BS EN 62271-109:2009+A1:2013

BSI Standards Publication

High-voltage switchgear and controlgear

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

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National foreword

This British Standard is the UK implementation of EN 62271-109:2009+A1:2013. It is identical to IEC 62271-109:2008 incorporating amendment 1:2013. It supersedes BS EN 62271-109:2009, which is withdrawn.

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

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

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English version

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

(IEC 62271-109:2008)

Appareillage à haute tension - Partie 109: Interrupteurs de contournement pour condensateurs série à courant alternatif (CEI 62271-109:2008)

Hochspannungs-Schaltgeräte und -Schaltanlagen - Teil 109: Wechselstrom-Überbrückungsschalter für Reihenkondensatoren (IEC 62271-109:2008)

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

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

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

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CENELEC

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

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Foreword

The text of document 17A/837/FDIS, future edition 2 of IEC 62271-109, prepared by SC 17A, High-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62271-109 on 2009-03-01.

This European Standard supersedes EN 62271-109:2006.

This standard is to be read in conjunction with EN 62271-100 and EN 62271-1:2008, to which it refers and which is applicable, unless otherwise specified in this standard. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in EN 62271-1. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2009-12-01

– latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2012-03-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62271-109:2008 was approved by CENELEC as a European Standard without any modification.

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

IEC 60071-1	NOTE	Harmonized as EN 60071-1:2006 (not modified).
IEC 60071-2	NOTE	Harmonized as EN 60071-2:1997 (not modified).
IEC 60137	NOTE	Harmonized as EN 60137:2008 (not modified).
IEC 62271-200	NOTE	Harmonized as EN 62271-200:2004 (not modified).
IEC 62271-203	NOTE	Harmonized as EN 62271-203:2004 (not modified).

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Foreword to amendment A1

The text of document 17A/1038/FDIS, future IEC 62271-109:2008/A1, prepared by SC 17A, "High-voltage switchgear and controlgear", of IEC TC 17, "Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62271-109:2009/A1:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-04-02
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-07-02

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Endorsement notice

The text of the International Standard IEC 62271-109:2008/A1:2013 was approved by CENELEC as a European Standard without any modification.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

Publication	Year	Title	EN/HD	Year
IEC 60050-151	2001	International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices	-	-
IEC 60050-436	1990	International Electrotechnical Vocabulary (IEV) - Chapter 436: Power capacitors	-	-
IEC 60050-441	1984	International Electrotechnical Vocabulary (IEV) - Chapter 441: Switchgear, controlgear and fuses	-	-
IEC 60050-604	1987	International Electrotechnical Vocabulary (IEV) - Chapter 604: Generation, transmission and distribution of electricity - Operation	-	-
IEC 60060	Series	High-voltage test techniques	EN 60060	Series
IEC 60143-1	2004	Series capacitors for power systems - Part 1: General	EN 60143-1	2004
IEC 60143-2	1994	Series capacitors for power systems - Part 2: Protective equipment for series capacitor banks	EN 60143-2	1994
IEC 60296	- [1)]	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear	EN 60296 + corr. September	2004 [2)] 2004
IEC 60376	- [1)]	Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment	EN 60376	2005 [2)]
IEC 60480	- [1)]	Guidelines for the checking and treatment of sulphur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use	EN 60480	2004 [2)]
IEC 60529	- [1)]	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 [2)] 1993
IEC 62271-1	2007	High-voltage switchgear and controlgear - Part 1: Common specifications	EN 62271-1	2008
IEC 62271-100	2008	High-voltage switchgear and controlgear - Part 100: Alternating current circuit-breakers	EN 62271-100	2009

[1)] Undated reference.

[2)] Valid edition at date of issue.

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Publication	Year	Title	EN/HD	Year
IEC 62271-101	- [1)]	High-voltage switchgear and controlgear - Part 101: Synthetic testing	EN 62271-101	2006 [2)]
IEC 62271-102 + corr. April + corr. May	2001 2002 2003	High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches	EN 62271-102 + corr. March	2002 2005
IEC/TR 62271-303	- [1)]	High-voltage switchgear and controlgear - Part 303: Use and handling of sulphur hexafluoride (SF_6)	-	-

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Annex ZB
(informative)

A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CENELEC national member.

This European Standard does not fall under any Directive of the EU.

In the relevant CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

Clause	Deviation
1.1	**Italy** (I.S.P.E.S.L. (*) Rules, 95 revision: VSR.8.B.1; VSR.8.B.2; M.15.D.2 to .4.) For high-voltage alternating current circuit-breakers containing gas-filled compartments, the design pressure is limited to a maximum of 0,5 bar (gauge) and the volume is limited to a maximum of 2 m^3. Gas filled compartments having a design pressure exceeding 0,5 bar (gauge) or a volume exceeding 2 m^3 shall be designed according to Italian pressure vessel code for electrical switchgear (DM1 December 1980 and DM 10 September 1981 published on Gazzetta Ufficiale n°285 dated 16.10.1981). This requirement is not applicable for gas filled compartments having a design pressure exceeding 0,5 bar (gauge) but a volume not exceeding 25 dm^3. Italian laws apply to gas pressurised enclosures made of both insulating and metallic materials with a capacity of 25 litres or above, a design pressure higher than 0,05 kg/cm^2 and a temperature range: -25 °C/+100 °C (only for insulating materials). Moreover, the manufacturer of any electrical equipment which comprehends gas pressurised enclosures shall submit the design of the pressurised enclosures itself to a proper legal Authority indicating the stresses and the loads which have any influence on the design itself. For each of the stresses the manufacturer shall indicate the design values and the relevant computations. Only the use of porcelain type A or S (Aluminous or Siliceous) is permitted. (*) I.S.P.E.S.L.: Istituto Superiore per la Prevenzione e la Sicurezza del Lavoro.

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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 a.c. 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 standard is also applicable to the operating devices of by-pass switches and to their auxiliary equipment.

1.2 Normative references

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

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

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

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

IEC 60296, *Fluids for electrotchnical applications ± Unused mineral insulating oils for transformers and switchgear*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF_6) for use in electrical equipment*

IEC 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use*

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

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

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

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

IEC 62271-102:2001, *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 (SF_6)*

2 Normal and special service conditions

Clause 2 of IEC 62271-1 is applicable.

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 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.

3.1 General terms

3.1.101
switchgear and controlgear
[IEV 441-11-01]

3.1.102
outdoor switchgear and controlgear
[IEV 441-11-05]

3.1.103
short-circuit current
[IEV 441-11-07]

3.1.104
ambient air temperature
[IEV 441-11-13]

3.1.105
temperature rise (of a part of a by-pass switch)
difference between the temperature of the part and the ambient air temperature

3.1.106
overvoltage (in a 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]

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3.1.107
unit test
test made 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 air and the surfaces in contact with open air of solid insulation of the equipment, which are subject to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity, vermin, etc.

[IEV 604-03-02, modified]

3.1.109
internal insulation
internal 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]

3.1.110
self-restoring insulation
insulation which completely recovers its insulating properties after a disruptive discharge

[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

[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

NOTE 1 This term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

NOTE 2 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 only temporary (self-restoring insulation).

NOTE 3 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.

3.1.113
restrike performance
expected probability of restrike during insertion current test-duty as demonstrated by specified type test

NOTE Specific numeric probabilities cannot be applied throughout a by-pass switch service life.

3.1.114
re-ignition (of an a.c. mechanical switching device)
[IEV 441-17-45]

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3.1.115
restrike (of an a.c. mechanical switching device)
[IEV 441-17-46]

3.1.116
non-sustained disruptive discharge (NSDD)
disruptive discharge associated with current interruption, that does not result in the resumption of power frequency current or, in the case of insertion does not result in current in the series capacitor bank

NOTE 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.

3.2 Assemblies

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices

3.4.101
switching device
[IEV 441-14-01]

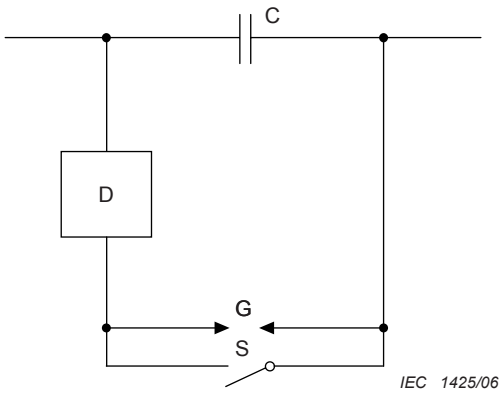
3.4.102
mechanical switching device
[IEV 441-14-02]

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. By-pass switches may be three-pole or single-pole operated

NOTE 1 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 2 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).

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:



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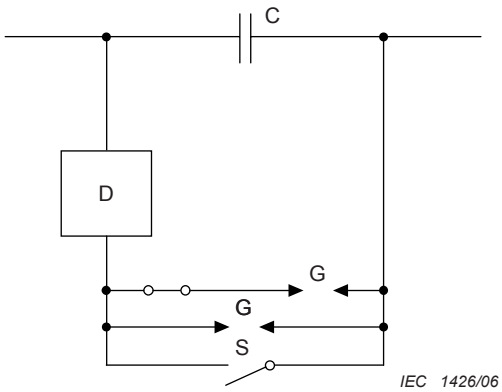
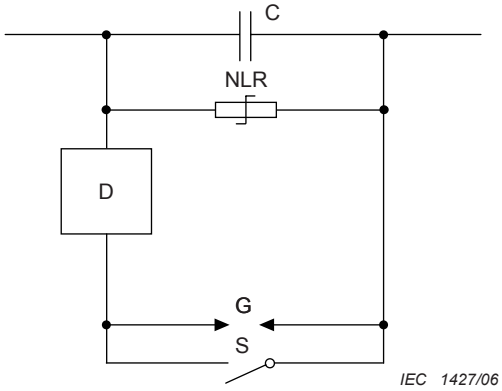
Single gap



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

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

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). This type of by-pass switch is normally used on multi-segmented capacitors where the control of the capacitor impedance is a frequent duty

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3.5 Parts of by-pass switches

3.5.101
pole
[IEV 441-15-01]

3.5.102
main circuit
[IEV 441-15-02]

3.5.103
control circuit
[IEV 441-15-03]

3.5.104
auxiliary circuit
[IEV 441-15-04]

3.5.105
contact
[IEV 441-15-05]

3.5.106
contact piece
[IEV 441-15-06]

3.5.107
main contact
[IEV 441-15-07]

3.5.108
arcing contact
[IEV 441-15-08]

3.5.109
control contact
[IEV 441-15-09]

3.5.110
auxiliary contact
[IEV 441-15-10]

3.5.111
auxiliary switch
[IEV 441-15-11]

3.5.112
™a∫ contact;
make contact
[IEV 441-15-12]

3.5.113
™b∫ contact;
break contact
[IEV 441-15-13]

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3.5.114
sliding contact
[IEV 441-15-15]

3.5.115
rolling contact
[IEV 441-15-16]

3.5.116
release
[IEV 441-15-17]

3.5.117
arc control device
[IEV 441-15-18]

3.5.118
position indicating device
[IEV 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 (or 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 By-pass units and insertion units are normally combined but may be separated. Each unit may have several contacts.

NOTE 2 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 approach to or contact with live parts and against contact with moving parts

[IEV 441-13-01, modified]

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3.5.124
operating mechanism
part of 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 See also A.3.5.111 of IEC 62271-102.

3.5.126
alternative operating mechanism
an alternative operating mechanism is 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 Mechanical characteristics are defined in 6.101.1.1. The use of mechanical characteristics and related requirements are described in Annex G.

NOTE 2 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 A change in the secondary equipment does not lead to an alternative operating mechanism.

3.6 Operation

3.6.101
operation
[IEV 441-16-01]

3.6.102
operating cycle
[IEV 441-16-02]

3.6.103
operating sequence
[IEV 441-16-03]

3.6.104
closing operation
[IEV 441-16-08]

3.6.105
opening operation
[IEV 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
[IEV 441-16-11]

3.6.108
positively driven operation
[IEV 441-16-12]

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3.6.109
dependent power operation
[IEV 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
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

[IEV 441-16-16]

3.6.112
closed position
[IEV 441-16-22]

3.6.113
open position
[IEV 441-16-23]

3.6.114
shunt release
[IEV 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
[IEV 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 which cause the closing operation remain established

3.7 Characteristic quantities

Figures 1 to 3 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.

3.7.101
rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of component, device or equipment

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3.7.102
prospective current (of a circuit and with respect to a switching device or a fuse)
[IEV 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 The definition assumes that the current is made by an ideal by-pass switch, i.e. with 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
⟨A1⟩ 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. This 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 1 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 2 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 3 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 by-pass switch. ⟨A1⟩

3.7.107
(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 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
[IEV 441-17-10]

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3.7.111
short-time withstand current
[IEV 441-17-17]

3.7.112
peak withstand current
[IEV 441-17-18]

3.7.113
applied voltage
[IEV 441-17-24]

3.7.114
recovery voltage
[IEV 441-17-25]

3.7.115
power-frequency recovery voltage
[IEV 441-17-27]

3.7.116
peak arc voltage
[IEV 441-17-30]

3.7.117
clearance
[IEV 441-17-31]

3.7.118
clearance between poles
[IEV 441-17-32]

3.7.119
clearance to earth
[IEV 441-17-33]

3.7.120
clearance between open contacts
[IEV 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.

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 1 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 2 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.

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3.7.122
arcing time (of a multipole switching device)
interval of time between the instant of the first initiation of an arc and the instant of final arc extinction in all poles

[IEV 441-17-38]

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 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 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 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 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 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 The dead time may vary, e.g. due 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 The by-pass insertion time may vary due to the variation of the pre-arcing and arcing times.

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NOTE 2 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
r.m.s. value of sinusoidal power-frequency voltage that the by-pass switch can withstand during tests made under specified conditions and for a specified time

[IEV 604-03-40, modified]

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

3.7.135
minimum functional pressure for operation
pressure, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa, 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 device becomes necessary

NOTE This pressure is often designated as interlocking pressure (refer to 3.6.5.6 of IEC 62271-1).

3.7.136
minimum functional pressure for by-passing, insertion and insulation
pressure for by-passing, insertion and for insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa, 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 See also 3.6.5.5 of IEC 62271-1.

NOTE 2 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.

3.8 Definitions related to series capacitor banks

3.8.1
capacitor
the word “capacitor” is 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

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3.8.2
overvoltage protector (of a series capacitor)
quick-acting device that limits 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

[IEV 436-03-14, modified]

3.8.3
rated capacitance (of a capacitor)
C_N
capacitance value for which the capacitor has been designed

[IEV 436-01-12, modified]

3.8.4
rated current (of a capacitor)
I_N
r.m.s. value of the alternating current for which the capacitor has been designed

[IEV 436-01-13, modified]

3.8.5
rated reactance (of a capacitor)
X_N
reactance of each phase of the series capacitor at rated frequency and 20 °C dielectric temperature

3.8.6
rated voltage (of a capacitor)
U_N
r.m.s. value of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$

[IEV 436-01-15, modified]

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 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 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

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3.8.11
by-pass current
steady-state r.m.s. 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 load or fault current around the protected parts for a specified time (see Figure 2 of IEC 60143-2)

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
r.m.s. 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)

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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 The protective level may be expressed in terms of the actual peak voltage across a segment or in terms of the 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 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 capacitor bank. The maximum peak value of the capacitor discharge current occurs when the capacitor bank is charged to the protective level U_{PL}

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4 Ratings

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

a) rated voltage to earth and across the by-pass unit;
b) rated insulation level to earth and across the by-pass unit;
c) rated frequency;
d) rated normal current;
e) rated short-time withstand current;
f) rated peak withstand current;
g) rated duration of short-circuit;
h) rated supply voltage of closing and opening devices and of auxiliary circuits;
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.

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

4.1 Rated voltage (U_r)

Subclause 4.1 of IEC 62271-1 is applicable with the following addition.

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4.1.101 Rated voltage to earth (U_{re})

Subclause 4.1 of IEC 62271-1 is applicable.

4.1.102 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/ωC_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.

4.2 Rated insulation level

Subclause 4.2 of IEC 62271-1 is applicable with the following addition.

4.2.101 Rated insulation level to earth

The standard values of rated withstand voltages to earth are given in Tables 1a, 1b, 2a and 2b of IEC 62271-1.

4.2.102 Rated insulation level across the by-pass switch

The standard values of rated insulation voltages across the by-pass switch are given in Tables 1a, 1b, 2a and 2b of IEC 62271-1 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.

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 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 (r.m.s.);

U_{PL} is the protective level.

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 62271-1 is applicable with the following addition:

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

4.4 Rated normal current (I_r) and temperature rise

Subclause 4.4 of IEC 62271-1 is applicable.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 62271-1 is applicable.

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4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 62271-1 is applicable.

4.7 Rated duration of short-circuit (t_k)

Subclause 4.7 of IEC 62271-1 is applicable.

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

Subclause 4.8 of IEC 62271-1 is generally applicable. The tolerance given in 4.8.3 and in 5.8.1 of IEC 62271-1 for shunt opening releases shall be applied to shunt closing releases.

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

Subclause 4.9 of IEC 62271-1 is applicable.

4.10 Rated pressures of compressed gas supply for insulation, operation and/or by-passing and insertion

Subclause 4.10 of IEC 62271-1 is applicable.

4.101 Rated operating sequence

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

$$C - t \pm OC - t' \pm OC$$

Unless otherwise specified:

– t = 0,3 s for by-pass switches intended for rapid auto-reopening (by-passing-insertion time);

– t' = 3 min.

〈A1〉 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 1 Instead of t = 0,3 s, other value: t = 0,2 s is also used for by-pass switches intended for rapid auto-reopening.

NOTE 2 Instead of t' = 3 min., other values: t' = 15 s and t' = 1 min are also used for by-pass switches intended for rapid auto-reopening.

NOTE 3 Other operating sequences may be specified depending upon system requirements. 〈A1〉

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

〈A1〉 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 pre-charged 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. 〈A1〉

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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.

〈A1〉 NOTE 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 prearcing period (see also IEC 60143-2). 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. 〈A1〉

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 kApeak and 125 kA peak

f_{BP}: 500 Hz and 1 000 Hz

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

The rated by-pass insertion current is the r.m.s 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 than bthe rated current of the capacitor bank.

4.104 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 standard 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 of the series capacitor design parameters (capacitive impedance, rated normal current of the capacitor bank, protective level of the overvoltage protector, overload emergency current and power swing). See Annex F for more information.

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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.

4.105 Rated time quantities

Refer to Figures 1, 2, and 3.

Rated values shall be assigned to the following time quantities:

– opening time (no-load);
– maximum closing time (no-load);
– maximum 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 4.8),
– rated supply frequency of closing and opening devices and of auxiliary circuits (see 4.9),
– 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,
– an ambient air temperature of 20 °C ± 5 °C.

NOTE 1 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 2 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.

4.106 Number of mechanical operations

A by-pass switch shall be able to perform the following number of operations (as defined in 6.101.2.3 and Table 3 for type tests) taking into account the programme of maintenance specified by the manufacturer.

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

5 Design and construction

5.1 Requirements for liquids in by-pass switches

Subclause 5.1 of IEC 62271-1 is applicable.

5.2 Requirements for gases in by-pass switches

Subclause 5.2 of IEC 62271-1 is applicable.

5.3 Earthing of by-pass switches

Subclause 5.3 of IEC 62271-1 is applicable.

5.4 Auxiliary equipment

Subclause 5.4 of IEC 62271-1 is applicable with the following additions:

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– 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 1 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 closing time;

NOTE 2 If the current of the shunt closing release is interrupted by the control contact, the closing command should be positively longer than the rated 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 ±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.

5.5 Dependent power operation

Subclause 5.5 of IEC 62271-1 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.

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5.6 Stored energy operation

Subclause 5.6 of IEC 62271-1 is applicable with the following addition to the first paragraph.

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

5.7 Independent manual operation

Subclause 5.7 of IEC 62271-1 is not applicable for by-pass switches.

5.8 Operation of releases

Subclause 5.8 of IEC 62271-1 is generally not applicable and shall be replaced by the following.

5.8.1 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 d.c. – or 85 % in case of a.c. - and 110 % of the rated supply voltage of the closing device (see 4.8), the frequency in the case of a.c. being the rated supply frequency of the closing device (see 4.9).

5.8.2 Shunt opening releases

A shunt opening release shall operate correctly between 85 % and 110 % of the rated supply voltage of the opening device (see 4.8), the frequency in the case of a.c. being the rated supply frequency of the opening device (see 4.9).

5.8.3 Capacitor operation of shunt releases

Subclause 5.8.3 of IEC 62271-1 is applicable.

5.8.4 Under-voltage release

Subclause 5.8.4 of IEC 62271-1 is not applicable to by-pass switches.

5.8.101 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.

5.8.102 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.

5.8.103 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.

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5.9 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 5.6.1 of IEC 62271-1) 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.

5.10 Nameplates

Subclause 5.10 of IEC 62271-1 is applicable with the following additions: the nameplates of a by-pass switch and its operating devices shall be marked in accordance with Table 1.

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.

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Table 1 ± Nameplate information

	Abbre-viation	Unit	By-pass switch	Operating device	Condition: Marking only required if
1	2	3	4	5	6
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 300 kV and above
Rated switching impulse withstand voltage across by-pass switch	U_{sp}	kV	y		Rated voltage 300 kV and above
Rated frequency	f_r	Hz	y		Rating is not applicable at both 50 Hz and 60 Hz
Rated normal current	I_r	A	X		
Rated duration of short circuit	t_k	s	y		Different from 1 s
Rated short-time withstand current	I_k	kA	X		
Rated peak withstand current	I_p	kA	X		
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	P_{rm}	MPa		(X)	
Rated filling pressure for by-passing and insertion	P_{re}	MPa	(X)		
Rated supply voltage of closing and opening devices	U_{op}	V		(X)	
Rated supply frequency of closing and opening devices		Hz		(X)	
Rated supply voltage of auxiliary circuits	U_a	V		(X)	
Rated supply frequency of auxiliary circuits		Hz		(X)	
Mass (including oil for oil by-pass switches)	M	kg	y	y	More than 300 kg

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