,4	1,82	7,8	No
0,5	1,41	7,5	No
0,6	1,05	7,3	No
0,7	0,74	7,1	No
0,8	0,47	6,9	No

**Table F.8 – Typical examples of reinsertion voltages for systems
having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 50$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,6	Yes
0,3	2,20	6,4	Yes
0,4	1,98	7,8	No
0,5	1,53	7,5	No
0,6	1,15	7,3	No
0,7	0,81	7,1	No
0,8	0,51	6,9	No

**Table F.9 – Typical examples of reinsertion voltages for systems not having power swing nor emergency overload,
 $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,26	7,2	No
0,3	1,00	6,8	No
0,4	0,79	6,5	No
0,5	0,61	6,3	No
0,6	0,46	6,1	No
0,7	0,32	5,9	No
0,8	0,20	5,7	No

**Table F.10 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,51	7,2	No
0,3	1,20	6,8	No
0,4	0,95	6,5	No
0,5	0,74	6,3	No
0,6	0,55	6,1	No
0,7	0,39	5,9	No
0,8	0,25	5,7	No

**Table F.11 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	1,76	7,2	No
0,3	1,40	6,8	No
0,4	1,11	6,5	No
0,5	0,86	6,3	No
0,6	0,64	6,1	No
0,7	0,45	5,9	No
0,8	0,29	5,7	No

**Table F.12 – Typical examples of reinsertion voltages for systems not having power swing but with an emergency overload,
 $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz**

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,01	7,2	No
0,3	1,60	6,8	No
0,4	1,27	6,5	No
0,5	0,98	6,3	No
0,6	0,73	6,1	No
0,7	0,52	5,9	No
0,8	0,33	5,7	No

Table F.13 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	6,5	Yes
0,3	1,80	6,8	No
0,4	1,43	6,5	No
0,5	1,10	6,3	No
0,6	0,83	6,1	No
0,7	0,58	5,9	No
0,8	0,37	5,7	No

Table F.14 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	5,6	Yes
0,3	2,01	6,8	No
0,4	1,58	6,5	No
0,5	1,23	6,3	No
0,6	0,91	6,1	No
0,7	0,65	5,9	No
0,8	0,41	5,7	No

Table F.15 – Typical examples of reinsertion voltages for systems having power swing, $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	4,9	Yes
0,3	2,20	6,0	Yes
0,4	1,82	6,5	No
0,5	1,41	6,3	No
0,6	1,05	6,1	No
0,7	0,74	5,9	No
0,8	0,47	5,7	No

Table F.16 – Typical examples of reinsertion recovery voltages for systems having power swing, $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ and $f = 60$ Hz

Compensation factor k	Reinsertion voltage, first peak p.u.	Time to the first peak ms	Non-linear device conduction at first voltage peak
0,2	2,20	4,6	Yes
0,3	2,20	5,4	Yes
0,4	1,98	6,5	No
0,5	1,53	6,3	No
0,6	1,15	6,1	No
0,7	0,81	5,9	No
0,8	0,51	5,7	No

Based on these values, the following conclusion can be given:

- For series capacitor schemes having a low compensation factor ($k \leq 0,3$), the first reinsertion voltage peak across the by-pass switch is significant and can reach the varistor protective level (U_{PL}) for typical emergency overload or power swing ranges given in IEC 60143-1. The first voltage peak can be attained in relatively short time after current zero (less than $\frac{1}{2}$ of the power-frequency period).
- For series capacitor schemes having a relatively high compensation factor ($k > 0,3$), the first reinsertion voltage peak across the by-pass switch is lower and cannot reach the varistor protective level (U_{PL}) for typical emergency overload or power swing ranges given in IEC 60143-1. Nevertheless, for such schemes, the varistor protective level (U_{PL}) is reached on the following reinsertion voltage loops and the by-pass switch should be designed to withstand the varistor protective level.

Figures F.1 and F.2 give examples of typical recovery voltage waveshapes.

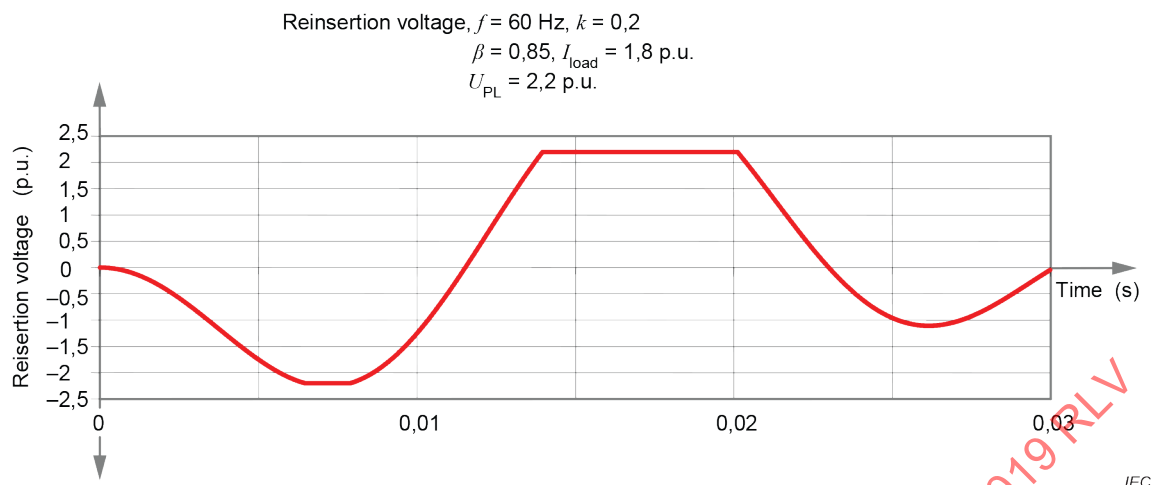


Figure F.1 – Typical example of the reinsertion voltage across a by-switch for a low compensation factor scheme ($k = 0,2$) and for a power swing of 1,8 p.u.

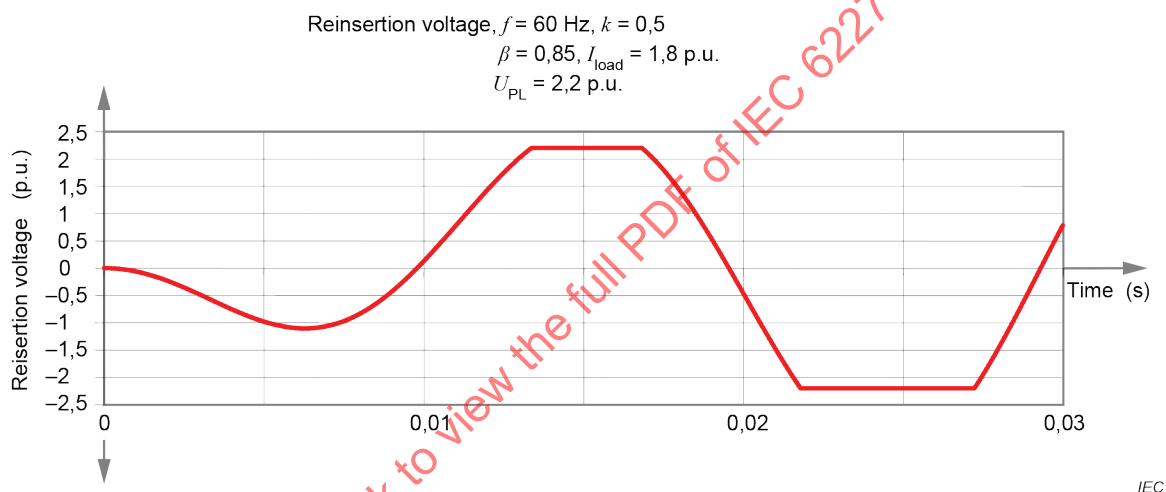


Figure F.2 – Typical example of the reinsertion voltage across a by-switch for a high compensation factor scheme ($k = 0,5$) and for a power swing of 1,8 p.u.

The cases shown in Tables F.1 to F.16 have been compiled in Figures F.3 and F.4, for 50 Hz and 60 Hz system frequencies, respectively. Different reinsertion voltage envelopes have been superimposed.

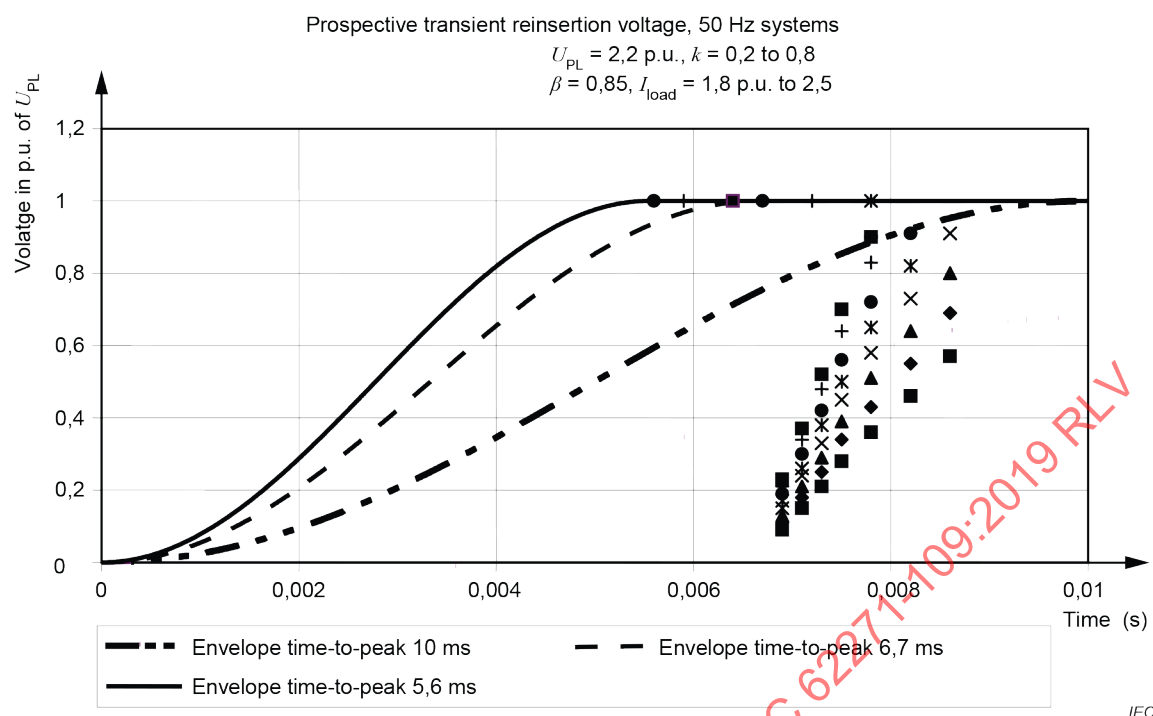


Figure F.3 – Comparison of the calculated reinsertion voltage examples and possible testing envelopes for 50 Hz systems

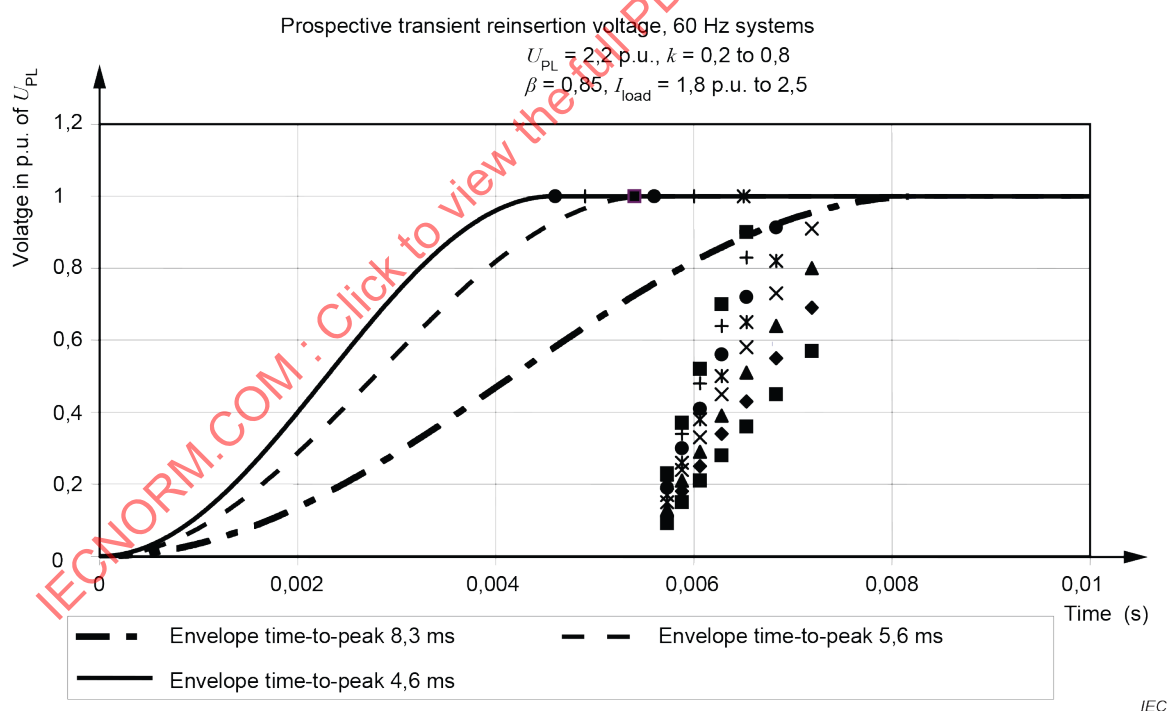


Figure F.4 – Comparison of the calculated reinsertion voltage examples and possible testing envelopes for 60 Hz systems

Based on the data shown in Figures F.3 and F.4, the following conclusions can be given:

- with the preferred reinsertion voltage first time-to-peak of 5,6 ms given in 5.104, 100 % of the computed examples will be covered for 50 Hz systems;
- with a reinsertion voltage first time-to-peak of 6,7 ms, 95 % of the computed examples will be covered for 50 Hz systems;

- with a reinsertion voltage first time-to-peak of 10 ms, 88 % of the computed examples will be covered for 50 Hz systems;
- with the preferred reinsertion voltage first time-to-peak of 5,6 ms given in 5.104, 95 % of the computed examples will be covered for 60 Hz systems;
- with a reinsertion voltage first time-to-peak of 4,6 ms, 100 % of the computed examples will be covered for 60 Hz systems;
- with a reinsertion voltage first time-to-peak of 8,3 ms, 89 % of the computed examples will be covered for 60 Hz systems.

Based on these results, the preferred first-time-to-peak value (5,6 ms) given in 5.104 will cover most of the practical cases for 50 Hz and 60 Hz and may be used as a uniform value for standardization purposes and for limiting the number of type tests required to a minimum. Nevertheless, this value may be too restrictive for certain schemes (e.g. high compensation factors $k > 0,3$ or low emergency current or low power swing) and higher first-time-to-peak values may be specified in order to get a more economical solution regarding the by-pass switch reinsertion capabilities.

If a different value than the preferred first time-to-peak value of the reinsertion voltage is specified, it should be supported by detailed system studies and the study should consider emergency overloads and power swings as well as the actual value of the varistor protective level associated with the load currents during emergency overloads and power swings.

Annex G (normative)

Use of mechanical characteristics and related requirements

At the beginning of the type tests, the mechanical characteristics of the by-pass switch shall be established, for example, by recording no-load travel curves and by defining additional characteristic parameters, such as, if applicable, momentary speed at a certain stroke, closing and opening times, damping time, etc. An example of such a no-load travel curve is given in Figure G.1. The tolerances applicable to these additional parameters shall also be defined and declared by the manufacturer. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behavior of the circuit-breaker.

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

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

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

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

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

The series of Figures G.1 to G.4 are for illustrative purposes and only illustrate the opening operation. They are idealised and do not show the variation in profile caused by the friction effect of the contacts or the end of travel damping. In particular, it is important to note that the effects of damping are not shown in these diagrams. The oscillations produced at the end of travel are dependent upon the efficiency of the damping of the drive system. The shape of these oscillations may be a deliberate function of the design and may slightly vary from one specimen to another. Therefore, it is important that any variations in the curve at the end of the stroke, which are outside the tolerance margin given by the envelope, are fully explained and understood before they are rejected or accepted as showing equivalence with the reference curves. In general, all curves should fall within the envelopes for acceptance.

The travel characteristics of all production units shall lie within the 10 % total allowable tolerance around the reference travel characteristic. The reference travel characteristic may lie at any point within the defined tolerance band but the parameters of the 10 % tolerance

and, once defined, shall remain unchanged. Figures G.3 and G.4 show the two extremes of the allowable cases which are -0% , $+10\%$ and -10% , $+0\%$ respectively.

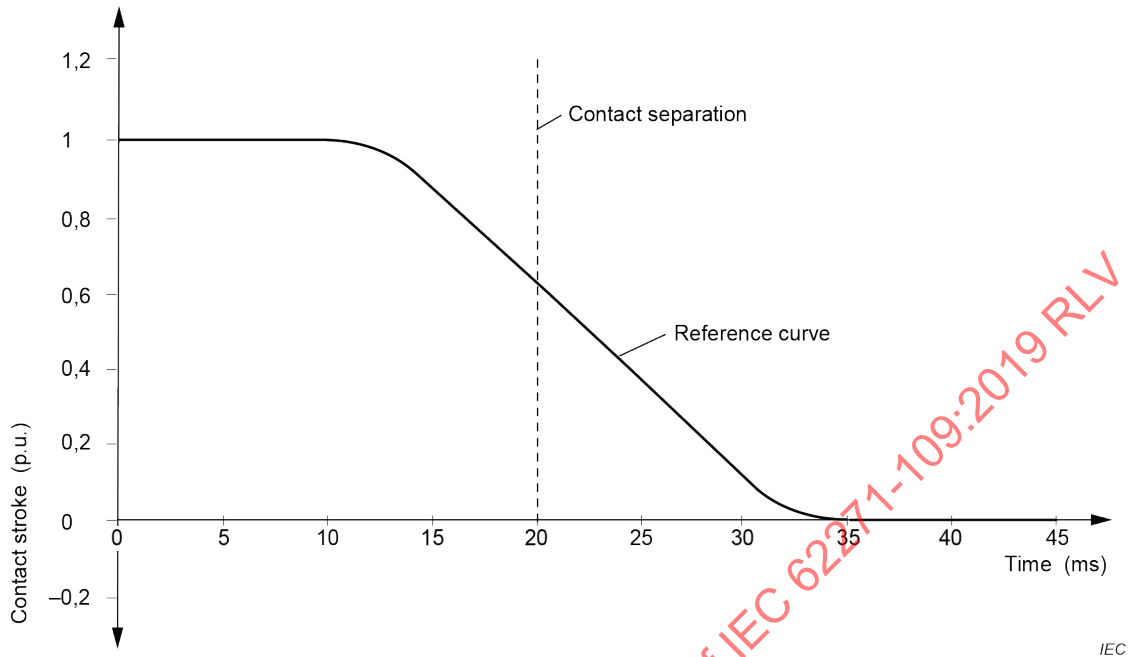


Figure G.1 – Reference mechanical travel characteristics (idealized curve)

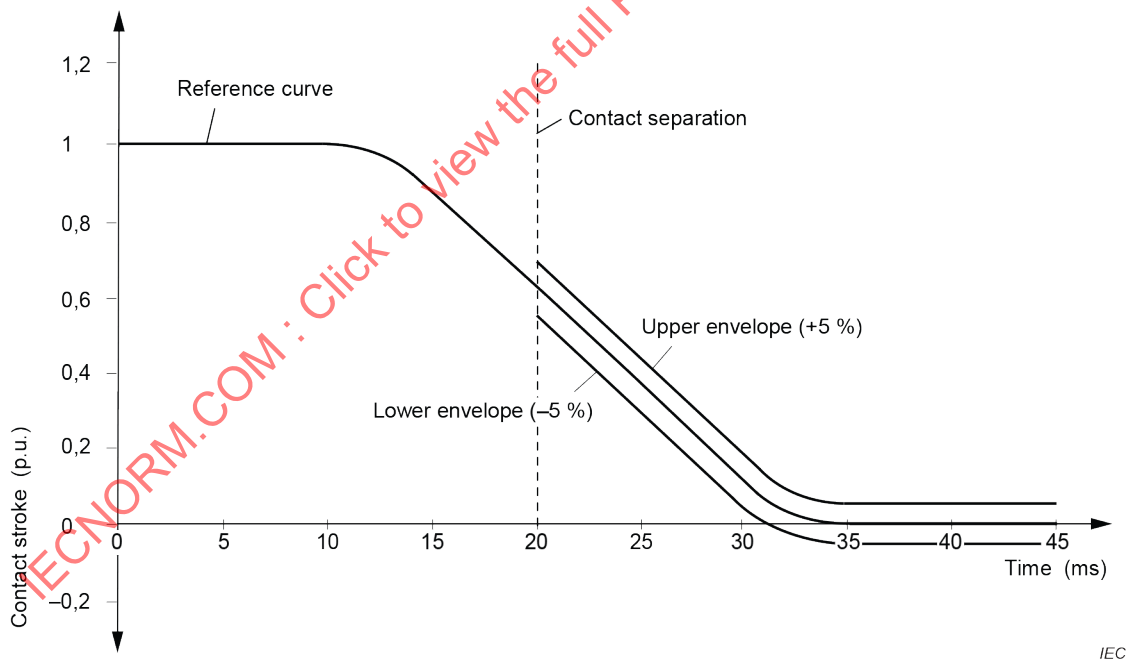


Figure G.2 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes centered over the reference curve ($\pm 5\%$), contact separation in this example at time $t = 20$ ms

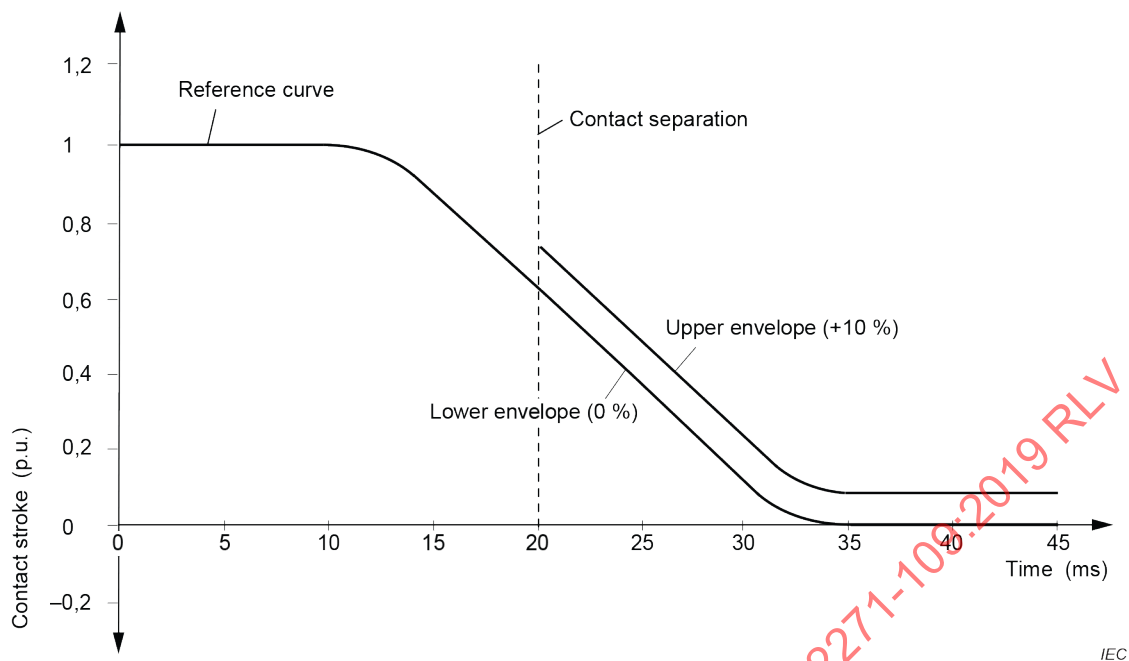


Figure G.3 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced upward from the reference curve ($+10\%$), contact separation in this example at time $t = 20$ ms

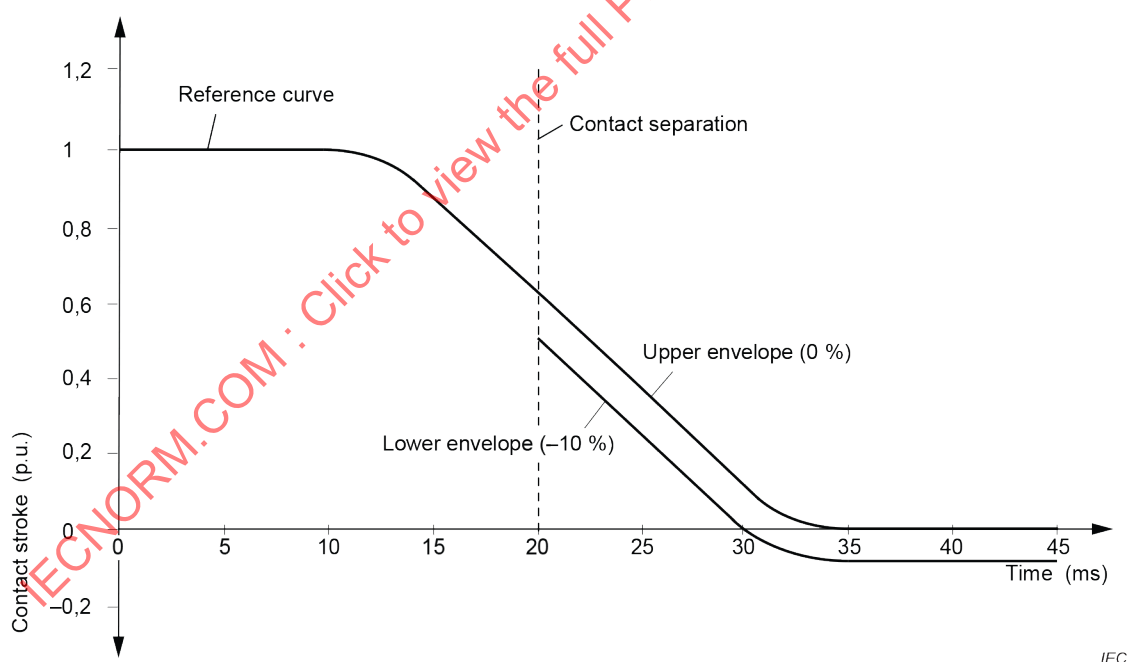


Figure G.4 – Reference mechanical travel characteristics (idealized curve) with the prescribed envelopes fully displaced downward from the reference curve (-10%), contact separation in this example at time $t = 20$ ms

Bibliography

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2, *Insulation co-ordination – Part 2: Application guidelines*

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

IEC 62271-203, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC TR 62271-300, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

IEC TR 62271-306, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

ISO/IEC Guide 98-1:2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

CIGRE Technical Brochure 163/2000, *Guide for SF₆ gas mixtures*

IECNORM.COM : Click to view the full PDF of IEC 62271-109:2019 RLV

SOMMAIRE

AVANT-PROPOS	143
1 Domaine d'application	145
2 Références normatives	145
3 Termes et définitions	146
3.1 Termes et définitions généraux	146
3.2 Ensembles	149
3.3 Parties d'ensembles	149
3.4 Appareils de connexion	149
3.5 Parties de l'interrupteur de contournement	151
3.6 Caractéristiques de fonctionnement des interrupteurs de contournement	155
3.7 Grandeurs caractéristiques	157
3.8 Termes et définitions en rapport avec les batteries de condensateurs série	166
3.9 Index des définitions	169
4 Conditions normales et spéciales de service	173
5 Caractéristiques assignées	173
5.1 Généralités	173
5.2 Tension assignée (U_r)	173
5.2.1 Généralités	173
5.2.2 Plage I pour les tensions assignées inférieures ou égales à 245 kV	174
5.2.3 Plage II pour les tensions assignées supérieures à 245 kV	174
5.3 Niveau d'isolement assigné (U_p, U_d, U_s)	174
5.3.101 Niveau d'isolement assigné par rapport à la terre (U_{pe}, U_{de}, U_{se})	174
5.3.102 Niveau d'isolement assigné entre les bornes de l'interrupteur de contournement (U_{pp}, U_{dp}, U_{sp})	174
5.4 Fréquence assignée (f_r)	174
5.5 Courant permanent assigné (I_r)	175
5.6 Courant de courte durée admissible assigné (I_k)	175
5.7 Valeur de crête du courant admissible assigné (I_p)	175
5.8 Durée de court-circuit assignée (t_k)	175
5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)	175
5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande	175
5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue	175
5.101 Séquence de manœuvres assignée	175
5.102 Courant assigné de contournement (I_{BP})	176
5.103 Courant assigné d'insertion (dans le circuit de contournement, I_{INS})	176
5.104 Tension assignée de réinsertion (U_{INS})	177
5.105 Nombre de manœuvres mécaniques	177
6 Conception et construction	177
6.1 Exigences pour les liquides utilisés dans les interrupteurs de contournement	177
6.2 Exigences pour les gaz utilisés dans les interrupteurs de contournement	177
6.3 Raccordement à la terre des interrupteurs de contournement	177
6.4 Équipements et circuits auxiliaires et de commande	178
6.4.1 Généralités	178
6.4.2 Protection contre les chocs électriques	178

6.4.3	Composants installés dans les enveloppes	178
6.5	Manœuvre dépendante à source d'énergie extérieure	179
6.6	Manœuvre à accumulation d'énergie	179
6.7	Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)	179
6.8	Organes de commande à manœuvre manuelle	179
6.9	Fonctionnement des déclencheurs	179
6.9.1	Généralités	179
6.9.2	Déclencheurs shunt de fermeture	179
6.9.3	Déclencheurs shunt d'ouverture	180
6.9.4	Fonctionnement des déclencheurs shunt à l'aide de condensateurs	180
6.9.5	Déclencheur à minimum de tension	180
6.9.101	Déclencheurs multiples	180
6.9.102	Limites de fonctionnement des déclencheurs	180
6.9.103	Puissance consommée par les déclencheurs	180
6.10	Indication de la pression / du niveau	180
6.10.101	Verrouillages à basse et à haute pression	180
6.11	Plaques signalétiques	180
6.12	Dispositifs de verrouillage	182
6.13	Indicateur de position	182
6.14	Degrés de protection procurés par les enveloppes	182
6.15	Lignes de fuite pour les isolateurs d'extérieur	182
6.16	Étanchéité au gaz et au vide	182
6.17	Étanchéité des systèmes de liquide	182
6.18	Risque de feu (inflammabilité)	182
6.19	Compatibilité électromagnétique (CEM)	182
6.20	Émission de rayons X	182
6.21	Corrosion	183
6.22	Niveaux de remplissage pour l'isolement, le contournement, l'insertion et/ou la manœuvre	183
6.101	Exigences de simultanéité au sein d'un pôle	183
6.102	Exigence générale de fonctionnement	183
6.103	Limites de pression des fluides pour la manœuvre	183
6.104	Orifices d'évacuation	184
6.105	Durées	184
6.106	Charges mécaniques statiques	184
7	Essais de type	185
7.1	Généralités	185
7.1.1	Principes fondamentaux	185
7.1.2	Informations pour l'identification des objets d'essai	186
7.1.3	Informations à inclure dans les rapports d'essais de type	186
7.1.101	Essais non valables	186
7.1.102	Répétition des essais de type pour les interrupteurs de contournement avec des mécanismes d'entraînement alternatifs	187
7.2	Essais diélectriques	187
7.2.1	Généralités	187
7.2.2	Conditions de l'air ambiant pendant les essais	187
7.2.3	Modalités des essais sous pluie	187
7.2.4	Disposition de l'appareil	187

7.2.5	Conditions de réussite des essais	188
7.2.6	Application de la tension d'essai et conditions d'essai	188
7.2.7	Essais des interrupteurs de contournement avec $U_{re} \leq 245$ kV ou $U_{rp} \leq 245$ kV	188
7.2.8	Essais des interrupteurs de contournement avec $U_{re} > 245$ kV ou $U_{rp} > 245$ kV	189
7.2.9	Essais de pollution artificielle pour les isolateurs d'extérieur	189
7.2.10	Essais de décharges partielles	190
7.2.11	Essais diélectriques sur les circuits auxiliaires et de commande	190
7.2.12	Essai de tension comme essai de vérification d'état	190
7.3	Essais de tension de perturbation radioélectrique	191
7.4	Mesurage de la résistance	192
7.5	Essais au courant permanent	193
7.5.1	État de l'objet d'essai	193
7.5.2	Disposition de l'appareil	193
7.5.3	Valeurs du courant d'essai et de sa durée	193
7.5.4	Mesurage de la température pendant l'essai	193
7.5.5	Résistance du circuit principal	193
7.5.6	Conditions de réussite des essais	193
7.6	Essais au courant de courte durée admissible et à la valeur de crête du courant admissible	193
7.6.1	Généralités	193
7.6.2	Disposition de l'interrupteur de contournement et du circuit d'essai	193
7.6.3	Valeurs du courant d'essai et de sa durée	193
7.6.4	État de l'interrupteur de contournement après l'essai	193
7.7	Vérification de la protection	193
7.7.1	Vérification de la codification IP	193
7.7.2	Vérification de la codification IK	193
7.8	Essais d'étanchéité	193
7.9	Essais de compatibilité électromagnétique (CEM)	194
7.9.1	Essais d'émission	194
7.9.2	Essais d'immunité sur les circuits auxiliaires et de commande	194
7.9.3	Essais de CEM complémentaires sur les circuits auxiliaires et de commande	194
7.10	Essais complémentaires sur les circuits auxiliaires et de commande	195
7.10.1	Généralités	195
7.10.2	Essais fonctionnels	195
7.10.3	Vérification des caractéristiques de fonctionnement des contacts auxiliaires	195
7.10.4	Essais d'environnement	195
7.10.5	Essais diélectriques	195
7.11	Essai des rayonnements X pour les ampoules à vide	195
7.101	Essais mécaniques et climatiques	195
7.101.1	Dispositions diverses pour les essais mécaniques et climatiques	195
7.101.2	Essai de fonctionnement mécanique à la température de l'air ambiant	198
7.101.3	Essais à haute et à basse températures	200
7.101.4	Essai à l'humidité	206
7.101.5	Essai pour vérifier le fonctionnement dans des conditions sévères de formation de glace	206
7.102	Dispositions diverses pour les essais de contournement et d'insertion	206

7.102.1	Généralités	206
7.102.2	Nombre de spécimens d'essai	207
7.102.3	Disposition de l'interrupteur de contournement pour les essais	207
7.102.4	Considérations générales concernant les méthodes d'essai	209
7.102.5	Essais synthétiques	212
7.102.6	Manœuvres à vide avant les essais	212
7.102.7	Mécanismes d'entraînement alternatifs	212
7.102.8	Comportement de l'interrupteur de contournement pendant les essais	213
7.102.9	État de l'interrupteur de contournement après les essais	214
7.103	Séquence d'essai d'établissement du courant de contournement et séquence d'essai de courant d'insertion, séquence des essais	215
7.103.1	Généralités	215
7.103.2	Séquence d'essai d'établissement du courant de contournement	216
7.103.3	Séquence d'essai de courant d'insertion	219
7.103.4	Critères de réussite des séquences d'essais	228
8	Essais individuels de série	228
8.1	Généralités	228
8.2	Essai diélectrique du circuit principal	228
8.3	Essais des circuits auxiliaires et de commande	230
8.3.1	Inspection des circuits auxiliaires et de commande, et vérification de la conformité aux schémas de circuits et schémas de câblage	230
8.3.2	Essais fonctionnels	230
8.3.3	Vérification de la protection contre les chocs électriques	230
8.3.4	Essais diélectriques	230
8.4	Mesurage de la résistance du circuit principal	231
8.5	Essai d'étanchéité	231
8.5.1	Généralités	231
8.5.2	Systèmes à pression entretenue de gaz	231
8.5.3	Systèmes à pression autonome de gaz	231
8.5.4	Systèmes à pression scellés	231
8.5.5	Essais d'étanchéité aux liquides	231
8.6	Contrôles visuels et de conception	231
8.101	Essais de fonctionnement mécanique	231
9	Guide pour le choix des interrupteurs de contournement (informative)	234
10	Renseignements à donner dans les appels d'offres, les soumissions et les commandes (informative)	234
10.1	Généralités	234
10.2	Renseignements dans les appels d'offres et les commandes	234
10.3	Renseignements pour les soumissions	235
11	Transport, stockage, installation, instructions de fonctionnement et maintenance	237
11.1	Généralités	237
11.2	Conditions à respecter pendant le transport, le stockage et l'installation	237
11.3	Installation	237
11.4	Instructions de fonctionnement	237
11.5	Maintenance	237
11.101	Guide pour les essais de mise en service	238
11.101.1	Généralités	238
11.101.2	Programme d'essai et de vérification de mise en service	238
11.101.3	Résistances et condensateurs (s'il y a lieu)	244

12	Sécurité.....	244
12.1	Généralités	244
12.2	Précautions devant être prises par les constructeurs	244
12.3	Précautions devant être prises par les utilisateurs	244
13	Influence du produit sur l'environnement	244
	Annexe A (normative) Tolérances sur les paramètres d'essais lors des essais de type	245
	Annexe B (normative) Enregistrements et rapports d'essais de type	249
B.1	Renseignements et résultats à enregistrer	249
B.2	Informations à inclure dans les rapports d'essais de type	249
B.2.1	Généralités	249
B.2.2	Appareil soumis aux essais	249
B.2.3	Caractéristiques assignées de l'interrupteur de contournement, incluant celles des mécanismes d'entraînement et des équipements auxiliaires	249
B.2.4	Conditions d'essai (pour chaque série d'essais; s'il y a lieu)	250
B.2.5	Essai au courant de courte durée admissible et à la valeur de crête du courant admissible	250
B.2.6	Manœuvre à vide	250
B.2.7	Séquence d'essai d'établissement du courant de contournement	250
B.2.8	Séquence d'essai de courant d'insertion	250
B.2.9	Relevés oscillographiques et autres enregistrements	251
	Annexe C (informative) (Vide)	252
	Annexe D (informative) Exemples de caractéristiques assignées d'un interrupteur de contournement	253
	Annexe E (normative) Interrupteurs de contournement utilisés comme dispositifs de contournement primaires	260
	Annexe F (informative) Note explicative concernant la tension de rétablissement pendant la réinsertion	262
	Annexe G (normative) Utilisation de caractéristiques mécaniques et exigences associées	272
	Bibliographie	276
	Figure 1 – Différentes configurations de batteries de condensateurs série	150
	Figure 2 – Interrupteur de contournement – Manœuvres d'ouverture et de fermeture	158
	Figure 3 – Interrupteur de contournement – Cycle de fermeture-ouverture	159
	Figure 4 – Interrupteur de contournement – Cycle d'ouverture-fermeture	160
	Figure 5 – Exemple de mesurage de la vitesse du vent	202
	Figure 6 – Séquences d'essais pour les essais à basse et à haute températures	203
	Figure 7 – Montage d'essai équivalent pour les essais sur éléments séparés des interrupteurs de contournement ayant plusieurs éléments de contournement séparés	210
	Figure 8 – Circuit d'essai typique pour une séquence d'essai d'établissement du courant de contournement	217
	Figure 9 – Oscillogramme obtenu avec le circuit d'essai typique pour une séquence d'essai d'établissement du courant de contournement	218
	Figure 10 – Circuit d'essai LC typique pour la séquence d'essai de courant d'insertion	221
	Figure 11 – Oscillogramme obtenu avec le circuit d'essai LC typique pour la séquence d'essai de courant d'insertion	222
	Figure 12 – Circuit d'essai typique pour la séquence d'essai de courant d'insertion (principalement pour un courant d'insertion assigné élevé)	223

Figure 13 – Oscillogramme obtenu avec le circuit d'essai typique représenté à la Figure 12 pour la séquence d'essai de courant d'insertion	224
Figure 14 – Circuit d'essai direct typique pour la séquence d'essai de courant d'insertion	225
Figure 15 – Oscillogramme obtenu avec le circuit d'essai direct typique pour la séquence d'essai de courant d'insertion	226
Figure 16 – Caractéristiques de déplacement mécanique de référence (courbe idéalisée)	233
Figure E.1 – Implantation type des composants pour les interrupteurs de contournement utilisés comme dispositifs de contournement primaires	260
Figure F.1 – Exemple typique de tension de réinsertion entre les bornes d'un interrupteur de contournement pour une installation à faible facteur de compensation ($k = 0,2$) et pour une oscillation de puissance de 1,8 p.u.	269
Figure F.2 – Exemple typique de tension de réinsertion entre les bornes d'un interrupteur de contournement pour une installation à facteur de compensation élevé ($k = 0,5$) et pour une oscillation de puissance de 1,8 p.u.	269
Figure F.3 – Comparaison des exemples de tensions de réinsertion calculées et enveloppes d'essais possibles pour les réseaux à 50 Hz	270
Figure F.4 – Comparaison des exemples de tensions de réinsertion calculées et enveloppes d'essais possibles pour les réseaux à 60 Hz	270
Figure G.1 – Caractéristiques de déplacement mécanique de référence (courbe idéalisée)	273
Figure G.2 – Caractéristiques de déplacement mécanique de référence (courbe idéalisée) avec les enveloppes exigées centrées autour de la courbe de référence ($\pm 5\%$), dans cet exemple la séparation des contacts a lieu à $t = 20$ ms	274
Figure G.3 – Caractéristiques de déplacement mécanique de référence (courbe idéalisée) avec les enveloppes exigées déplacées totalement vers le haut par rapport à la courbe de référence ($+10\%$), dans cet exemple la séparation des contacts a lieu à $t = 20$ ms	274
Figure G.4 – Caractéristiques de déplacement mécanique de référence (courbe idéalisée) avec les enveloppes exigées déplacées totalement vers le bas par rapport à la courbe de référence (-10%), dans cet exemple, la séparation des contacts a lieu à $t = 20$ ms	275
Tableau 1 – Nombre de manœuvres mécaniques	177
Tableau 2 – Informations sur la plaque signalétique	181
Tableau 3 – Exemples d'efforts statiques horizontaux et verticaux pour l'essai avec des efforts statiques aux bornes	185
Tableau 4 – Essais de type	186
Tableau 5 – Essais non valables	187
Tableau 6 – Nombre de séquences de manœuvres	199
Tableau 7 – Limites de tensions d'alimentation des déclencheurs d'ouverture et de fermeture	208
Tableau 8 – Procédures d'essai pour les essais d'établissement du courant de contournement	219
Tableau 9 – Application de la tension lors des essais diélectriques du circuit principal	229
Tableau 10 – Tension d'essai pour l'essai de décharge partielle	230
Tableau A.1 – Tolérances sur les paramètres d'essais lors des essais de type (1 de 3)	246

Tableau D.1 – Caractéristiques typiques d'un interrupteur de contournement pour batterie de condensateurs série – Cas 1 à 6	254
Tableau D.2 – Caractéristiques typiques d'un interrupteur de contournement pour batterie de condensateurs série – Cas 7 à 12	256
Tableau D.3 – Caractéristiques typiques d'un interrupteur de contournement pour batterie de condensateurs série – Cas 13 à 18	258
Tableau F.1 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance ni surcharge d'urgence $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	263
Tableau F.2 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	263
Tableau F.3 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	264
Tableau F.4 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	264
Tableau F.5 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	264
Tableau F.6 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	265
Tableau F.7 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	265
Tableau F.8 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 50$ Hz	265
Tableau F.9 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance ni surcharge d'urgence $I_{load} = 1,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	266
Tableau F.10 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,2$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	266
Tableau F.11 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,4$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	266
Tableau F.12 – Exemples typiques de tensions de réinsertion pour des réseaux sans oscillation de puissance, mais avec une surcharge d'urgence $I_{load} = 1,6$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	267
Tableau F.13 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 1,8$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	267
Tableau F.14 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,0$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	267
Tableau F.15 – Exemples typiques de tensions de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,3$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	268
Tableau F.16 – Exemples typiques de tensions de rétablissement de réinsertion pour des réseaux avec oscillation de puissance $I_{load} = 2,5$ p.u.; $U_{PL} = 2,2$ p.u.; $\beta = 0,85$ et $f = 60$ Hz	268

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPAREILLAGE À HAUTE TENSION –

**Partie 109: Interrupteurs de contournement
pour condensateurs série à courant alternatif**

AVANT-PROPOS

- 1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. À cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
- 2) Les décisions ou accords officiels de l'IEC concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux de l'IEC intéressés sont représentés dans chaque comité d'études.
- 3) Les Publications de l'IEC se présentent sous la forme de recommandations internationales et sont agréées comme telles par les Comités nationaux de l'IEC. Tous les efforts raisonnables sont entrepris afin que l'IEC s'assure de l'exactitude du contenu technique de ses publications; l'IEC ne peut pas être tenue responsable de l'éventuelle mauvaise utilisation ou interprétation qui en est faite par un quelconque utilisateur final.
- 4) Dans le but d'encourager l'uniformité internationale, les Comités nationaux de l'IEC s'engagent, dans toute la mesure possible, à appliquer de façon transparente les Publications de l'IEC dans leurs publications nationales et régionales. Toutes divergences entre toutes Publications de l'IEC et toutes publications nationales ou régionales correspondantes doivent être indiquées en termes clairs dans ces dernières.
- 5) L'IEC elle-même ne fournit aucune attestation de conformité. Des organismes de certification indépendants fournissent des services d'évaluation de conformité et, dans certains secteurs, accèdent aux marques de conformité de l'IEC. L'IEC n'est responsable d'aucun des services effectués par les organismes de certification indépendants.
- 6) Tous les utilisateurs doivent s'assurer qu'ils sont en possession de la dernière édition de cette publication.
- 7) Aucune responsabilité ne doit être imputée à l'IEC, à ses administrateurs, employés, auxiliaires ou mandataires, y compris ses experts particuliers et les membres de ses comités d'études et des Comités nationaux de l'IEC, pour tout préjudice causé en cas de dommages corporels et matériels, ou de tout autre dommage de quelque nature que ce soit, directe ou indirecte, ou pour supporter les coûts (y compris les frais de justice) et les dépenses découlant de la publication ou de l'utilisation de cette Publication de l'IEC ou de toute autre Publication de l'IEC, ou au crédit qui lui est accordé.
- 8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
- 9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 62271-109 a été établie par le sous-comité 17A: Appareils de connexion, du comité d'études 17 de l'IEC: Appareillage haute tension.

Cette troisième édition annule et remplace la deuxième édition parue en 2008 et son Amendement 1:2013. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) le document a été remanié selon l'édition 2.0 de l'IEC 62271-1;
- b) l'assignation de tensions assignées aux bornes de l'interrupteur de contournement a été alignée sur la règle définie dans l'IEC 60143-1;

- c) des précisions ont été apportées au sujet du courant permanent assigné de la ligne compensée et de la ligne non compensée;
- d) des clarifications ont été apportées suivant une perte des "précautions appropriées";
- e) conformément à l'Amendement 2 de l'IEC 62271-100, la section "Durées assignées" a été déplacée à l'Article 6 sous "Durées";
- f) conformément à l'Amendement 2 de l'IEC 62271-100, la section "Essai des charges mécaniques statiques" a été déplacée à l'Article 6 sous "Charges mécaniques statiques";
- g) des règles supplémentaires ont été introduites pour les ampoules à vide pendant les essais de chocs;
- h) des clarifications supplémentaires ont été apportées au sujet du nombre de chocs réduits pendant les essais de chocs;
- i) une tolérance plus grande pour l'amortissement du courant pendant la séquence d'essai d'établissement du courant de contournement a été introduite.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
17A/1208/FDIS	17A/1215/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 62271, publiées sous le titre général *Appareillage à haute tension*, peut être consultée sur le site web de l'IEC.

Cette norme doit être lue conjointement avec l'IEC 62271-100:2008 et son Amendement 1:2012 et Amendement 2:2017, ainsi qu'avec l'IEC 62271-1:2017, à laquelle elle fait référence et qui est applicable sauf spécification contraire dans la présente norme. Pour faciliter le repérage des exigences correspondantes, cette norme utilise une numérotation identique des articles et des paragraphes à celle de l'IEC 62271-1:2017. Les modifications de ces articles et de ces paragraphes ont des références identiques; les paragraphes supplémentaires qui n'ont pas d'équivalent dans l'IEC 62271-1, sont numérotés à partir de 101.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

APPAREILLAGE À HAUTE TENSION –

Partie 109: Interrupteurs de contournement pour condensateurs série à courant alternatif

1 Domaine d'application

La présente partie de l'IEC 62271 est applicable aux interrupteurs de contournement pour condensateurs série à courant alternatif conçus pour l'installation à l'extérieur et pour fonctionner à des fréquences de 50 Hz et 60 Hz, sur des réseaux de tensions supérieures à 52 kV.

Elle s'applique uniquement aux interrupteurs de contournement destinés à être utilisés dans les systèmes triphasés.

Le présent document est également applicable aux dispositifs de commande des interrupteurs de contournement et à leurs équipements auxiliaires.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-151:2001, *Vocabulaire Electrotechnique International – Partie 151: Dispositifs électriques et magnétiques*

IEC 60050-436:1990, *Vocabulaire Electrotechnique International – Chapitre 436: Condensateurs de puissance*

IEC 60050-441:1984, *Vocabulaire Electrotechnique International – Chapitre 441: Appareillage et fusibles*

IEC 60050-614:2016, *Vocabulaire Electrotechnique International – Chapitre 614: Production, transport et distribution de l'énergie électrique – Exploitation*

IEC 60060 (toutes les parties), *Techniques des essais à haute tension*

IEC 60137:2017, *Traversées isolées pour tensions alternatives supérieures à 1 000 V*

IEC 60143-1:2015, *Condensateurs série destinés à être installés sur des réseaux – Partie 1: Généralités*

IEC 60143-2:2012, *Condensateurs série destinés à être installés sur des réseaux – Partie 2: Matériel de protection pour les batteries de condensateurs série*

IEC 60270, *Techniques des essais à haute tension – Mesures des décharges partielles*

IEC 60376, *Spécification de la qualité technique de l'hexafluorure de soufre (SF₆) et des gaz complémentaires à employer dans les mélanges de SF₆ pour utilisation dans les matériels électriques*

IEC 60480, *Lignes directrices relatives au contrôle et au traitement de l'hexafluorure de soufre (SF₆) prélevé sur le matériel électrique et spécification en vue de sa réutilisation*

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-4, *Appareillage à haute tension – Partie 4: Utilisation et manipulation de l'hexafluorure de soufre (SF₆) et des mélanges contenant du SF₆*

IEC 62271-100:2008, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif*

IEC 62271-100:2008/AMD1:2012

IEC 62271-100:2008/AMD2:2017

IEC 62271-101, *Appareillage à haute tension – Partie 101: Essais synthétiques*

IEC 62271-102:2018, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-151, de l'IEC 60050-436, de l'IEC 60050-441, de l'IEC 60050-614, de l'IEC 60143-1, de l'IEC 60143-2 et de l'IEC 62271-1 s'appliquent. Pour faciliter l'utilisation de la norme, certains d'entre eux ont été rappelés ci-après.

Des termes et définitions additionnels sont classés de façon à être alignés sur la classification utilisée dans l'IEC 60050-441.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.1 Termes et définitions généraux

3.1.101

appareillage

terme général applicable aux appareils de connexion et à leur combinaison avec des appareils de commande, de mesure, de protection et de réglage qui leur sont associés, ainsi qu'aux ensembles de tels appareils avec les connexions, les accessoires, les enveloppes et les charpentes correspondantes

[SOURCE: IEC 60050-441:2000, 441-11-01]

3.1.102

appareillage pour l'extérieur

appareillage convenant pour l'installation en plein air, c'est-à-dire capable de supporter le vent, la pluie, la neige, les pollutions, la condensation, la glace et le givre

[SOURCE: IEC 60050-441:2000, 441-11-05]

3.1.103**courant de court-circuit**

surintensité résultant d'un court-circuit dû à un défaut ou à un branchement incorrect dans un circuit électrique

[SOURCE: IEC 60050-441:2000, 441-11-07]

3.1.104**température de l'air ambiant**

température déterminée dans des conditions prescrites de l'air qui entoure la totalité de l'appareil de connexion ou du fusible

Note 1 à l'article: Pour des appareils de connexion ou des fusibles installés à l'intérieur d'une enveloppe, c'est la température de l'air à l'extérieur de l'enveloppe.

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.1.105**échauffement**

<d'une partie d'un interrupteur de contournement>

différence entre la température de la partie considérée et la température de l'air ambiant

[SOURCE: IEC 60050-151:2001, 151-16-26, modifié – L'expression "une température de référence" remplacée par "la température de l'air ambiant".]

3.1.106**surtension**

<dans un système électrique>

tension:

- entre un conducteur de phase et la terre ou à travers une isolation longitudinale dont la valeur de crête dépasse la valeur de crête correspondant à la tension la plus élevée du réseau divisée par $\sqrt{3}$

ou;

- entre conducteurs de phase dont la valeur de crête dépasse l'amplitude de la tension la plus élevée du réseau

[SOURCE: IEC 60050-614:2016, 614-03-10]

3.1.107**essai sur élément**

essai effectué sur un élément de contournement ou d'insertion ou sur un groupe d'éléments au courant de contournement établi ou au courant d'insertion, spécifié pour l'essai du pôle complet d'un interrupteur de contournement et à la fraction appropriée de la tension appliquée, ou de la tension de rétablissement, spécifiée pour l'essai du pôle complet de l'interrupteur de contournement

3.1.108**isolation externe**

distances dans l'air atmosphérique et sur les surfaces des isolations solides d'un matériel en contact avec l'air atmosphérique, qui sont soumises aux contraintes diélectriques et à l'influence des conditions atmosphériques ou d'autres conditions environnementales provenant du site

Note 1 à l'article: Des exemples de conditions environnementales sont la pollution, l'humidité, les animaux.

[SOURCE: IEC 60050-614:2016, 614-03-02]

3.1.109

isolation interne

distances internes dans l'isolation solide, liquide ou gazeuse des matériels qui sont à l'abri de l'influence des conditions atmosphériques ou d'autres agents externes

[SOURCE: IEC 60050-614:2016, 614-03-03]

3.1.110

Isolation autorégénératrice

isolation qui retrouve intégralement ses propriétés isolantes en un intervalle de temps court après une décharge disruptive

[SOURCE: IEC 60050-614:2016, 614-03-04]

3.1.111

isolation non autorégénératrice

isolation qui perd ses propriétés isolantes, ou ne les retrouve pas intégralement, après une décharge disruptive

[SOURCE: IEC 60050-614:2016, 614-03-05]

3.1.112

décharge disruptive

phénomène associé à la défaillance de l'isolation en cas de contrainte électrique incluant un effroulement de la tension et le passage de courant

Note 1 à l'article: Le terme s'applique au claquage électrique dans des diélectriques solides, liquides et gazeux et aux combinaisons de ceux-ci.

Note 2 à l'article: Une décharge disruptive dans un diélectrique solide produit une perte permanente de la tenue diélectrique (isolation non autorégénératrice); dans un diélectrique liquide ou gazeux la perte peut être seulement temporaire.

Note 3 à l'article: Le terme "amorçage" est utilisé lorsque la décharge disruptive se produit dans un diélectrique gazeux ou liquide; le terme "contournement" est utilisé lorsque la décharge disruptive longe la surface d'un diélectrique solide entouré d'un gaz ou d'un liquide isolant; le terme "perforation" est utilisé lorsque la décharge disruptive se produit à travers un diélectrique solide.

[SOURCE: IEC 60050-614:2016, 614-03-16, modifié – Note 3 à l'article ajoutée.]

3.1.113

performance en réamorçage

probabilité présumée de réamorçage pendant la séquence d'essai de courant d'insertion, comme démontré par l'essai de type spécifié

Note 1 à l'article: Des probabilités chiffrées spécifiques ne peuvent pas être appliquées durant toute la durée de service de l'interrupteur de contournement.

3.1.114

réallumage

<d'un appareil mécanique de connexion à courant alternatif>

rétablissement du courant entre les contacts d'un appareil mécanique de connexion au cours d'une manœuvre de coupure, l'intervalle de temps durant lequel le courant est resté nul étant inférieur à un quart de la période correspondant à la fréquence industrielle

[SOURCE: IEC 60050-441:2000, 441-17-45]

3.1.115**réamorçage**

<d'un appareil mécanique de connexion à courant alternatif>

rétablissement du courant entre les contacts d'un appareil mécanique de connexion au cours d'une manœuvre de coupure, l'intervalle de temps durant lequel le courant est resté nul étant égal ou supérieur à un quart de la période correspondant à la fréquence industrielle

[SOURCE: IEC 60050-441:2000, 441-17-46]

3.1.116**décharge disruptive non maintenue****NSDD**

décharge disruptive associée à une coupure de courant, qui n'entraîne pas de rétablissement du courant à fréquence industrielle ou, dans le cas d'une insertion, qui n'entraîne pas de courant dans la batterie de condensateurs série

Note 1 à l'article: Les oscillations suivant les décharges disruptives non maintenues sont associées à la capacité et à l'inductance parasites à proximité de l'interrupteur de contournement ou provenant de l'interrupteur de contournement lui-même. Les décharges disruptives non maintenues peuvent également impliquer la capacité parasite par rapport à la terre des appareils situés à proximité.

Note 2 à l'article: L'abréviation "NSDD" est dérivée du terme anglais développé correspondant "non-sustained disruptive discharge".

3.2 Ensembles

Pas de définition particulière.

3.3 Parties d'ensembles

Pas de définition particulière.

3.4 Appareils de connexion**3.4.101****appareil de connexion**

appareil destiné à établir ou à interrompre le courant dans un ou plusieurs circuits électriques

[SOURCE: IEC 60050-441:2000, 441-14-01]

3.4.102**appareil mécanique de connexion**

appareil de connexion destiné à fermer et à ouvrir un ou plusieurs circuits électriques au moyen de contacts séparables

Note 1 à l'article: Tout appareil mécanique de connexion peut être désigné en fonction du milieu dans lequel ses contacts s'ouvrent et se ferment, par exemple: air, SF₆, huile.

[SOURCE: IEC 60050-441:2000, 441-14-02]

3.4.103**interrupteur de contournement**

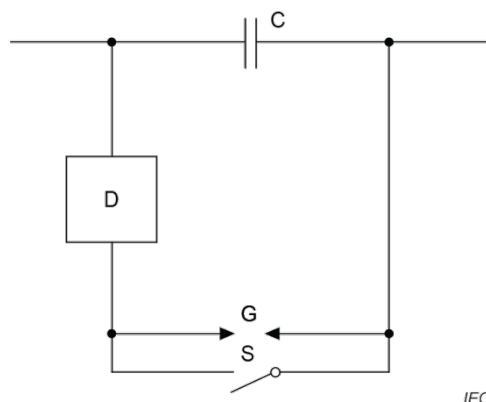
appareil de connexion triphasé utilisé en parallèle avec un condensateur série et son dispositif de protection contre les surtensions pour shunter le courant de ligne d'un niveau spécifié pendant une durée spécifiée ou continuellement

Note 1 à l'article: Les interrupteurs de contournement peuvent être unipolaires ou tripolaires.

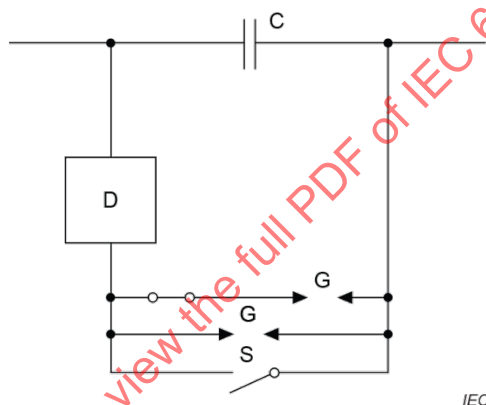
Note 2 à l'article: Outre le contournement du condensateur, cet appareil est normalement capable d'insérer le condensateur dans un circuit qui transporte un niveau de courant spécifié.

Note 3 à l'article: Les interrupteurs de contournement sont normalement utilisés en combinaison avec un dispositif de mise en contournement rapide, par exemple un éclateur (pour les applications spéciales n'employant pas de dispositif de mise en contournement rapide, voir l'Annexe E).

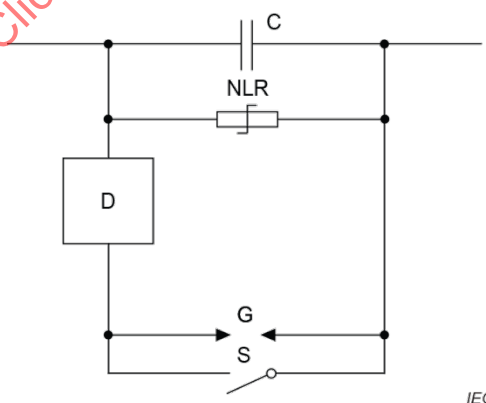
Note 4 à l'article: La Figure 1 présente des exemples de configurations de condensateurs série employant un dispositif de mise en contournement rapide en parallèle avec l'interrupteur de contournement (voir l'IEC 60143-1).



Éclateur simple



Éclateur double



Résistance non linéaire avec éclateur de contournement

Légende

C	condensateur série
D	circuit d'amortissement
G	éclateur de contournement
S	interrupteur de contournement
NLR	résistance non linéaire

Figure 1 – Différentes configurations de batteries de condensateurs série

3.4.104**interrupteur de contournement de classe M1**

interrupteur de contournement à endurance mécanique normale comme démontré par des essais de type spécifiques

3.4.105**interrupteur de contournement de classe M2**

interrupteur de contournement à manœuvres fréquentes pour des exigences de service spéciales et conçu pour ne nécessiter qu'une maintenance limitée comme démontré par des essais de type spécifiques

Note 1 à l'article: Ce type d'interrupteur de contournement est normalement utilisé sur les condensateurs à segments multiples pour lesquels la commande de l'impédance du condensateur est une fonction fréquente.

3.5 Parties de l'interrupteur de contournement**3.5.101****pôle d'un appareil de connexion**

élément constituant d'un appareil de connexion associé exclusivement à un chemin conducteur électriquement séparé appartenant à son circuit principal, cet élément ne comprenant pas les éléments constituant assurant la fixation et le fonctionnement d'ensemble de tous les pôles

Note 1 à l'article: Un appareil de connexion est appelé unipolaire s'il n'a qu'un pôle. S'il a plus d'un pôle, il peut être appelé multipolaire (bipolaire, tripolaire, etc.) à condition que les pôles soient ou puissent être liés entre eux de façon qu'ils fonctionnent ensemble.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.102**circuit principal**

<d'un appareil de connexion>

ensemble de pièces conductrices d'un appareil de connexion insérées dans le circuit qu'il a pour fonction de fermer ou d'ouvrir

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.103**circuit de commande**

<d'un appareil de connexion>

ensemble de pièces conductrices d'un appareil de connexion, autres que celles du circuit principal, insérées dans un circuit utilisé pour commander la manœuvre de fermeture ou la manœuvre d'ouverture ou les deux manœuvres de l'appareil

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.104**circuit auxiliaire**

<d'un appareil de connexion>

ensemble de pièces conductrices d'un appareil de connexion destinées à être insérées dans un circuit autre que le circuit principal et les circuits de commande de l'appareil

Note 1 à l'article: Certains circuits auxiliaires remplissent des fonctions supplémentaires telles que la signalisation, le verrouillage, etc., et, à ce titre, ils peuvent faire partie du circuit de commande d'un autre appareil de connexion.

[SOURCE: IEC 60050-441:2000, 441-15-04]

3.5.105

contact

<d'un appareil mécanique de connexion>

pièces conductrices destinées à établir la continuité d'un circuit lorsqu'elles se touchent et qui, par leur mouvement relatif pendant la manœuvre, ouvrent et ferment un circuit ou, dans le cas de contacts pivotants ou glissants, maintiennent la continuité du circuit

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.106

contact

pièce de contact

une des pièces conductrices formant un contact

[SOURCE: IEC 60050-441:2000, 441-15-06]

3.5.107

contact principal

contact inséré dans le circuit principal d'un appareil mécanique de connexion, prévu pour supporter, dans la position de fermeture, le courant du circuit principal

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.108

contact d'arc

contact prévu pour que l'arc s'y établisse

Note 1 à l'article: Un contact d'arc peut jouer le rôle de contact principal; il peut être un contact distinct conçu de façon à s'ouvrir après et se fermer avant un autre contact qu'il a pour but de protéger contre les détériorations.

[SOURCE: IEC 60050-441:2000, 441-15-08]

3.5.109

contact de commande

contact inséré dans un circuit de commande d'un appareil mécanique de connexion et manœuvré mécaniquement par cet appareil

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.110

contact auxiliaire

contact inséré dans un circuit auxiliaire et manœuvré mécaniquement par l'appareil de connexion

[SOURCE: IEC 60050-441:2000, 441-15-10]

3.5.111

interrupteur auxiliaire

<d'un appareil mécanique de connexion>

interrupteur comprenant un ou plusieurs contacts auxiliaires et/ou de commande, manœuvré mécaniquement par un appareil de connexion

[SOURCE: IEC 60050-441:2000, 441-15-11]

3.5.112**contact "a"****contact à fermeture**

contact de commande ou auxiliaire qui est fermé lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est ouvert lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.113**contact "b"****contact à ouverture**

contact de commande ou auxiliaire qui est ouvert lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est fermé lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.114**contact glissant**

contact dont les pièces se déplacent pratiquement parallèlement à la surface de contact

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

3.5.115**contact roulant**

contact dont l'une des pièces roule sur l'autre

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

3.5.116**déclencheur**

<d'un appareil mécanique de connexion>

dispositif raccordé mécaniquement à un appareil mécanique de connexion dont il libère les organes de retenue et qui permet l'ouverture ou la fermeture de l'appareil

[SOURCE: IEC 60050-441:2000, 441-15-17]

3.5.117**chambre d'extinction**

dispositif entourant les contacts d'arc d'un appareil mécanique de connexion, destiné à limiter le développement de l'arc et à faciliter son extinction

[SOURCE: IEC 60050-441:2000, 441-15-18]

3.5.118**indicateur de position**

partie d'un appareil mécanique de connexion qui indique les positions de celui-ci, par exemple: position d'ouverture, position de fermeture, ou, le cas échéant, position de mise à la terre

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.119**raccord**

ensemble de pièces conductrices (deux ou davantage) destinées à assurer la continuité permanente d'un circuit lorsqu'elles sont assemblées au moyen de vis, de boulons ou de dispositifs équivalents

3.5.120**borne**

composant destiné à raccorder un appareil aux conducteurs extérieurs

3.5.121**élément de contournement****élément d'insertion**

partie d'un interrupteur de contournement qui en elle-même joue le rôle d'un interrupteur de contournement et qui, en série avec un ou plusieurs éléments de contournement ou d'insertion identiques manœuvrés simultanément, forme l'interrupteur de contournement complet

Note 1 à l'article: Les éléments de contournement et les éléments d'insertion sont normalement combinés, mais peuvent être séparés. Chaque élément peut comporter plusieurs contacts.

Note 2 à l'article: Les moyens utilisés pour la répartition de la tension entre les éléments peuvent différer d'un élément à l'autre.

3.5.122**module**

<d'un interrupteur de contournement> ensemble comprenant généralement des éléments de contournement ou d'insertion, des supports isolants (pour les interrupteurs de contournement de type isolation dans l'air), des traversées (pour les interrupteurs de contournement à cuve mise à la terre) et des parties mécaniques, et qui est assemblé électriquement et mécaniquement à d'autres ensembles identiques pour constituer un pôle d'interrupteur de contournement

3.5.123**enveloppe**

partie d'appareillage procurant un degré de protection spécifié du matériel contre les influences externes et un degré de protection spécifié contre l'approche des parties actives ou le contact avec elles ou contre le contact avec des pièces en mouvement

[SOURCE: IEC 60050-441:2000, 441-13-01, modifié – "partie d'un ensemble" a été remplacée par "partie d'appareillage"]

3.5.124**mécanisme d'entraînement**

partie de l'interrupteur de contournement qui actionne, par l'intermédiaire de la chaîne cinématique de puissance, les contacts du circuit principal de l'interrupteur de contournement

3.5.125**chaîne cinématique de puissance**

dispositif de liaison mécanique entre le mécanisme d'entraînement, mécanisme d'entraînement inclus, et les contacts mobiles, contacts mobiles inclus

Note 1 à l'article: Voir également la Figure 1 de l'IEC 62271-102:2018.

3.5.126**mécanisme d'entraînement alternatif**

mécanisme obtenu lorsqu'une modification de la chaîne cinématique de puissance du mécanisme d'entraînement d'origine, ou lorsque l'utilisation d'un mécanisme d'entraînement complètement différent, conduit aux mêmes caractéristiques mécaniques

Note 1 à l'article: Les caractéristiques mécaniques sont définies en 7.101.1.1. L'utilisation des caractéristiques mécaniques et les exigences qui y sont liées sont décrites à l'Annexe G.

Note 2 à l'article: Un mécanisme d'entraînement alternatif peut mettre en œuvre un principe d'entraînement différent de celui du mécanisme d'entraînement d'origine (par exemple, le mécanisme alternatif peut être à ressort et celui d'origine peut être hydraulique).

Note 3 à l'article: Une modification de l'équipement secondaire ne donne pas lieu à un mécanisme d'entraînement alternatif.

3.6 Caractéristiques de fonctionnement des interrupteurs de contournement

3.6.101

manœuvre

<d'un appareil mécanique de connexion>

passage d'un ou de plusieurs contacts mobiles d'une position à une position adjacente

Note 1 à l'article: Par exemple, pour un disjoncteur ce pourra être une manœuvre de fermeture ou une manœuvre d'ouverture.

Note 2 à l'article: Si une distinction est nécessaire, on emploiera les mots manœuvre électrique (par exemple: établissement ou coupure) et manœuvre mécanique (par exemple: fermeture ou ouverture).

[SOURCE: IEC 60050-441:2000, 441-16-01]

3.6.102

cycle de manœuvres

<d'un appareil mécanique de connexion>

suite de manœuvres d'une position à une autre avec retour à la première position en passant par toutes les autres positions, s'il en existe

[SOURCE: IEC 60050-441:2000, 441-16-02]

3.6.103

séquence de manœuvres

<d'un appareil mécanique de connexion>

suite de manœuvres spécifiées effectuées à des intervalles de temps spécifiés

[SOURCE: IEC 60050-441:2000, 441-16-03]

3.6.104

manœuvre de fermeture

<d'un appareil mécanique de connexion>

manœuvre par laquelle on fait passer l'appareil de la position d'ouverture à la position de fermeture

[SOURCE: IEC 60050-441:2000, 441-16-08]

3.6.105

manœuvre d'ouverture

<d'un appareil mécanique de connexion>

manœuvre par laquelle on fait passer l'appareil de la position de fermeture à la position d'ouverture

[SOURCE: IEC 60050-441:2000, 441-16-09]

3.6.106

réouverture automatique

séquence de manœuvres d'un interrupteur de contournement au cours de laquelle, après sa fermeture, il s'ouvre automatiquement après une durée prédéterminée

3.6.107

manœuvre positive d'ouverture

<d'un appareil mécanique de connexion>

manœuvre d'ouverture qui, en conformité avec des prescriptions spécifiées, donne l'assurance que tous les contacts principaux sont dans la position ouverte lorsque l'organe de commande est dans la position correspondant à la position d'ouverture de l'appareil

[SOURCE: IEC 60050-441:2000, 441-16-11]

3.6.108

manœuvre effectuée positivement

manœuvre qui, conformément à des prescriptions spécifiées, est conçue pour assurer que les contacts auxiliaires d'un appareil mécanique de connexion sont dans des positions correspondant respectivement aux positions d'ouverture et de fermeture des contacts principaux

[SOURCE: IEC 60050-441:2000, 441-16-12]

3.6.109

manœuvre dépendante à source d'énergie extérieure

<d'un appareil mécanique de connexion>

manœuvre effectuée au moyen d'une énergie autre que manuelle et dont l'achèvement dépend de la continuité de l'alimentation en énergie (de solénoïdes, moteurs électriques ou pneumatiques, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.110

manœuvre à accumulation d'énergie

manœuvre de connexion effectuée au moyen d'énergie emmagasinée dans le mécanisme lui-même avant la manœuvre et suffisante pour achever la séquence de manœuvres spécifiée dans des conditions prédéterminées

3.6.111

manœuvre indépendante manuelle

<d'un appareil mécanique de connexion>

manœuvre à accumulation d'énergie dans laquelle l'énergie provient de l'énergie manuelle accumulée et libérée en une seule manœuvre continue, de telle sorte que la vitesse et la force de la manœuvre sont indépendantes de l'action de l'opérateur

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

3.6.112

position de fermeture

<d'un appareil mécanique de connexion>

position dans laquelle la continuité prédéterminée du circuit principal de l'appareil est assurée

[SOURCE: IEC 60050-441:2000, 441-16-22]

3.6.113

position d'ouverture

<d'un appareil mécanique de connexion>

position dans laquelle la distance prédéterminée d'isolement entre contacts ouverts est assurée dans le circuit principal de l'appareil

[SOURCE: IEC 60050-441:2000, 441-16-23]

3.6.114

déclencheur shunt

déclencheur alimenté par une source de tension

Note 1 à l'article: La source de tension peut être indépendante de la tension du circuit principal.

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

3.6.115**dispositif d'antipompage**

dispositif qui empêche la réouverture après une manœuvre d'ouverture/fermeture tant que le dispositif qui est à l'origine de l'ouverture est maintenu dans la position provoquant l'ouverture

3.6.116**dispositif de verrouillage**

dispositif qui subordonne la possibilité de fonctionnement d'un appareil de connexion à la position ou au fonctionnement d'un ou de plusieurs autres éléments de l'équipement

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.6.117**interrupteur de contournement à dispositif de verrouillage empêchant l'ouverture**

interrupteur de contournement dans lequel aucun des contacts mobiles ne peut insérer le condensateur si la commande d'ouverture est initiée tant que les conditions qui provoquent la manœuvre de fermeture sont maintenues

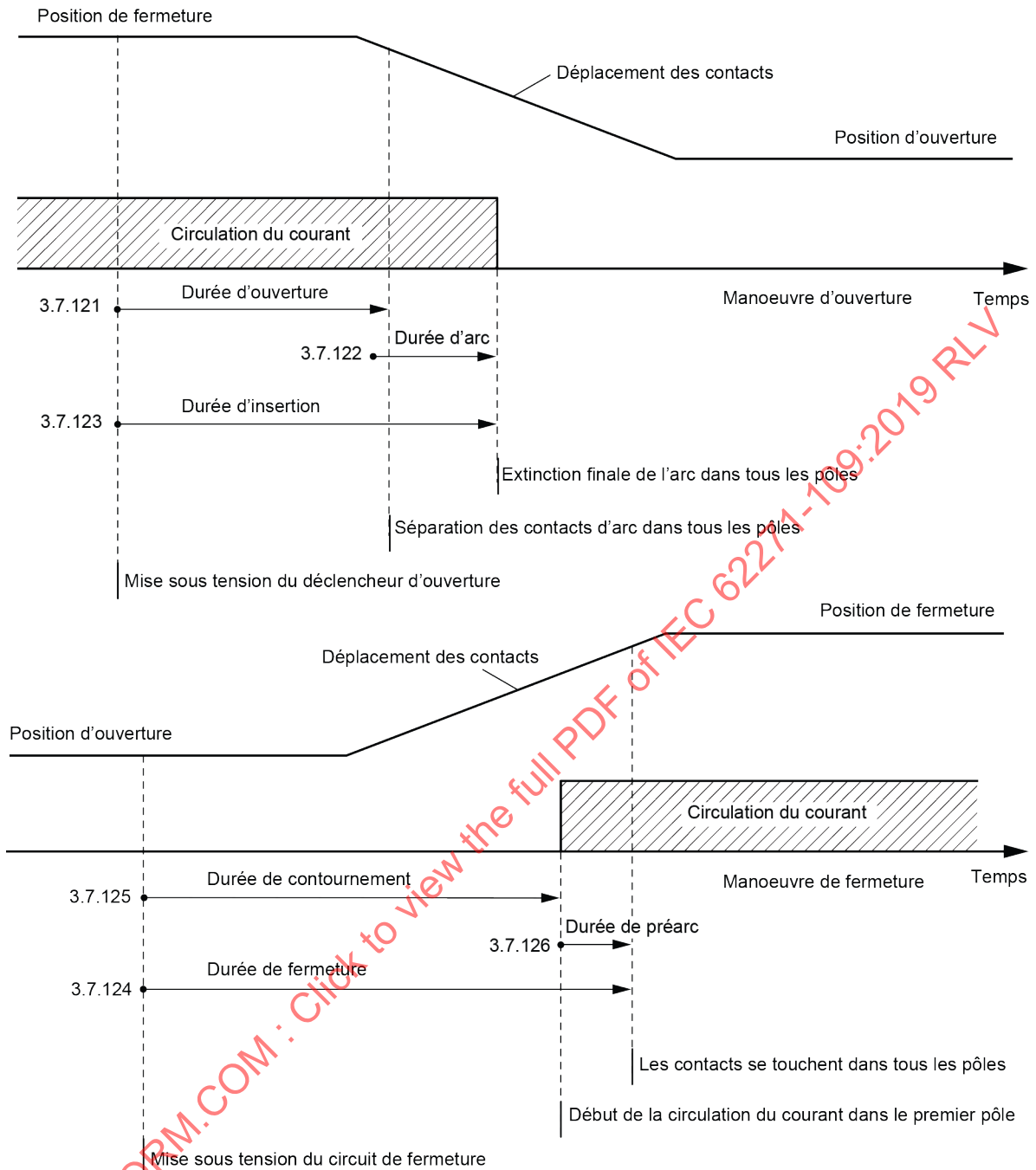
3.7 Grandeurs caractéristiques

Les Figures 2 à 4 présentent quelques définitions de ce paragraphe.

Les durées (voir les définitions 3.7.120 à 3.7.130) sont exprimées en millisecondes ou en cycles. Lorsqu'elles sont exprimées en cycles, la fréquence industrielle doit être donnée entre parenthèses.

Concernant les Figures 2 à 4 suivantes:

- En pratique, il se produit un écart de simultanéité entre les courses des contacts des trois pôles. Pour plus de clarté sur les figures, la course des contacts est indiquée avec une seule ligne pour les trois pôles.
- En pratique, il se produit un écart de simultanéité entre le début ainsi qu'entre la fin de la circulation du courant dans les trois pôles. Pour plus de clarté sur les figures, le début ainsi que la fin de la circulation du courant sont indiqués avec une seule ligne pour les trois pôles.



IEC

Figure 2 – Interrupteur de contournement – Manœuvres d'ouverture et de fermeture

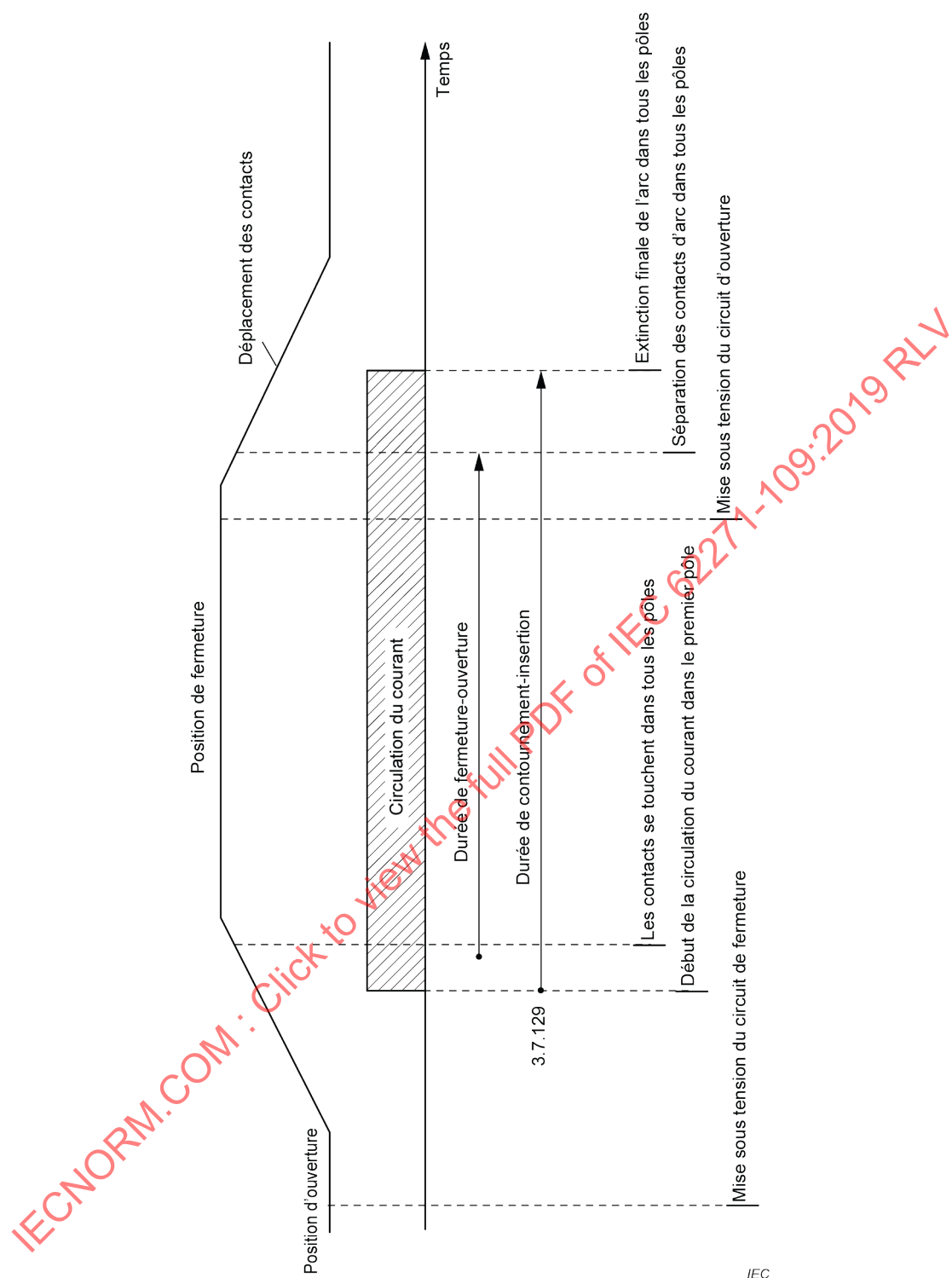


Figure 3 – Interrupteur de contournement – Cycle de fermeture-ouverture

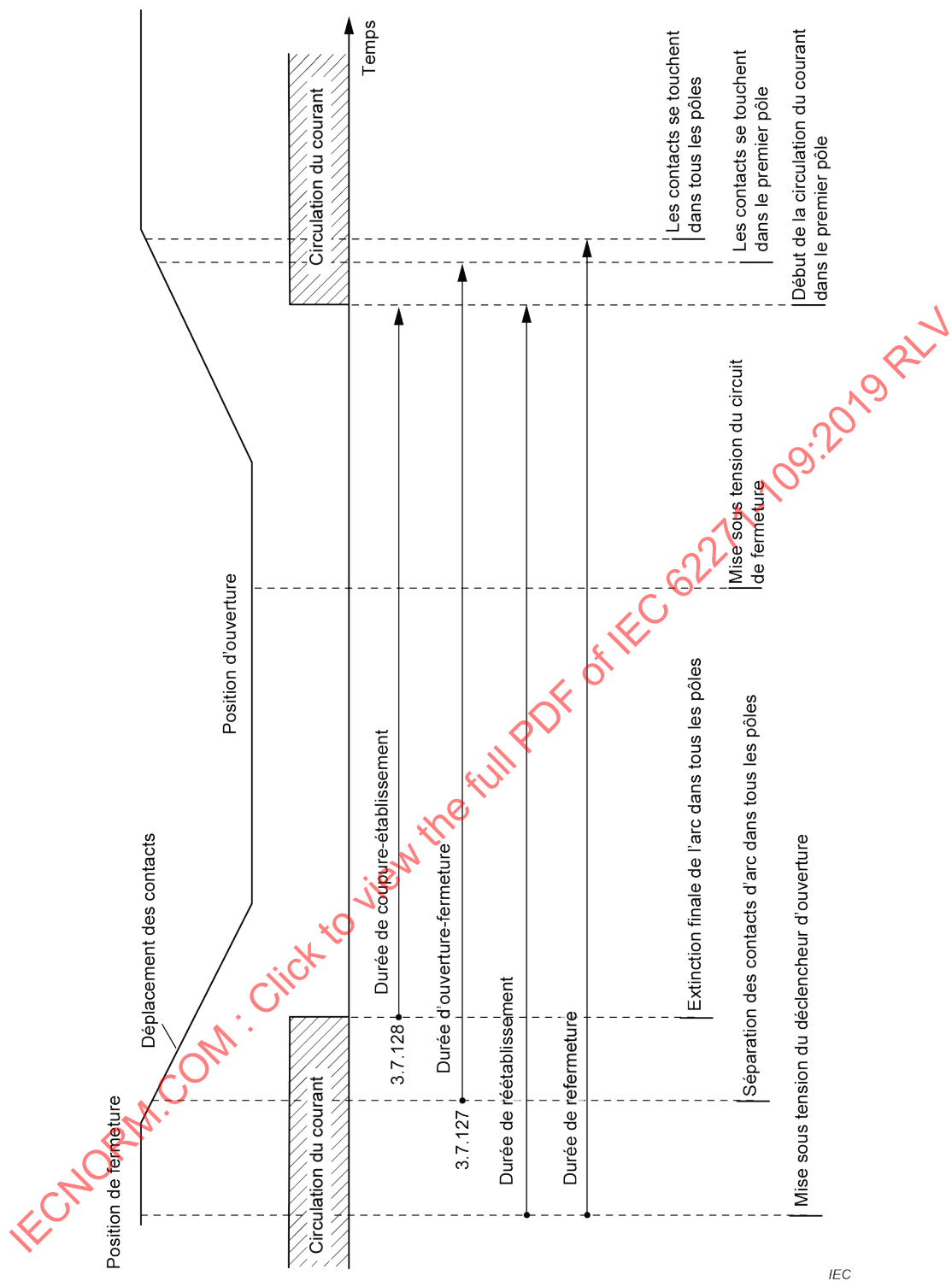


Figure 4 – Interrupteur de contournement – Cycle d'ouverture-fermeture

3.7.101

valeur assignée

valeur d'une grandeur fixée, généralement par le constructeur, pour un fonctionnement spécifié d'un composant, d'un dispositif ou d'un matériel

Note 1 à l'article: Les valeurs assignées habituellement déclarées pour les fusibles sont, par exemple, la tension, le courant et le pouvoir de coupe.

3.7.102**courant présumé**

<d'un circuit et relatif à un appareil de connexion ou à un fusible>

courant qui circulerait dans le circuit si chaque pôle de l'appareil de connexion ou le fusible était remplacé par un conducteur d'impédance négligeable

Note 1 à l'article: La méthode à employer pour évaluer et pour exprimer le courant présumé doit être spécifiée dans les publications particulières.

[SOURCE: IEC 60050-441:2000, 441-17-01]

3.7.103**valeur de crête du courant présumé**

valeur de crête de la première alternance du courant présumé pendant la période transitoire qui suit son établissement

Note 1 à l'article: La définition implique que le courant est établi par un interrupteur de contournement idéal, c'est-à-dire dont l'impédance entre les bornes de chaque pôle passe instantanément et simultanément de l'infini à zéro. La valeur de crête peut être différente d'un pôle à l'autre; elle dépend de la tension instantanée entre les bornes du condensateur avant le contournement.

3.7.104**valeur de crête du courant**

valeur de crête de la première alternance du courant pendant la période transitoire qui suit son établissement

3.7.105**courant de contournement transitoire**

superposition du courant de décharge de la batterie de condensateurs et du courant à fréquence industrielle

3.7.106**courant de contournement établi**

valeur de crête du courant de contournement dans un pôle d'un interrupteur de contournement pendant la période transitoire qui suit l'établissement du courant pendant une manœuvre de contournement

Note 1 à l'article: Cette valeur est la valeur instantanée maximale de la somme des composantes du courant de décharge de la batterie de condensateurs et du courant à fréquence industrielle. Dans le cas de défaut du réseau, le courant de défaut à fréquence industrielle est égal au courant de coordination maximal de la varistance ou, dans les cas d'installation sans varistance, au courant de défaut à fréquence industrielle maximal réel à l'emplacement particulier.

Note 2 à l'article: La valeur de crête peut être différente d'un pôle à l'autre et d'une manœuvre à l'autre car elle dépend de la tension instantanée du condensateur avant le contournement.

Note 3 à l'article: Lorsqu'une seule valeur de crête du courant de contournement établi est indiquée pour un circuit triphasé, il s'agit de la plus grande valeur dans n'importe quelle phase, sauf indication contraire.

Note 4 à l'article: Le courant de défaut à fréquence industrielle maximal à un endroit particulier ou le courant de coordination maximal de la varistance est généralement nettement inférieur à la valeur de crête du courant admissible assigné de l'interrupteur de contournement.

3.7.107**courant d'insertion****courant d'insertion dans le circuit de contournement**

courant efficace stabilisé qui passe à travers l'interrupteur de contournement immédiatement avant l'ouverture

3.7.108**capacité d'insertion**

valeur du courant présumé qu'un interrupteur de contournement est capable d'insérer à la tension indiquée sous les conditions d'utilisation et de comportement exigées

3.7.109

capacité de contournement

valeur du courant présumé qu'un interrupteur de contournement est capable d'établir à la tension indiquée sous les conditions d'utilisation et de comportement exigées

3.7.110

pouvoir de fermeture en court-circuit

pouvoir de fermeture pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

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

3.7.111

courant de courte durée admissible

courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter pendant un court intervalle de temps spécifié et dans des conditions prescrites d'emploi et de comportement

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

3.7.112

valeur de crête du courant admissible

valeur de crête du courant qu'un circuit ou un appareil de connexion dans la position de fermeture peut supporter dans des conditions prescrites d'emploi et de comportement

[SOURCE: IEC 60050-441:2000, 441-17-18]

3.7.113

tension appliquée

<pour un appareil de connexion>

tension qui existe entre les bornes d'un pôle d'un appareil de connexion immédiatement avant l'établissement du courant

[SOURCE: IEC 60050-441:2000, 441-17-24]

3.7.114

tension de rétablissement

tension qui apparaît entre les bornes d'un appareil de connexion ou d'un fusible après l'interruption du courant

Note 1 à l'article: Cette tension peut être considérée durant deux intervalles de temps consécutifs, l'un durant lequel existe une tension transitoire, suivi par un second intervalle durant lequel la tension de rétablissement à fréquence industrielle ou en régime établi existe seule.

[SOURCE: IEC 60050-441:2000, 441-17-25]

3.7.115

tension de rétablissement à fréquence industrielle

tension de rétablissement après la disparition des phénomènes transitoires de tension

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

3.7.116

tension d'arc

<d'un appareil mécanique de connexion> <en valeur de crête>

valeur maximale instantanée de tension qui, dans des conditions prescrites, apparaît entre les bornes d'un pôle d'un appareil de connexion pendant la durée d'arc

[SOURCE: IEC 60050-441:2000, 441-17-30]

3.7.117**distance d'isolement**

distance entre deux parties conductrices le long d'un fil tendu suivant le plus court trajet possible entre ces deux parties conductrices

[SOURCE: IEC 60050-441:2000, 441-17-31]

3.7.118**distance d'isolement entre pôles**

distance d'isolement entre n'importe quelles parties conductrices de pôles adjacents

[SOURCE: IEC 60050-441:2000, 441-17-32]

3.7.119**distance d'isolement à la terre**

distance d'isolement entre n'importe quelle partie conductrice et n'importe quelle partie réunie à la terre ou prévue pour être réunie à la terre

[SOURCE: IEC 60050-441:2000, 441-17-33]

3.7.120**distance d'isolement entre contacts ouverts**

distance d'isolement totale entre les contacts, ou n'importe quelles parties conductrices qui leur sont reliées, d'un pôle d'un appareil mécanique de connexion dans la position d'ouverture

[SOURCE: IEC 60050-441:2000, 441-17-34]

3.7.121**durée d'ouverture**

durée d'ouverture d'un interrupteur de contournement définie suivant le mode de déclenchement, comme indiqué ci-dessous, et tout dispositif de retard faisant partie intégrante de l'interrupteur de contournement étant, s'il y a lieu, réglé pour la durée minimale

Note 1 à l'article: Pour un interrupteur de contournement déclenché par une source quelconque d'énergie auxiliaire, la durée d'ouverture est l'intervalle de temps entre l'instant de mise sous tension du déclencheur, l'interrupteur de contournement étant en position de fermeture, et l'instant de séparation des contacts d'arc sur tous les pôles.

Note 2 à l'article: Pour les interrupteurs de contournement à plusieurs éléments d'insertion par pôle, l'instant de séparation des contacts d'arc sur tous les pôles est déterminé comme l'instant de séparation des contacts du premier élément du dernier pôle.

Note 3 à l'article: La durée d'ouverture comprend la durée de fonctionnement de tout équipement auxiliaire nécessaire pour ouvrir l'interrupteur de contournement et qui fait partie intégrante de ce dernier.

3.7.122**durée d'arc**

<d'un pôle>

intervalle de temps entre l'instant du premier début d'un arc sur un pôle et l'instant de l'extinction finale de l'arc sur ce pôle

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

3.7.123**durée d'insertion**

intervalle de temps entre le début de la durée d'ouverture d'un interrupteur de contournement et la fin de la durée d'arc

3.7.124

durée de fermeture

intervalle de temps entre la mise sous tension du circuit de fermeture, l'interrupteur de contournement étant en position d'ouverture, et l'instant où les contacts se touchent dans tous les pôles

Note 1 à l'article: La durée de fermeture comprend la durée de fonctionnement de tout équipement auxiliaire nécessaire pour fermer l'interrupteur de contournement et qui fait partie intégrante de ce dernier.

3.7.125

durée de contournement

intervalle de temps entre la mise sous tension du circuit de fermeture, l'interrupteur de contournement étant en position d'ouverture, et l'instant où le courant commence à circuler dans le premier pôle

Note 1 à l'article: La durée de contournement comprend la durée de fonctionnement de tout équipement auxiliaire nécessaire pour fermer l'interrupteur de contournement et qui fait partie intégrante de ce dernier.

Note 2 à l'article: La durée de contournement peut varier, par exemple, à cause de la variation de la durée de préarc.

3.7.126

durée de préarc

intervalle de temps entre le début de la circulation de courant dans le premier pôle pendant une manœuvre de contournement et l'instant où les contacts se touchent dans tous les pôles pour les conditions triphasées ou l'instant où les contacts du pôle qui voit l'arc se touchent pour les conditions monophasées

Note 1 à l'article: La durée de préarc dépend de la valeur instantanée de la tension appliquée pendant une manœuvre de contournement spécifique et peut donc varier considérablement.

3.7.127

durée d'ouverture-fermeture

intervalle de temps entre l'instant de séparation des contacts d'arc dans tous les pôles et l'instant où les contacts se touchent dans le premier pôle pendant une manœuvre de contournement

Note 1 à l'article: Sauf indication contraire, le déclencheur de fermeture incorporé dans l'interrupteur de contournement est réputé être mis sous tension au moment où les contacts se sont séparés dans tous les pôles pendant l'ouverture. Cela représente la durée d'ouverture-fermeture minimale.

3.7.128

durée de coupure-établissement

<pendant la refermeture automatique>

intervalle de temps entre l'extinction finale de l'arc dans tous les pôles lors de la manœuvre d'insertion et le premier rétablissement du courant dans l'un quelconque des pôles lors de la manœuvre de contournement qui lui fait suite

Note 1 à l'article: La durée de coupure-établissement peut varier, par exemple, à cause de la variation de la durée de préarc.

3.7.129

durée de contournement-insertion

intervalle de temps entre le début de la circulation du courant dans le premier pôle pendant une manœuvre de contournement et la fin de la durée d'arc pendant la manœuvre d'insertion qui lui fait suite

Note 1 à l'article: La durée de contournement-insertion peut varier à cause de la variation de la durée de préarc et de la durée d'arc.

Note 2 à l'article: Il convient que la durée de contournement-insertion soit compatible avec les exigences du réseau.

3.7.130**durée minimale de l'ordre d'ouverture**

durée minimale pendant laquelle la tension d'alimentation auxiliaire est appliquée au déclencheur d'ouverture pour assurer l'ouverture complète de l'interrupteur de contournement

3.7.131**durée minimale de l'ordre de fermeture**

durée minimale pendant laquelle la tension d'alimentation auxiliaire est appliquée au dispositif de fermeture pour assurer la fermeture complète de l'interrupteur de contournement

3.7.132**niveau d'isolement**

pour un interrupteur de contournement, une caractéristique définie par les valeurs indiquant les tensions de tenue de l'isolation par rapport à la terre et/ou entre les éléments de contournement

3.7.133**tension de tenue à fréquence industrielle**

valeur efficace de la tension sinusoïdale à fréquence industrielle que l'interrupteur de contournement peut supporter lors d'essais faits dans des conditions spécifiées et pendant une durée spécifiée

[SOURCE: IEC 60050-614:2016, 614-03-22, modifié, l'expression "isolation du matériel considéré" a été remplacé par "interrupteur de contournement"]

3.7.134**tension de tenue aux chocs**

valeur de crête de l'onde de tension de choc normalisée que l'isolation de l'interrupteur de contournement peut supporter lors d'essais faits dans des conditions spécifiées

Note 1 à l'article: Selon la forme de l'onde, cette expression peut être précisée: "tension de tenue aux chocs de manœuvre" ou "tension de tenue aux chocs de foudre".

3.7.135**pression p_{mm} minimale de fonctionnement pour la manœuvre**

pression (en Pa), pour la manœuvre, rapportée aux conditions atmosphériques normales de 20 °C et de 101,3 kPa (ou masse volumique), pouvant être exprimée de façon relative ou absolue, à laquelle et au-dessus de laquelle les caractéristiques assignées d'un interrupteur de contournement sont conservées, et à laquelle un complément de remplissage du dispositif d'accumulation d'énergie devient nécessaire

Note 1 à l'article: Cette pression est souvent appelée pression de verrouillage (se reporter à 3.6.5.6 de l'IEC 62271-1:2017).

3.7.136**pression p_{me} minimale de fonctionnement pour le contournement, l'insertion et l'isolement**

pression (en Pa), pour le contournement, l'insertion et l'isolement, rapportée aux conditions atmosphériques normales de +20 °C et de 101,3 kPa (ou masse volumique), pouvant être exprimée de façon relative ou absolue, à laquelle et au-dessus de laquelle les caractéristiques assignées d'un interrupteur de contournement sont conservées, et à laquelle un complément de remplissage du fluide de contournement, d'insertion et/ou d'isolement devient nécessaire

Note 1 à l'article: Voir également 3.6.5.5 de l'IEC 62271-1:2017.

Note 2 à l'article: Pour les interrupteurs de contournement avec système à pression scellé (aussi appelé scellé à vie), la pression minimale pour le contournement et l'insertion est celle à laquelle les caractéristiques assignées de l'interrupteur de contournement sont conservées, en prenant en compte la perte de pression à la fin de la durée de service escomptée.

3.7.137

début de manœuvre de fermeture

instant de réception d'une commande de manœuvre de fermeture au niveau du circuit de commande

3.7.138

début de manœuvre d'ouverture

instant de réception d'une commande de manœuvre d'ouverture au niveau du circuit de commande

3.8 Termes et définitions en rapport avec les batteries de condensateurs série

3.8.1

condensateur

terme utilisé lorsqu'il n'est pas nécessaire de faire la distinction entre les différentes significations du terme "condensateur" et l'ensemble de condensateurs associés à un segment

3.8.2

dispositif de protection contre les surtensions

<d'un condensateur série>

dispositif à action rapide destiné à limiter la tension aux bornes du condensateur à une valeur admissible dans les cas où un défaut du circuit ou toute autre condition anormale du réseau d'énergie pourrait entraîner un dépassement de cette valeur

[SOURCE: IEC 60050-436:1990, 436-03-14, modifié – l'expression suivante a été ajoutée: "dans les cas où un défaut du circuit ou toute autre condition anormale du réseau d'énergie pourrait entraîner un dépassement de cette valeur"]

3.8.3

capacité assignée

C_N

<d'un condensateur>

valeur de la capacité pour laquelle le condensateur a été conçu

3.8.4

courant assigné d'un condensateur

I_N

valeur efficace du courant alternatif pour laquelle le condensateur a été conçu

[SOURCE: IEC 60050-436:1990, 436-01-13]

3.8.5

réactance assignée

X_N

<d'un condensateur>

réactance de chaque phase du condensateur série à la fréquence assignée et à une température du diélectrique de 20 °C

3.8.6

tension assignée

U_N

<d'un condensateur>

valeur efficace de la tension entre les bornes, dérivée de la réactance assignée et du courant assigné $U_N = X_N \times I_N$

[SOURCE: IEC 60050-436:1990, 436-01-15, modifié – l'expression "de la tension alternative pour laquelle le condensateur a été conçu" a été remplacée par "de la tension entre les bornes, dérivée de la réactance assignée et du courant assigné $U_N = X_N \times I_N$ "]

3.8.7**tension limite** U_{LIM}

crête maximale de la tension à fréquence industrielle se produisant entre les bornes de l'élément condensateur immédiatement avant ou pendant la manœuvre du dispositif de protection contre les surtensions, divisée par $\sqrt{2}$

3.8.8**batterie de condensateurs série**

ensemble triphasé de condensateurs avec protection associée et structure support isolée

Note 1 à l'article: La batterie peut comprendre un ou plusieurs modules.

3.8.9**segment**

<d'un condensateur série>

lorsque chaque phase d'une batterie est divisée en une ou plusieurs parties branchées en série et que chacune de ces parties contient son propre ensemble d'éléments condensateurs, de dispositifs de protection contre les surtensions, de fonctions de protection et d'interrupteurs de contournement, une telle partie complète est appelée un segment

Note 1 à l'article: Les segments ne sont normalement pas séparés par des sectionneurs d'isolation. Une même plate-forme isolée peut comporter plusieurs segments.

3.8.10**protection de la batterie**

terme général qui désigne tout équipement de protection d'une batterie de condensateurs ou d'une partie de celle-ci

3.8.11**courant de contournement**

courant efficace stabilisé qui circule à travers l'interrupteur de contournement en parallèle avec le condensateur

3.8.12**courant de défaut de contournement**

courant qui circule à travers la batterie de condensateurs série contournée par suite d'un défaut sur la ligne

3.8.13**éclateur de contournement (éclateur de protection)**

éclateur ou système d'éclateurs destiné à protéger soit le condensateur (type K) contre les surtensions, soit la résistance non linéaire (type M) contre les surcharges en détournant des parties protégées le courant de charge ou de défaut pendant une durée spécifiée (voir la Figure 2 de l'IEC 60143-2:2012)

3.8.14**dispositif de verrouillage de contournement**

dispositif qui impose que les trois pôles de l'interrupteur de contournement se trouvent dans la même position ouverte ou fermée

3.8.15**équipement d'amortissement limitant le courant**

réactance ou une réactance en parallèle de laquelle est branchée une résistance pour limiter l'amplitude et la fréquence du courant et pour fournir un amortissement suffisant de la décharge des condensateurs lors du fonctionnement de l'éclateur de contournement ou de la manœuvre de l'interrupteur de contournement

3.8.16**insertion**

ouverture de l'interrupteur de contournement du condensateur série pour insérer le condensateur série en série avec la ligne de transmission

3.8.17**courant d'insertion**

courant efficace qui circule à travers le condensateur série après l'ouverture de l'interrupteur de contournement. Ce courant peut présenter les amplitudes spécifiées du courant en régime permanent ou de surcharge

3.8.18**tension d'insertion**

tension de crête qui apparaît entre les bornes du condensateur série lors du transfert du courant de contournement lors de l'ouverture de l'interrupteur de contournement

3.8.19**éclateur principal**

partie de l'éclateur de protection qui est destinée à transporter le courant de défaut pendant une durée spécifiée, comprenant deux électrodes à usage intensif ou plus

3.8.20**module**

<gradin de condensateur>

élément fonctionnel triphasé constitué d'un segment de condensateur (ou plusieurs) par phase avec des dispositions pour la manœuvre à verrouillage des interrupteurs de contournement monophasés

3.8.21**résistance non linéaire****varistance**

dispositif destiné à agir comme une protection du condensateur contre les surtensions et constitué de résistances dont la valeur varie de façon non linéaire en fonction de la tension (normalement des varistances à oxyde métallique)

3.8.22**niveau de protection**

U_{PL}

amplitude de la crête maximale de la tension à fréquence industrielle qui apparaît entre les bornes de la protection contre les surtensions pendant un défaut de réseau

($U_{PL} = U_{LIM} \times \sqrt{2}$)

Note 1 à l'article: Le niveau de protection peut être exprimé comme la tension de crête réelle entre les bornes d'un segment ou comme l'unité de crête de la tension assignée aux bornes du condensateur.

3.8.23**réinsertion**

rétablissement du courant de charge vers le condensateur série à partir de la branche de contournement

3.8.24**courant de réinsertion**

courant transitoire, courant à la fréquence industrielle, ou les deux circulant à travers le condensateur série pendant l'ouverture de la branche de contournement

3.8.25**tension de réinsertion**

tension de rétablissement qui apparaît entre les bornes du condensateur série pendant l'ouverture de la branche de contournement

3.8.26**surtension temporaire**

tension temporaire à fréquence industrielle supérieure à la tension assignée en service permanent du condensateur série

3.8.27**courant de coordination de la varistance**

amplitude du courant de varistance maximal associé au niveau de protection

3.8.28**courant de décharge de la batterie de condensateurs** **$I_{\text{DÉCHARGE}}$**

courant qui circule pendant la décharge de la batterie de condensateurs

Note 1 à l'article: La valeur de crête maximale du courant de décharge du condensateur se produit lorsque la batterie de condensateurs est chargée au niveau de protection U_{PL} .

3.9 Index des définitions**A**

Appareil de connexion	3.4.101
Appareil mécanique de connexion	3.4.102
Appareillage pour l'extérieur	3.1.102
Appareillage	3.1.101

B

Batterie de condensateurs série	3.8.8
Borne	3.5.120

C

Capacité assignée <d'un condensateur> C_N	3.8.3
Capacité d'insertion	3.7.108
Capacité de contournement	3.7.109
Chaîne cinématique de puissance	3.5.125
Chambre d'extinction	3.5.117
Circuit auxiliaire <d'un appareil de connexion>	3.5.104
Circuit de commande <d'un appareil de connexion>	3.5.103
Circuit principal <d'un appareil de connexion>	3.5.102
Condensateur	3.8.1
Contact "a", contact à fermeture	3.5.112
Contact "b", contact à ouverture	3.5.113
Contact à fermeture	3.5.112
Contact à ouverture	3.5.113
Contact auxiliaire	3.5.110
Contact d'arc	3.5.108
Contact de commande	3.5.109
Contact glissant	3.5.114
Contact principal	3.5.107
Contact roulant	3.5.115

Contact <d'un appareil mécanique de connexion>	3.5.105
Courant assigné <d'un condensateur> I_N	3.8.4
Courant d'insertion <dans le circuit de contournement>	3.7.107
Courant d'insertion	3.8.17
Courant de contournement établi	3.7.106
Courant de coordination de la varistance	3.8.27
Courant de court-circuit	3.1.103
Courant de courte durée admissible	3.7.111
Courant de décharge de la batterie de condensateurs ($I_{\text{DÉCHARGE}}$)	3.8.28
Courant de défaut de contournement	3.8.12
Courant de contournement transitoire	3.7.105
Courant de contournement	3.8.11
Courant de réinsertion	3.8.24
Courant présumé <d'un circuit et relatif à un appareil de connexion ou à un fusible>	3.7.102
Cycle de manœuvres <d'un appareil mécanique de connexion>	3.6.102

D

Début de manœuvre de fermeture	3.7.137
Début de manœuvre d'ouverture	3.7.138
Décharge disruptive	3.1.112
Décharge disruptive non maintenue	3.1.116
Déclencheur shunt	3.6.114
Déclencheur <d'un appareil mécanique de connexion>	3.5.116
Dispositif d'antipompage	3.6.115
Dispositif de protection contre les surtensions <d'un condensateur série>	3.8.2
Dispositif de verrouillage de contournement	3.8.14
Dispositif de verrouillage	3.6.116
Distance d'isolement à la terre	3.7.119
Distance d'isolement entre contacts	3.7.120
Distance d'isolement entre pôles	3.7.118
Distance d'isolement	3.7.117
Durée d'arc <d'un pôle>	3.7.122
Durée d'insertion	3.7.123
Durée d'ouverture-fermeture	3.7.127
Durée d'ouverture	3.7.121
Durée de coupure-établissement <pendant la refermeture automatique>	3.7.128
Durée de contournement	3.7.125
Durée de fermeture	3.7.124
Durée de mise en contournement – insertion	3.7.129
Durée de préarc	3.7.126
Durée minimale de l'ordre d'ouverture	3.7.130
Durée minimale de l'ordre de fermeture	3.7.131

E

Échauffement <d'une partie d'un interrupteur de contournement>	3.1.105
Éclateur de contournement (éclateur de protection)	3.8.13
Éclateur principal	3.8.19
Élément de contournement (ou d'insertion)	3.5.121
Ensembles	3.2
Enveloppe	3.5.123
Équipement d'amortissement limitant le courant	3.8.15
Essai sur élément	3.1.107

F

Fonctionnement	3.6

I

Indicateur de position	3.5.118
Insertion	3.8.16
Interrupteur auxiliaire <d'un appareil mécanique de connexion>	3.5.111
Interrupteur de contournement à dispositif de verrouillage empêchant l'ouverture	3.6.117
Interrupteur de contournement de classe M1	3.4.104
Interrupteur de contournement de classe M2	3.4.105
Interrupteur de contournement	3.4.103
Isolation autorégénératrice	3.1.110
Isolation externe	3.1.108
Isolation interne	3.1.109
Isolation non autorégénératrice	3.1.111

M

Manœuvre à accumulation d'énergie	3.6.110
Manœuvre d'ouverture <d'un appareil mécanique de connexion>	3.6.105
Manœuvre de fermeture <d'un appareil mécanique de connexion>	3.6.104
Manœuvre dépendante à source d'énergie extérieure <d'un appareil mécanique de connexion>	3.6.109
Manœuvre effectuée positivement	3.6.108
Manœuvre indépendante manuelle <d'un appareil mécanique de connexion>	3.6.111
Manœuvre positive d'ouverture <d'un appareil mécanique de connexion>	3.6.107
Manœuvre <d'un appareil mécanique de connexion>	3.6.101
Mécanisme d'entraînement	3.5.124
Mécanisme d'entraînement alternatif	3.5.126
Module <d'un interrupteur de contournement>	3.5.122
Module <gradin de condensateur>	3.8.20

N

Niveau d'isolement	3.7.132
Niveau de protection U_{PL}	3.8.22

P

Parties d'ensembles	3.3
Performance en réamorçage	3.1.113
Pièce de contact	3.5.106
Pôle <d'un appareil de connexion>	3.5.101
Position d'ouverture <d'un appareil mécanique de connexion>	3.6.113
Position de fermeture <d'un appareil mécanique de connexion>	3.6.112
Pouvoir de fermeture en court-circuit	3.7.110
Pression p_{mm} minimale de fonctionnement pour la manœuvre	3.7.135
Pression p_{me} minimale de fonctionnement pour le contournement, l'insertion et l'isolement	3.7.136
Protection de la batterie	3.8.10

R

Raccord	3.5.119
Réactance assignée <d'un condensateur> X_N	3.8.5
Réallumage <d'un appareil mécanique de connexion à courant alternatif>	3.1.114
Réamorçage <d'un appareil mécanique de connexion à courant alternatif>	3.1.115
Réinsertion	3.8.23
Réouverture automatique	3.6.106
Résistance non linéaire (varistance)	3.8.21

S

Segment <d'un condensateur série>	3.8.9
Séquence de manœuvres <d'un appareil mécanique de connexion>	3.6.103
Surtension <dans un système électrique>	3.1.106
Surtension temporaire	3.8.26

T

Température de l'air ambiant	3.1.104
Tension appliquée <d'un appareil de connexion>	3.7.113
Tension assignée <d'un condensateur> U_N	3.8.6
Tension d'arc de crête <d'un appareil mécanique de connexion>	3.7.116
Tension d'insertion	3.8.18
Tension limite (U_{LIM})	3.8.7
Tension de réinsertion	3.8.25
Tension de rétablissement à fréquence industrielle	3.7.115
Tension de rétablissement	3.7.114
Tension de tenue à fréquence industrielle	3.7.133
Tension de tenue aux chocs	3.7.134

V

Valeur assignée	3.7.101
Valeur de crête du courant admissible	3.7.112

Valeur de crête du courant présumé

3.7.103

Valeur de crête du courant

3.7.104

4 Conditions normales et spéciales de service

L'Article 4 de l'IEC 62271-1:2017 s'applique.

5 Caractéristiques assignées

5.1 Généralités

Les caractéristiques d'un interrupteur de contournement, y compris celles de ses dispositifs de commande et de son équipement auxiliaire, qui doivent servir à fixer les caractéristiques assignées sont les suivantes.

Caractéristiques assignées à indiquer pour tous les interrupteurs de contournement

- a) tension assignée par rapport à la terre (U_{re}) et entre les bornes de l'interrupteur de contournement (U_{rp});
- b) niveau d'isolement assigné par rapport à la terre (U_{pe} , U_{de} , U_{se}) et entre les bornes de l'interrupteur de contournement (U_{pp} , U_{dp} , U_{sp});
- c) fréquence assignée (f_r);
- d) courant permanent assigné (I_r);
- e) courant de courte durée admissible assigné (I_k);
- f) valeur de crête du courant admissible assigné (I_p);
- g) durée de court-circuit assignée (t_k);
- h) tension d'alimentation assignée des circuits auxiliaires et de commande (U_a);
- i) fréquence d'alimentation assignée des dispositifs de fermeture et d'ouverture et des circuits auxiliaires;
- j) pressions assignées du gaz comprimé d'alimentation et/ou du circuit hydraulique, pour la manœuvre, l'insertion, le contournement et l'isolement, selon le cas;
- k) courant assigné de contournement;
- l) courant assigné d'insertion;
- m) tension assignée de réinsertion (valeur de crête);
- n) séquence de manœuvres assignée;
- o) classe d'endurance mécanique assignée.

Les caractéristiques assignées de l'interrupteur de contournement sont rattachées à la séquence de manœuvres assignée.

5.2 Tension assignée (U_r)

5.2.1 Généralités

Le 5.2.1 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

5.2.1.101 Tension assignée par rapport à la terre (U_{re})

Le 5.2.2 et le 5.2.3 de l'IEC 62271-1:2017 s'appliquent. La tension assignée par rapport à la terre est la tension entre phases du réseau d'énergie pour laquelle l'isolation phase-terre de l'interrupteur de contournement est conçue.

5.2.1.102 Tension assignée de l'interrupteur de contournement (U_{rp})

La tension assignée entre les bornes de l'interrupteur de contournement doit être déduite de la tension de tenue à fréquence industrielle, qui lui est associée, telle que déterminée en 5.3.102 et en 6.1.3 de l'IEC 60143-1:2015.

Les Tableaux 1 à 4 de l'IEC 62271-1:2017 doivent servir à associer une tension assignée entre les bornes de l'interrupteur de contournement avec une tension de tenue à fréquence industrielle de l'interrupteur de contournement.

5.2.2 Plage I pour les tensions assignées inférieures ou égales à 245 kV

Le 5.2.2 de l'IEC 62271-1:2017 s'applique.

5.2.3 Plage II pour les tensions assignées supérieures à 245 kV

Le 5.2.3 de l'IEC 62271-1:2017 s'applique.

5.3 Niveau d'isolement assigné (U_p , U_d , U_s)

Le 5.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

5.3.101 Niveau d'isolement assigné par rapport à la terre (U_{pe} , U_{de} , U_{se})

Les valeurs normales des tensions de tenue assignées par rapport à la terre sont données dans les Tableaux 1, 2, 3 et 4 de l'IEC 62271-1:2017.

5.3.102 Niveau d'isolement assigné entre les bornes de l'interrupteur de contournement (U_{pp} , U_{dp} , U_{sp})

Les valeurs normales des tensions d'isolement assignées entre les bornes de l'interrupteur de contournement sont données dans les Tableaux 1, 2, 3 et 4 de l'IEC 62271-1:2017 pour la tension assignée correspondante aux bornes de l'interrupteur de contournement. Les niveaux d'isolement assignés doivent être déterminés conformément à 6.1.3 de l'IEC 60143-1:2015.

Les niveaux d'isolement pour les isolants et les équipements des condensateurs série montés sur la plate-forme support sont indiqués en référence à la plate-forme. Des niveaux d'isolement supérieurs peuvent être nécessaires pour les installations à des altitudes supérieures à 1 000 m. Il convient de choisir le niveau d'isolement des isolateurs et des équipements sur la plate-forme en fonction du niveau de protection établi par le dispositif de protection contre les surtensions en utilisant l'équation ci-dessous. L'équation s'applique à l'isolement entre les bornes de la totalité du segment en utilisant le niveau de protection de ce segment. Elle s'applique également à l'isolement au sein du segment en utilisant le niveau de protection applicable entre les bornes de cette partie du segment.

$$U_{ipf} \geq 1,2 U_{PL} / \sqrt{2}$$

où

U_{ipf} est la tension de tenue à fréquence industrielle (efficace);

U_{PL} est le niveau de protection.

5.4 Fréquence assignée (f_r)

Le 5.4 de l'IEC 62271-1:2017 ne s'applique pas.

Les valeurs normales de la fréquence assignée aux interrupteurs de contournement à haute tension sont 50 Hz et 60 Hz.

5.5 Courant permanent assigné (I_r)

Le 5.5 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Le courant permanent assigné de l'interrupteur de contournement (ligne non compensée) peut être inférieur à la batterie de condensateurs série (ligne compensée).

5.6 Courant de courte durée admissible assigné (I_k)

Le 5.6 de l'IEC 62271-1:2017 s'applique.

5.7 Valeur de crête du courant admissible assigné (I_p)

Le 5.7 de l'IEC 62271-1:2017 s'applique.

5.8 Durée de court-circuit assignée (t_k)

Le 5.8 de l'IEC 62271-1:2017 s'applique.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le 5.9 de l'IEC 62271-1:2017 s'applique généralement. Les tolérances indiquées en 6.9.3 de l'IEC 62271-1:2017 pour les déclencheurs shunt d'ouverture doivent être appliquées aux déclencheurs shunt de fermeture.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le 5.10 de l'IEC 62271-1:2017 s'applique.

5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue

Le 5.11 de l'IEC 62271-1:2017 s'applique.

5.101 Séquence de manœuvres assignée

Les caractéristiques assignées de l'interrupteur de contournement sont rattachées à la séquence de manœuvres assignée.

$$C - t - OC - t' - OC$$

Sauf spécification contraire:

- $t = 0,3$ s pour les interrupteurs de contournement prévus pour fonctionner en réouverture automatique rapide (durée de contournement – insertion);
- $t' = 3$ min.

où

C représente une manœuvre de fermeture;

OC représente une manœuvre d'ouverture suivie immédiatement (c'est-à-dire sans délai intentionnel) d'une manœuvre de fermeture;

t et t' sont les intervalles de temps entre les manœuvres successives;

t et t' il convient de toujours les exprimer en minutes ou en secondes.

Il convient de spécifier les limites de réglage lorsque la durée de contournement-insertion est réglable.

Au lieu de $t = 0,3$ s, une autre valeur $t = 0,2$ s peut être aussi utilisée pour les interrupteurs de contournement prévus pour fonctionner en réouverture automatique rapide.

Au lieu de $t' = 3$ min, d'autres valeurs $t' = 15$ s et $t' = 1$ min peuvent être aussi utilisées pour les interrupteurs de contournement prévus pour fonctionner en réouverture automatique rapide.

D'autres séquences de manœuvres peuvent être spécifiées suivant les exigences du système.

5.102 Courant assigné de contournement (I_{BP})

Le courant assigné de contournement est la valeur maximale du courant de contournement établi que l'interrupteur de contournement doit être capable d'établir dans des conditions de défaut de ligne lorsque la batterie de condensateurs est préchargée à la tension de limitation du dispositif de protection contre les surtensions (U_{PL}) et à une fréquence du courant de décharge de contournement correspondant à la capacité réelle de la batterie de condensateurs avec l'inductance associée du circuit d'amortissement. L'amortissement effectif du courant de décharge de contournement peut être pris en considération.

Ce courant doit être égal à la somme de la composante de courant de décharge de la batterie de condensateurs et de la composante de courant de défaut à fréquence industrielle (voir 3.7.106). Il convient généralement que la composante de courant de défaut à fréquence industrielle soit égale au courant maximal de coordination de la varistance.

Il convient de déterminer le courant assigné de contournement par des études du réseau comme étant la somme maximale du courant de décharge instantané de la batterie de condensateurs et de la valeur instantanée de la composante relative au courant de défaut durant la durée de préarc (voir aussi l'IEC 60143-2:2012). Une valeur du préarc de 5 ms est suggérée dans le cas où cette information ne serait pas disponible.

Les performances relatives au contournement sont couvertes lorsque la valeur de crête exigée du courant de contournement établi est égale ou inférieure à la valeur de crête utilisée pour l'essai de type considéré. Cette règle est considérée comme valide seulement lorsque la fréquence f_{BP} du courant de contournement établi est égale ou inférieure à 130 % de la valeur correspondante utilisée lors des essais de type.

Il est généralement impossible d'assigner des caractéristiques assignées spécifiques, car celles-ci sont propres aux paramètres de chaque projet. L'Annexe D contient des exemples de caractéristiques assignées d'un interrupteur de contournement. Les valeurs préférentielles du courant assigné de contournement et de la fréquence assignée de contournement sont néanmoins:

I_{BP} : 63 kA – 100 kA et 125 kA

f_{BP} : 500 Hz et 1 000 Hz

5.103 Courant assigné d'insertion (dans le circuit de contournement, I_{INS})

Le courant assigné d'insertion (dans le circuit de contournement) est la valeur efficace du courant à la fréquence industrielle que l'interrupteur de contournement doit être capable de transférer de la branche du circuit de contournement vers la branche principale des condensateurs série sous la tension assignée de réinsertion. Il est impossible d'assigner des caractéristiques assignées spécifiques, car celles-ci sont propres aux paramètres de chaque projet. L'Annexe D contient des exemples de caractéristiques assignées d'un interrupteur de contournement.

Il convient que le courant assigné d'insertion (dans le circuit de contournement) soit prélevé de la série R10 et celui-ci (ligne non compensée) peut être égal ou inférieur au courant assigné de la batterie de condensateurs (ligne compensée).

5.104 Tension assignée de réinsertion (U_{INS})

La tension assignée de réinsertion est la valeur de crête de la tension de rétablissement que l'interrupteur de contournement doit être capable de supporter sans réamorçage pendant le transfert du courant assigné d'insertion (dans le circuit de contournement).

La tension de réinsertion doit généralement être égale à U_{PL} pour tenir compte de toutes les conditions de surcharge en situation d'urgence et des fluctuations de la puissance qui pourraient donner lieu à des tensions d'insertion jusqu'au niveau de protection du dispositif de protection contre les surtensions.

Plusieurs formes d'onde de tension de réinsertion peuvent être obtenues en service. Il convient de déterminer la forme d'onde de la tension de réinsertion par des études du réseau. Pour des raisons de normalisation, et en vue de couvrir le plus grand nombre de situations pratiques, le présent document recommande une forme d'onde "1-cos" dont la durée préférentielle pour atteindre la première crête est de 5,6 ms. D'autres formes d'onde peuvent être exigées et il convient de les spécifier clairement au constructeur au moment de la demande.

Il est impossible d'assigner des caractéristiques assignées spécifiques, car celles-ci sont propres aux paramètres de chaque projet. L'Annexe D contient des exemples de caractéristiques assignées d'un interrupteur de contournement. L'Annexe F contient des informations supplémentaires concernant la tension de rétablissement pendant la réinsertion.

NOTE 1 Aucune valeur recommandée spécifique ne peut être donnée pour la tension de réinsertion, car cette valeur dépend des paramètres de conception du condensateur série (impédance capacitive, courant assigné en service continu de la batterie de condensateurs, niveau de protection du dispositif de protection contre les surtensions, courant de surcharge en situation d'urgence et fluctuations de la puissance). Voir l'Annexe F pour plus d'informations.

NOTE 2 Pour couvrir la majorité des applications à 50 Hz et à 60 Hz avec une seule séquence d'essai, la tension de rétablissement a été définie avec une durée jusqu'à la première crête de 5,6 ms.

5.105 Nombre de manœuvres mécaniques

Un interrupteur de contournement doit être capable d'effectuer le nombre de manœuvres indiqué au Tableau 1 (tel qu'il est défini en 7.101.2.3 et dans le Tableau 6 pour les essais de type) en tenant compte du programme de maintenance spécifié par le constructeur.

Tableau 1 – Nombre de manœuvres mécaniques

Interrupteur de contournement standard (endurance mécanique normale) classe M1	2 000 séquences de manœuvres
Interrupteur de contournement pour des exigences spéciales de service (endurance mécanique accrue) classe M2	10 000 séquences de manœuvres

6 Conception et construction

6.1 Exigences pour les liquides utilisés dans les interrupteurs de contournement

Le 6.1 de l'IEC 62271-1:2017 s'applique.

6.2 Exigences pour les gaz utilisés dans les interrupteurs de contournement

Le 6.2 de l'IEC 62271-1:2017 s'applique.

6.3 Raccordement à la terre des interrupteurs de contournement

Le 6.3 de l'IEC 62271-1:2017 s'applique.

6.4 Équipements et circuits auxiliaires et de commande

6.4.1 Généralités

Le 6.4.1 de l'IEC 62271-1:2017 s'applique.

6.4.2 Protection contre les chocs électriques

Le 6.4.2 de l'IEC 62271-1:2017 s'applique.

6.4.3 Composants installés dans les enveloppes

Le 6.4.3 de l'IEC 62271-1:2017 s'applique avec les modifications suivantes:

- à la suite de la perte des "précautions appropriées" pendant plus de 2 h, les fonctionnalités de l'interrupteur de contournement doivent être rétablies à leurs caractéristiques initiales au rétablissement des conditions de service;
- lorsque des déclencheurs shunt d'ouverture et de fermeture sont utilisés, des mesures appropriées doivent être prises pour éviter d'endommager les déclencheurs quand des ordres sont maintenus en permanence à l'ouverture ou à la fermeture. Par exemple, des contacts de commande en série peuvent être utilisés pour que lorsque l'interrupteur de contournement est fermé, le contact du déclencheur de fermeture (contact "b" ou contact d'ouverture) soit ouvert et le contact de commande du déclencheur d'ouverture (contact "a" ou contact de fermeture) soit fermé, et lorsque l'interrupteur de contournement est ouvert, le contact de commande du déclencheur d'ouverture soit ouvert et le contact de commande du déclencheur de fermeture soit fermé;
- des systèmes autres que des contacts sont possibles et peuvent être utilisés;
- pour les déclencheurs shunt de fermeture, des mesures de protection des déclencheurs shunt de fermeture (le contact "b"), comme indiqué au premier tiret ci-dessus, ne doivent pas s'ouvrir avant la durée minimale de l'ordre de fermeture (3.7.131) exigée par l'interrupteur de contournement, ni après la durée de fermeture spécifiée;
- si le courant du déclencheur shunt de fermeture est coupé par le contact de commande, il convient que la durée de l'ordre de fermeture soit avec certitude plus longue que la durée de fermeture spécifiée;
- pour les déclencheurs shunt d'ouverture, des mesures de protection des déclencheurs shunt d'ouverture (le contact "a"), comme indiqué au premier tiret ci-dessus, ne doivent pas s'ouvrir avant la durée minimale de l'ordre d'ouverture (3.7.130) exigée par l'interrupteur de contournement et pas plus tard que 20 ms après la séparation des contacts principaux;
- dans le cas d'exigences de courte durée d'ouverture-fermeture, des mesures de protection des déclencheurs shunt de fermeture (le contact "b"), comme indiqué au premier tiret ci-dessus, ne doivent pas se fermer avant l'ouverture du contact "a";
- lorsque des contacts auxiliaires sont utilisés comme indicateurs de position, ils doivent indiquer la position finale de l'interrupteur de contournement au repos, ouvert ou fermé. La signalisation doit être maintenue;
- les connexions doivent supporter les contraintes imposées par l'interrupteur de contournement, spécialement celles qui sont dues aux efforts mécaniques pendant les manœuvres;
- tous les équipements auxiliaires, y compris le câblage, doivent être protégés correctement contre la pluie et l'humidité;
- lorsque des équipements de commande particuliers sont utilisés, ils doivent fonctionner dans les limites spécifiées pour les tensions d'alimentation des circuits auxiliaires et de commande, et pour les fluides pour la manœuvre, la coupure et/ou l'isolement, de plus ils doivent pouvoir manœuvrer les charges indiquées par le constructeur de l'interrupteur de contournement;
- les équipements auxiliaires spéciaux tels qu'indicateurs de niveau de liquide, indicateurs de pression, soupapes de sécurité, équipement de remplissage et de vidange, chauffage

et contacts de verrouillage, doivent fonctionner dans les limites spécifiées des tensions d'alimentation des circuits auxiliaires et de commande et/ou dans les limites d'utilisation des fluides de manœuvre, de coupure et/ou d'isolement;

- la puissance consommée par les dispositifs de chauffage à la tension assignée doit avoir la valeur indiquée par le constructeur à ± 10 % près;
- lorsque des dispositifs d'antipompage font partie du schéma de commande de l'interrupteur de contournement, et si l'installation en comporte plus d'un, ils doivent agir sur chaque circuit de commande;
- lorsqu'un schéma de contrôle de discordance de phases fait partie de l'interrupteur de contournement, la position des pôles, ouvert ou fermé, doit être surveillée. La fermeture d'un pôle doit provoquer la fermeture des pôles restants. Chaque interrupteur de contournement doit être verrouillé de manière similaire pour la manœuvre d'ouverture.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le 6.5 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant:

Un interrupteur de contournement configuré pour une ouverture dépendante d'une source d'énergie extérieure doit également être capable de se fermer immédiatement après une manœuvre d'ouverture.

6.6 Manœuvre à accumulation d'énergie

Le 6.6 de l'IEC 62271:2017 s'applique avec l'ajout suivant en 6.6.1.

Un interrupteur de contournement configuré pour une manœuvre à accumulation d'énergie doit également être capable de se fermer immédiatement après une manœuvre d'ouverture.

6.7 Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)

Le 6.7 de l'IEC 62271-1:2017 ne s'applique pas aux interrupteurs de contournement.

6.8 Organes de commande à manœuvre manuelle

Le 6.8 de l'IEC 62271-1:2017 s'applique.

6.9 Fonctionnement des déclencheurs

Le 6.9 de l'IEC 62271-1:2017 ne s'applique généralement pas et doit être remplacé par ce qui suit.

6.9.1 Généralités

Le 6.9.1 de l'IEC 62271-1:2017 s'applique.

6.9.2 Déclencheurs shunt de fermeture

Un déclencheur shunt de fermeture doit fonctionner correctement sous toutes les conditions de manœuvre de l'appareil de connexion jusqu'à son courant assigné de contournement, et entre 70 % dans le cas du courant continu – ou 85 % dans le cas du courant alternatif – et 110 % de la tension d'alimentation assignée du dispositif de fermeture (voir 5.9), la fréquence dans le cas du courant alternatif étant la fréquence d'alimentation assignée du dispositif de fermeture (voir 5.10).

6.9.3 Déclencheurs shunt d'ouverture

Un déclencheur shunt d'ouverture doit fonctionner correctement entre 85 % et 110 % de la tension d'alimentation assignée du dispositif d'ouverture (voir 5.9), la fréquence dans le cas du courant alternatif étant la fréquence d'alimentation assignée du dispositif d'ouverture (voir 5.10).

6.9.4 Fonctionnement des déclencheurs shunt à l'aide de condensateurs

Le 6.9.4 de l'IEC 62271-1:2017 s'applique.

6.9.5 Déclencheur à minimum de tension

Le 6.9.5 de l'IEC 62271-1:2017 ne s'applique pas aux interrupteurs de contournement.

6.9.101 Déclencheurs multiples

Si un interrupteur de contournement est équipé de plusieurs déclencheurs de même fonction, un défaut sur un déclencheur ne doit pas influencer sur le fonctionnement des autres. Les déclencheurs qui sont utilisés pour la même fonction doivent être physiquement distincts, c'est-à-dire découplés magnétiquement.

6.9.102 Limites de fonctionnement des déclencheurs

La durée minimale d'ouverture des déclencheurs shunt d'ouverture et la durée minimale de commande des déclencheurs shunt de fermeture à la tension d'alimentation assignée ne doit pas être inférieure à 2 ms.

Pour prévenir toute manœuvre intempestive causée par des tensions parasites qui peuvent être présentes dans les circuits de commande, la tension d'alimentation minimale pour la manœuvre des déclencheurs shunt ne doit pas être inférieure à 20 % de la tension d'alimentation assignée.

6.9.103 Puissance consommée par les déclencheurs

La puissance consommée par les déclencheurs shunt, d'ouverture ou de fermeture, d'un interrupteur de contournement tripolaire ne doit pas dépasser 1 200 VA. Pour certaines conceptions d'interrupteurs de contournement, des valeurs plus élevées peuvent être nécessaires.

6.10 Indication de la pression / du niveau

Le 6.10 de l'IEC 62271-1:2017 s'applique.

6.10.101 Verrouillages à basse et à haute pression

Tous les interrupteurs de contournement à accumulation d'énergie dans des réservoirs à gaz ou dans des accumulateurs hydrauliques (voir 6.6.2 de l'IEC 62271-1:2017) et tous les interrupteurs de contournement utilisant un gaz comprimé pour le contournement et l'insertion (voir 5.103), à l'exception des appareils à pression scellés, doivent être équipés d'un dispositif de verrouillage à basse pression, et peuvent aussi être équipés d'un dispositif de verrouillage à haute pression, réglés pour fonctionner aux valeurs limites appropriées de la pression ou à l'intérieur des limites de pression indiquées par le constructeur.

6.11 Plaques signalétiques

Le 6.11 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants: les plaques signalétiques d'un interrupteur de contournement et de ses dispositifs de manœuvre doivent être marquées conformément au Tableau 2.

Les bobines des dispositifs de manœuvre doivent porter un repère permettant de retrouver les indications complètes chez le constructeur.

Les déclencheurs doivent porter les indications appropriées.

Tableau 2 – Informations sur la plaque signalétique

	Abré viation	Unité	Interrupteur de contour- nement ^b	Dispositif de manœuvre ^b	Condition: marquage seulement exigé si
1	2	3	4	5	6
Nom du constructeur			X	X	
Désignation de type et numéro de série			X	X	
Tension assignée par rapport à la terre	U_{re}	kV	X		
Tension assignée entre les bornes de l'interrupteur de contournement	U_{rp}	kV	X		
Tension de tenue assignée aux chocs de foudre par rapport à la terre	U_{pe}	kV	X		
Tension de tenue assignée aux chocs de foudre entre les bornes de l'interrupteur de contournement	U_{pp}	kV	X		
Tension de tenue assignée aux chocs de manœuvre par rapport à la terre	U_{se}	kV	Y		U_{re} supérieure ou égale à 300 kV
Tension de tenue assignée aux chocs de manœuvre entre les bornes de l'interrupteur de contournement	U_{sp}	kV	Y		U_{rp} supérieure ou égale à 300 kV
Fréquence assignée	f_r	Hz	X		les caractéristiques assignées ne sont pas applicables simultanément à 50 Hz et 60 Hz
Courant permanent assigné	I	A	X		
Courant de courte durée admissible assigné	I_k	kA	X		
Valeur de crête du courant admissible assigné	I_p	kA	X		
Durée de court-circuit assignée	t_k	s	Y		différente de 1 s
Courant assigné de contournement	I_{BP}	kA	X		
Fréquence du courant assigné de contournement	f_{BP}	Hz	X		
Courant assigné d'insertion (dans le circuit de contournement)	I_{INS}	A	X		
Tension assignée de réinsertion	U_{INS}	kV	X		
Pression de remplissage pour la manœuvre ^a	P_{rm}	MPa		Y	Si applicable
Pression de remplissage pour l'isolement, le contournement et l'insertion ^a	P_{re}	MPa	Y		Si applicable
Pression d'alarme pour la manœuvre ^a	P_{am}	MPa		Y	Si applicable
Pression d'alarme pour l'isolement, le contournement et l'insertion ^a	P_{ae}	MPa	Y		Si applicable
Pression minimale de fonctionnement pour la manœuvre ^a	P_{mm}	MPa		Y	Si applicable
Pression minimale de fonctionnement pour le contournement, l'insertion et l'isolement ^a	P_{me}	MPa	Y		Si applicable
Tension(s) d'alimentation assignée(s) des circuits auxiliaires et de commande. Spécifier courant continu/courant alternatif (avec la fréquence assignée)	U_a	V		X	
Type et masse du fluide (liquide ou gaz) pour l'isolement	M_f	kg	X		

	Abré- viation	Unité	Interrupteur de contour- nement ^b	Dispositif de manœuvre ^b	Condition: marquage seulement exigé si
Masse de l'interrupteur de contournement (y compris tout fluide)	<i>M</i>	kg	Y	Y	supérieure à 300 kg
Séquence de manœuvres assignée			X		
Année de fabrication			X		
Température ambiante minimale et maximale		°C	Y	Y	Si différente de -5 °C et 40 °C
Classification			Y		différente de M1
Date de diffusion de la norme de référence			X	X	
NOTE Les abréviations de la colonne 2 peuvent être utilisées à la place des termes de la colonne 1. Lorsque les termes de la colonne 1 sont employés, il n'est pas nécessaire de faire apparaître le mot "assigné".					
^a Pression absolue (abs.) ou pression relative (rel.) à indiquer sur la plaque signalétique. ^b X = le marquage de ces valeurs est obligatoire; pour ces valeurs, les indications qui n'apparaissent pas sur la plaque sont réputées avoir une valeur nulle; Y = le marquage de ces valeurs dépend des conditions figurant à la colonne 6.					

6.12 Dispositifs de verrouillage

Le 6.12 de l'IEC 62271-1:2017 s'applique.

6.13 Indicateur de position

Le 6.13 de l'IEC 62271-1:2017 s'applique.

6.14 Degrés de protection procurés par les enveloppes

Le 6.14 de l'IEC 62271-1:2017 s'applique.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le 6.15 de l'IEC 62271-1:2017 s'applique.

6.16 Étanchéité au gaz et au vide

Le 6.16 de l'IEC 62271-1:2017 s'applique.

6.17 Étanchéité des systèmes de liquide

Le 6.17 de l'IEC 62271-1:2017 s'applique.

6.18 Risque de feu (inflammabilité)

Le 6.18 de l'IEC 62271-1:2017 s'applique.

6.19 Compatibilité électromagnétique (CEM)

Le 6.19 de l'IEC 62271-1:2017 s'applique.

6.20 Émission de rayons X

Le 6.20 de l'IEC 62271-1:2017 s'applique uniquement aux ampoules à vide utilisées comme interrupteurs de contournement.

6.21 Corrosion

Le 6.21 de l'IEC 62271-1:2017 s'applique.

6.22 Niveaux de remplissage pour l'isolement, le contournement, l'insertion et/ou la manœuvre

Le 6.22 de l'IEC 62271-1:2017 s'applique.

6.101 Exigences de simultanéité au sein d'un pôle

Si un pôle possède plusieurs éléments de contournement connectés en série, la différence maximale entre les instants de séparation des contacts ou du toucher des contacts de ces éléments de contournement en série ne doit pas dépasser un huitième de période de la fréquence assignée.

NOTE L'écart de simultanéité entre les pôles n'est normalement pas pris en compte à moins qu'une manœuvre monopolaire d'un interrupteur de contournement soit interdite pour le fonctionnement du réseau.

6.102 Exigence générale de fonctionnement

Un interrupteur de contournement, y compris ses organes de manœuvre, doit pouvoir effectuer sa séquence de manœuvres assignée (5.101) conformément aux dispositions correspondantes de 6.5 à 6.9 et de 6.103, pour toute température ambiante de sa classe telle qu'elle est définie dans l'Article 4 de l'IEC 62271-1:2017.

Cette exigence ne s'applique pas aux organes de manœuvre manuels auxiliaires; lorsque ces organes sont fournis, ils ne doivent être utilisés que pour l'entretien et pour des manœuvres de secours sur un circuit hors tension.

Les interrupteurs de contournement munis de dispositifs de chauffage doivent être conçus pour autoriser une manœuvre de fermeture à la température ambiante minimale, définie par la classe de températures, lorsque le chauffage ne fonctionne pas pendant une durée minimale de 2 h.

6.103 Limites de pression des fluides pour la manœuvre

Le constructeur doit indiquer les pressions minimales et maximales du fluide pour la manœuvre pour lesquelles l'interrupteur de contournement est capable de fonctionner suivant ses caractéristiques assignées et auxquelles les dispositifs de verrouillage à basse et haute pressions appropriés doivent être réglés (voir 6.10.101). Le constructeur doit indiquer les pressions minimales de fonctionnement pour la manœuvre, le contournement et l'insertion (voir 3.7.135 et 3.7.136).

Le constructeur peut spécifier les limites de pression pour lesquelles l'interrupteur de contournement est capable d'effectuer chacune des performances suivantes:

- a) établir son courant assigné de contournement, c'est-à-dire une manœuvre "C";
- b) réinsérer son courant assigné d'insertion (dans le circuit de contournement), suivi immédiatement de l'établissement de son courant assigné de contournement, c'est-à-dire un cycle de manœuvre "OC";
- c) pour les interrupteurs de contournement prévus pour la réinsertion automatique rapide: l'établissement de son courant assigné de contournement suivi, après un intervalle de temps t de la séquence de manœuvres assignée (5.101), par la réinsertion de son courant assigné d'insertion (dans le circuit de contournement), immédiatement suivie par un nouvel établissement de son courant assigné de contournement, c'est-à-dire une séquence de manœuvres "C – t – OC".

L'interrupteur de contournement doit comporter des réserves d'énergie de capacité suffisante pour lui permettre d'accomplir de façon satisfaisante les manœuvres appropriées aux pressions minimales correspondantes indiquées.

6.104 Orifices d'évacuation

Les orifices d'évacuation sont des dispositifs qui permettent l'échappement délibéré de la pression contenue dans un interrupteur de contournement pendant une manœuvre.

NOTE Cela est applicable aux interrupteurs de contournement à air comprimé et à huile.

Les orifices d'évacuation des interrupteurs de contournement doivent être placés de telle sorte que l'évacuation des vapeurs d'huile, du gaz ou des deux, ne provoque pas d'amorçage électrique et soit dirigée en dehors de toute zone dans laquelle une personne quelconque est susceptible de se trouver. La distance nécessaire de sécurité doit être indiquée par le constructeur.

La construction doit être telle que le gaz ne puisse s'accumuler à un endroit quelconque où l'inflammation peut être provoquée, pendant ou après la manœuvre, par des étincelles dues à la manœuvre normale de l'interrupteur de contournement ou de ses équipements auxiliaires.

6.105 Durées

Se reporter aux Figures 2, 3 et 4.

Des valeurs peuvent être assignées pour les durées suivantes:

- durée d'ouverture (à vide);
- durée de fermeture (à vide);
- durée de fermeture-ouverture (à vide);
- durée d'ouverture-fermeture (à vide).

Les durées se rapportent

- aux tensions d'alimentation assignées des dispositifs de fermeture et d'ouverture et des circuits auxiliaires et de commande (voir 5.9);
- à la fréquence d'alimentation assignée des dispositifs de fermeture et d'ouverture et des circuits auxiliaires (voir 5.10);
- à la pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue (voir 5.11);
- niveaux de remplissage assignés pour l'isolement et/ou la manœuvre (voir 5.11);
- à la température de l'air ambiant de $20\text{ °C} \pm 5\text{ °C}$.

NOTE La variation de la durée d'arc et de la durée de préarc ne permet pas d'assigner une valeur à la durée de contournement ou à la durée de contournement-insertion.

6.106 Charges mécaniques statiques

Les interrupteurs de contournement doivent être conçus de manière à résister et à fonctionner correctement quand des contraintes mécaniques résultant de la glace, du vent et du raccordement des conducteurs leur sont appliquées. Cette capacité de l'interrupteur de contournement est prouvée par des calculs, si cela est exigé.

La couche de glace et la pression du vent sur l'interrupteur de contournement doivent être conformes aux indications de l'Article 4 de l'IEC 62271-1:2017.

Quelques exemples d'efforts statiques dus au vent, à la glace et au poids sur des conducteurs flexibles et tubulaires raccordés sont donnés dans le Tableau 3 à titre de recommandation.

L'effort de traction dû aux conducteurs raccordés est défini comme s'appliquant à l'extrémité de la borne de l'interrupteur de contournement.

Le constructeur doit tenir compte du fait que ces efforts peuvent être appliqués simultanément.

Tableau 3 – Exemples d'efforts statiques horizontaux et verticaux pour l'essai avec des efforts statiques aux bornes

Plage de tensions assignées par rapport à la terre	Plage de courants assignés	Effort statique horizontal F_{th}		Effort statique vertical (vers le haut ou vers le bas de l'axe vertical) F_{tv}
U_{re} kV	I_r A	Longitudinal F_{thA} N	Transversal F_{thB} N	
< 100	800 à 1 250	500	400	500
< 100	1 600 à 2 500	750	500	750
100 à 170	1 250 à 2 500	1 000	750	750
100 à 170	2 500 à 4 000	1 250	750	1 000
245 à 362	1 600 à 4 000	1 250	1 000	1 250
420 à 800	2 000 à 4 000	1 750	1 250	1 500
1 100 à 1 200	4 000 à 6 300	3 500	3 000	2 500

7 Essais de type

7.1 Généralités

7.1.1 Principes fondamentaux

Le 7.1.1 de l'IEC 62271-1:2017 s'applique généralement avec les ajouts suivants.

Les essais de type pour les interrupteurs de contournement sont donnés dans le Tableau 4.

Pour les essais de type, les tolérances sur les grandeurs d'essais sont données dans l'Annexe A.

En principe, chaque essai de type doit être effectué sur un interrupteur de contournement à l'état neuf et propre. Dans le cas des interrupteurs de contournement qui utilisent le SF₆ pour l'isolement, le contournement et l'insertion et/ou la manœuvre, la qualité du gaz doit au moins satisfaire aux critères d'acceptation de l'IEC 60480.

La responsabilité du constructeur est limitée aux valeurs assignées spécifiées et non aux valeurs obtenues au cours des essais de type.

L'incertitude des mesurages effectués par un oscillographe ou par des équipements équivalents (par exemple enregistreur de transitoire), incluant tous ses dispositifs associés, sur les grandeurs qui définissent les caractéristiques assignées (par exemple courant de

contournement, tension appliquée et tension de rétablissement) doit être de $\pm 5\%$ (soit un facteur d'élargissement de 2,0).

NOTE Pour la signification du facteur d'élargissement, se référer au Guide ISO/IEC 98-1:2009.

Tableau 4 – Essais de type

Essais de type obligatoires	Paragraphe
Essais diélectriques	7.2
Mesurage de la résistance du circuit principal	7.4
Essais d'échauffement	7.5
Essais au courant de courte durée et à la valeur de crête du courant admissible	7.6
Essais d'étanchéité	7.8
Essais complémentaires sur les circuits auxiliaires et de commande	7.10
Essai de fonctionnement mécanique à la température de l'air ambiant	7.101.2
Essais de courant de contournement	7.103.2
Essais de courant d'insertion	7.103.3
Essais de type obligatoires s'il y a lieu	Paragraphe
Essais de tension de perturbation radioélectrique	7.3
Vérification du degré de protection	7.7
Essais de compatibilité électromagnétique	7.9
Procédure d'essai des rayonnements X pour les ampoules de vide	7.11
Essais d'endurance mécanique accrue sur les interrupteurs de contournement prévus pour des exigences spéciales de service	7.101.2.4
Essais à haute et à basse températures	7.101.3
Essais pour vérifier le fonctionnement dans des conditions sévères de formation de glace	7.101.5

7.1.2 Informations pour l'identification des objets d'essai

Le 7.1.2 de l'IEC 62271-1:2017 s'applique.

7.1.3 Informations à inclure dans les rapports d'essais de type

Le 7.1.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

D'autres détails concernant les enregistrements et les rapports d'essais de type pour l'établissement du courant de contournement et les essais d'insertion sont donnés à l'Annexe B.

7.1.101 Essais non valables

Dans le cas d'essais non valables, il peut devenir nécessaire d'effectuer un nombre d'essais supérieur à celui qu'exige le présent document. Un essai non valable est un essai au cours duquel au moins un paramètre d'essai exigé par le document n'est pas atteint. Cela comprend, par exemple, les courants, les tensions, les temps, de même que les exigences de synchronisme sur l'onde (si cela est spécifié) et les particularités complémentaires des essais synthétiques comme la manœuvre correcte de l'interrupteur auxiliaire et le temps d'injection correct.

Tout écart par rapport au présent document peut rendre l'essai plus ou moins sévère. Quatre cas différents sont envisagés dans le Tableau 5.

La partie non valable d'une séquence d'essai peut être répétée sans reconditionnement de l'interrupteur de contournement. En cas de défaillance de l'interrupteur de contournement au cours de ces essais supplémentaires, ou à la discrétion du constructeur, l'interrupteur de contournement peut être reconditionné et la séquence d'essai complète répétée. Dans ces cas, le rapport d'essai doit mentionner les essais non valables.

Si l'enregistrement d'une manœuvre ne peut pas être produit pour des raisons techniques, cette manœuvre est considérée comme valable dans la mesure où il peut être démontré par un autre moyen que l'interrupteur de contournement n'a pas été en défaut et que les valeurs d'essai exigées étaient conformes.

Tableau 5 – Essais non valables

Conditions d'essai par rapport au présent document	Interrupteur de contournement	
	Réussit	Échoue
Plus sévère	Essai valable, résultat accepté	Essai à refaire avec les paramètres corrects Modification de la conception de l'interrupteur de contournement non exigée
Moins sévère	Essai à refaire avec les paramètres corrects Modification de la conception de l'interrupteur de contournement non exigée	L'interrupteur de contournement a échoué à l'essai. Une modification de la conception de l'interrupteur de contournement est nécessaire pour améliorer ses performances Essai à refaire avec l'interrupteur de contournement modifié

7.1.102 Répétition des essais de type pour les interrupteurs de contournement avec des mécanismes d'entraînement alternatifs

Les essais de type suivants doivent être répétés sur les interrupteurs de contournement avec des mécanismes d'entraînement alternatifs:

- essais de fonctionnement mécanique à température ambiante (selon 7.101.2);
- essais à haute et à basse températures (selon 7.101.3);
- essai d'établissement du courant de contournement (selon 7.102.7);
- essais au courant de courte durée admissible et à la valeur de crête du courant admissible sur les interrupteurs de contournement ayant des contacts principaux de type à pression directe (selon 7.6).

7.2 Essais diélectriques

7.2.1 Généralités

Le 7.2.1 de l'IEC 62271-1:2017 s'applique.

7.2.2 Conditions de l'air ambiant pendant les essais

Le 7.2.2 de l'IEC 62271-1:2017 s'applique.

7.2.3 Modalités des essais sous pluie

Le 7.2.3 de l'IEC 62271-1:2017 s'applique avec la note suivante:

NOTE Pour les interrupteurs de contournement à cuve mise à la terre, les essais sous pluie peuvent être omis lorsque les traversées ont été soumises aux essais au préalable conformément à la norme IEC applicable.

7.2.4 Disposition de l'appareil

Le 7.2.4 de l'IEC 62271-1:2017 s'applique.

7.2.5 Conditions de réussite des essais

Le 7.2.5 de l'IEC 62271-1:2017 s'applique avec la modification suivante:

La procédure d'essai B suivante, adaptée pour des appareils de connexion comprenant des isolations autorégénératrices et non autorégénératrices, est la procédure d'essai préférentielle pour les interrupteurs de contournement. L'interrupteur de contournement a réussi les essais aux chocs si les conditions suivantes sont remplies:

- a) chacune des séries a au moins 15 essais;
- b) aucune décharge disruptive ne doit se produire sur l'isolation non autorégénératrice. Cela est confirmé par 5 essais consécutifs de tenue aux chocs suivant la dernière décharge disruptive;
- c) le nombre de décharges disruptives ne doit pas dépasser deux pendant chaque série complète.

Cette procédure conduit à un nombre maximal de 25 chocs par série.

La procédure C de l'IEC 60060-1:2010 peut être utilisée lorsque chacun des trois pôles est soumis aux essais.

Si des décharges disruptives se produisent et si la preuve que les décharges disruptives étaient exclusivement sur l'isolation autorégénératrice ne peut être donnée, l'interrupteur de contournement doit être démonté après les essais diélectriques et inspecté. Si un dommage de l'isolation non autorégénératrice est observé, l'interrupteur de contournement a échoué à l'essai.

Si le facteur de correction atmosphérique K_1 est inférieur à 1,00 mais supérieur à 0,95, il est permis de suivre le critère énoncé en 7.2.5 de l'IEC 62271-1:2017 si le facteur de correction n'est pas appliqué durant les essais. Si dans ces conditions, une ou deux décharges disruptives, sur les 15 chocs, se produisent sur l'isolation externe, la série d'essais particulière qui a révélé un ou des contournements est répétée avec le facteur de correction approprié de façon à ce qu'aucune décharge disruptive externe ne se produise.

Pour les interrupteurs de contournement d'appareillage à isolation gazeuse soumis aux essais avec des traversées d'essai qui ne font pas partie de l'interrupteur de contournement, il convient de ne pas prendre en compte les contournements aux bornes des traversées d'essai.

Il convient que le laboratoire détermine l'emplacement des décharges disruptives observées en utilisant des moyens de détection suffisants, comme des photographies, des enregistrements vidéo, une inspection interne.

7.2.6 Application de la tension d'essai et conditions d'essai

Le 7.2.6 de l'IEC 62271-1:2017 s'applique avec les modifications suivantes:

- La tolérance applicable aux chocs préliminaires pour les ampoules à vide ne s'applique pas aux interrupteurs de contournement;
- Le nombre de chocs réduits, avant un essai ou avant un changement de polarité, doit être limité à deux chocs appliqués entre 60 % et 80 % de la tension de tenue assignée.

7.2.7 Essais des interrupteurs de contournement avec $U_{re} \leq 245 \text{ kV}$ ou $U_{rp} \leq 245 \text{ kV}$

Le 7.2.7 de l'IEC 62271-1:2017 s'applique. Il est seulement nécessaire de réaliser cette série d'essais pour la partie de l'isolement qui répond aux critères ci-dessus.

7.2.7.1 Généralités

Le 7.2.7.1 de l'IEC 62271-1:2017 s'applique.

7.2.7.2 Essais de tension à fréquence industrielle

Le 7.2.7.2 de l'IEC 62271-1:2017 s'applique avec la note suivante:

NOTE Pour les interrupteurs de contournement à cuve mise à la terre, les essais sous pluie peuvent être omis lorsque les traversées ont été soumises aux essais au préalable conformément à la norme IEC applicable.

7.2.7.3 Essais de tension de choc de foudre

Le 7.2.7.3 de l'IEC 62271-1:2017 s'applique.

7.2.8 Essais des interrupteurs de contournement avec $U_{re} > 245 \text{ kV}$ ou $U_{rp} > 245 \text{ kV}$

7.2.8.1 Généralités

Le 7.2.8.1 de l'IEC 62271-1:2017 s'applique. Il est seulement nécessaire de réaliser cette série d'essais pour la partie de l'isolement qui répond aux critères ci-dessus.

7.2.8.2 Essais de tension à fréquence industrielle

Le 7.2.8.2 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

La procédure d'essai qui suit la méthode en variante est plus sévère que celle qui suit la méthode préférentielle.

7.2.8.3 Essais à la tension de choc de manœuvre

Le 7.2.8.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Les essais à sec doivent uniquement être effectués à la polarité positive. L'interrupteur de contournement étant en position de fermeture, une tension d'essai égale à la tension de tenue assignée par rapport à la terre doit être appliquée pour chaque condition d'essai du Tableau 10 de l'IEC 62271-1:2017.

L'interrupteur de contournement étant en position d'ouverture, une tension d'essai égale à la tension de tenue assignée entre les bornes de l'interrupteur de contournement ouvert doit être appliquée pour chaque condition d'essai du Tableau 10 de l'IEC 62271-1:2017.

7.2.8.4 Essais de tension de choc de foudre

Le 7.2.8.4 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

L'interrupteur de contournement étant en position de fermeture, une tension d'essai égale à la tension de tenue assignée par rapport à la terre doit être appliquée pour chaque condition d'essai du Tableau 10 de l'IEC 62271-1:2017.

L'interrupteur de contournement étant en position d'ouverture, une tension d'essai égale à la tension de tenue assignée entre les bornes de l'interrupteur de contournement ouvert doit être appliquée pour chaque condition d'essai du Tableau 10 de l'IEC 62271-1:2017.

7.2.9 Essais de pollution artificielle pour les isolateurs d'extérieur

Le 7.2.9 de l'IEC 62271-1:2017 s'applique.

7.2.10 Essais de décharges partielles

Le 7.2.10 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

La réalisation d'essais de décharges partielles sur l'interrupteur de contournement complet n'est normalement pas exigée. Toutefois, pour les interrupteurs de contournement comportant des éléments auxquels s'applique une norme particulière de l'IEC, et si cette norme particulière exige des mesurages de décharges partielles (par exemple les traversées, voir l'IEC 60137), le constructeur doit prouver que ces éléments ont satisfait aux essais de décharges partielles prévus par la norme particulière de l'IEC.

7.2.11 Essais diélectriques sur les circuits auxiliaires et de commande

Le 7.2.11 de l'IEC 62271-1:2017 s'applique.

7.2.12 Essai de tension comme essai de vérification d'état

Le 7.2.12 de l'IEC 62271-1:2017 ne s'applique pas; les essais qui y sont spécifiés sont remplacés par ce qui suit:

Lorsqu'après des essais mécaniques ou climatiques (voir 7.101.1.4), les propriétés d'isolement entre les contacts ouverts d'un interrupteur de contournement ne peuvent pas être vérifiées avec suffisamment de confiance par examen visuel, un essai de tenue de tension à fréquence industrielle à sec, conformément à 7.2.12 de l'IEC 62271-1:2017, entre les bornes de l'interrupteur de contournement ouvert, doit être appliqué comme vérification d'état. Pour les interrupteurs de contournement sous enveloppe métallique à isolation gazeuse ou à cuve mise à la terre, pour lesquels l'isolation à la terre peut être affectée, un essai de tenue de tension à fréquence industrielle à sec, conformément à 7.2.12 de l'IEC 62271-1:2017, à la terre, avec l'interrupteur de contournement en position fermée, doit également être effectué comme vérification d'état.

Pour un interrupteur de contournement de type isolation dans l'air avec de multiples éléments identiques selon 7.102.4.2.3, l'essai de tension à titre de vérification d'état peut être réalisé comme un essai sur éléments séparés.

Pour les interrupteurs de contournement sous vide placés dans une enveloppe métallique à isolation gazeuse, l'essai de tension à titre de vérification d'état peut ne pas être suffisant. Dans de tels cas, l'intégrité du vide doit être démontrée.

Lorsqu'après des essais de contournement et d'insertion (voir 7.102.9), un essai de tension est réalisé à titre de vérification d'état, les conditions suivantes doivent s'appliquer.

Pour les interrupteurs de contournement ayant une disposition asymétrique des pièces de passage du courant, les connexions doivent être interverties. Les essais complets doivent être effectués une fois pour chaque disposition des connexions.

Il est seulement nécessaire de réaliser cette série d'essais pour la partie de l'isolement qui répond aux critères ci-dessous.

- Interrupteurs de contournement avec $U_{re} \leq 72,5 \text{ kV}$ ou $U_{rp} \leq 72,5 \text{ kV}$

Un essai de tension à la fréquence industrielle de 1 min doit être effectué. La tension d'essai doit être égale à 80 % de la valeur indiquée au Tableau 1 ou au Tableau 2, colonne (2) de l'IEC 62271-1:2017.

- Interrupteurs de contournement avec $72,5 \text{ kV} < U_{re} \leq 245 \text{ kV}$ ou $72,5 \text{ kV} < U_{rp} \leq 245 \text{ kV}$

Un essai de tension de choc doit être effectué. La valeur de crête de la tension de choc doit être égale à 60 % de la valeur la plus élevée applicable du Tableau 1 ou du Tableau 2, colonne (4) de l'IEC 62271-1:2017.

- Interrupteurs de contournement avec $300 \text{ kV} \leq U_{re} \leq 420 \text{ kV}$ ou $300 \text{ kV} \leq U_{rp} \leq 420 \text{ kV}$

Un essai de tension de choc doit être effectué. La valeur de crête de la tension de choc doit être égale à 80 % de la tension assignée de tenue aux chocs de manœuvre indiquée au Tableau 3 ou au Tableau 4 de l'IEC 62271-1:2017. La tension assignée de tenue aux chocs de manœuvre doit être prise dans la colonne (4). La valeur de référence pour la vérification d'état doit être prise dans la même colonne.

- Interrupteurs de contournement avec $550 \text{ kV} \leq U_{re} \leq 800 \text{ kV}$ ou $550 \text{ kV} \leq U_{rp} \leq 800 \text{ kV}$

Un essai de tension de choc doit être effectué. La valeur de crête de la tension de choc doit être égale à 90 % de la tension assignée de tenue aux chocs de manœuvre indiquée au Tableau 3 ou au Tableau 4 de l'IEC 62271-1:2017. La tension assignée de tenue aux chocs de manœuvre doit être prise dans la colonne (4) de ce tableau. La valeur de référence pour la vérification d'état doit être prise dans la même colonne.

Lorsqu'un essai de tension de choc doit être effectué, cinq chocs de chaque polarité doivent être appliqués aux bornes de l'appareil de connexion et par rapport à la terre (si exigé). L'interrupteur de contournement doit être considéré comme ayant réussi l'essai, s'il ne se produit aucune décharge disruptive.

Pour l'essai de tension de choc, les équipements d'essai synthétique du laboratoire de puissance peuvent être utilisés. La forme d'onde de la tension de choc doit être, soit un choc de manœuvre normal, soit une forme d'onde conforme à la tension transitoire de rétablissement (TTR) spécifiée pour le défaut aux bornes T10, tel que décrit dans l'IEC 62271-100. Pour les essais avec la forme d'onde conforme à T10, des tolérances de -10 % à $+200$ % sont autorisées sur le temps t_3 .

L'isolement aux bornes du pôle et la terre ne peut généralement pas être vérifié simultanément, car les niveaux d'isolement aux bornes du pôle sont différents des niveaux d'isolement par rapport à la terre. Un essai de vérification d'état supplémentaire peut s'avérer nécessaire comme mentionné ci-dessus.

Pour les interrupteurs de contournement de type isolation dans l'air, l'isolation du pôle à terre n'est généralement pas influencée par les opérations de contournement et d'insertion et l'essai de tension comme vérification d'état par rapport à la terre n'est généralement pas exigé. Pour les interrupteurs de contournement à cuve mise à la terre, l'isolation par rapport à la terre peut être affectée par les opérations de contournement et d'insertion et il convient que l'essai de tension comme vérification d'état, si cela est exigé, soit aussi effectué entre phase et terre. Si l'essai est effectué avec des impulsions de type TTR avec la forme d'onde T10, l'équivalence avec l'impulsion de choc de manœuvre normalisée est maintenue si les règles suivantes sont appliquées:

- il convient que l'amortissement de la tension transitoire de rétablissement (TTR) soit tel que la deuxième crête de l'oscillation de la TTR ne dépasse pas 80 % de la première;
- 2,5 ms environ après la crête, il convient que la valeur réelle de la tension de rétablissement soit de l'ordre de 50 % de la valeur de crête.

NOTE Des essais comparatifs ont montré qu'il n'y a pratiquement pas de différence dans le comportement des disjoncteurs, à l'état neuf ou usagé, quand l'essai est effectué avec des chocs de manœuvre normalisée ou avec des impulsions de type TTR avec une forme d'onde conforme au défaut aux bornes T10.

7.3 Essais de tension de perturbation radioélectrique

Le 7.3 de l'IEC 62271-1:2017 s'applique avec l'ajout suivant.

Les essais peuvent être effectués sur un pôle de l'interrupteur de contournement en position de fermeture uniquement. Pendant les essais, l'interrupteur de contournement doit être équipé de tous les accessoires tels que condensateurs de répartition, anneaux de garde, connecteurs HT, etc., qui peuvent influencer la performance de tension de perturbation radioélectrique.

Voir aussi le 7.9.1.1.

NOTE Si l'interrupteur de contournement fait partie intégrante de la plate-forme de condensateurs série et que des essais de tension de perturbation radioélectrique ont été effectués sur la plate-forme, l'essai de tension de perturbation radioélectrique sur l'interrupteur de contournement est considéré comme couvert.

7.4 Mesurage de la résistance

Les Paragraphes 7.4.1 à 7.4.3 de l'IEC 62271-1:2017 s'appliquent. Le 7.4.4 est remplacé par ce qui suit.

7.4.4 Mesurage de la résistance des contacts et des connexions dans le circuit principal sous forme de vérification d'état

7.4.4.101 Procédure d'essai de mesure de la résistance

Lorsque des mesurages de la résistance sont requis à titre de vérification d'état après un essai spécifique, la procédure suivante doit être appliquée.

La résistance entre les contacts de l'interrupteur de contournement doit être mesurée avant l'essai. Les points de mesure doivent être les points accessibles les plus proches situés de part et d'autre des contacts. Une valeur moyenne de la résistance doit être calculée à partir de trois mesurages. Il convient d'effectuer si possible un cycle de manœuvre à vide d'ouverture / fermeture entre chacun des mesurages. Lorsqu'il n'est pas possible d'effectuer des manœuvres à vide, les trois mesurages doivent être effectués sans manœuvre à vide de l'interrupteur de contournement.

NOTE 1 Il est admis que pour certains essais, il n'est pas pratique (par exemple, si une manipulation de gaz est exigée entre les mesurages) ni possible (par exemple, pendant l'essai au courant permanent en raison de la présence de capteurs de température dans la ou les chambres de l'interrupteur de contournement) d'effectuer des manœuvres à vide entre chacun des trois mesurages de la résistance.

Les mesurages doivent être effectués en courant continu, avec une valeur égale au plein courant permanent assigné (-20 % à 0 %) s'il est inférieur ou égal à 50 A, ou avec une valeur quelconque convenable de courant comprise entre 50 A (inclus) et le courant permanent assigné s'il est supérieur à 50 A.

NOTE 2 Dans certaines conceptions, il peut être seulement réalisable de mesurer en série plusieurs connexions et/ou contacts dans le circuit principal ou même de mesurer les pôles complets d'un interrupteur de contournement au cours des essais de type.

À l'issue de l'essai la résistance doit être mesurée à nouveau en utilisant une procédure identique à celle utilisée pour les mesurages de résistance effectués avant les essais. Avant d'effectuer ce mesurage de la résistance, il est admis de procéder à une certaine mise en condition des contacts sur la base des recommandations du constructeur telles que des cycles de manœuvre à vide ou l'application du courant permanent assigné pendant un certain temps.

Les mesurages de la résistance avant et après l'essai doivent être effectués à la température ambiante avec une différence maximale de 10 K entre eux. L'augmentation de la résistance se calcule par la différence entre la valeur moyenne des mesurages avant et après l'essai.

7.4.4.102 Essais de contournement et d'insertion

Pour les interrupteurs de contournement comportant des ampoules scellées à vie, la vérification de l'état de résistance de l'échantillon d'essai à la fin des essais de contournement et d'insertion est jugée satisfaisante si l'augmentation de la résistance de chaque phase déterminée en 7.4.4.101 n'est pas supérieure à 100 %. Pour d'autres types d'interrupteurs de contournement, l'examen visuel du système de contact est généralement suffisant comme mentionné en 7.102.9.2.