IEC TS 62271-316

Edition 1.0 2024-11
EXTENDED VERSION

TECHNICAL SPECIFICATION

colour inside

This full version of IEC TS 62271-316:2024 includes the content of the references made to IEC TS 62271-5:2024

High-voltage switchgear and controlgear – Part 316: Direct current by-pass switches and paralleling switches

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IEC TS 62271-316:2024-11 EXV(en)

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

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

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 316: Direct current by-pass switches and paralleling switches

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IEC TS 62271-316:2024 EXV includes the content of IEC TS 62271-316:2024, and the references made to IEC TS 62271-5:2024.

The specific content of IEC TS 62271-316:2024 is displayed on a blue background.

IEC TS 62271-316 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
17A/1407/DTS	17A/1414/RVDTS

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

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document shall be read in conjunction with IEC TS 62271-5:2024, to which it refers, and which is applicable unless otherwise specified in this document. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC TS 62271-5. Modifications to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

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

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

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION to IEC TS 62271-5:2024

This Technical Specification has been prepared by TC 17 and it defines common specifications for high-voltage direct current (HVDC) switchgear and controlgear covering both types of air insulated (AIS) and gas insulated (GIS) equipment of HVDC substations. This document includes rules for service conditions, ratings, design and construction requirements. Test requirements and criteria to proof for passing type and routine tests are defined in this document for development and manufacturing of HVDC switchgear.

This specification is applicable for both LCC and VSC HVDC technology.

SC 17A is in the process of preparing documents for the following HVDC switching devices:

– circuit-breakers (IEC TS 62271-313 [1])[1];
– disconnectors and earthing switches (IEC TS 62271-314 [2]);
– transfer switches (IEC TS 62271-315 [3]);
– by-pass switches and paralleling switches (IEC TS 62271-316 [4]).

SC 17C is in the process of preparing a document for DC gas insulated switchgears (IEC TS 62271-318 [5]).

Standardization of direct voltages is the responsibility of TC 8 (System aspects of electrical energy supply).

TC 99 (Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC) defines requirements of DC substations for safety of insulation, equipment, installation and earthing (IEC 61936-2).

TC 115 (High Voltage Direct Current (HVDC) transmission for DC voltages above 100 kV) is responsible for DC transmission system aspects. It is the responsibility of TC 115 to define requirements for different equipment (e. g. switching devices) from system point of view. These definitions are implemented in documents from other TCs. Several Working Groups and Maintenance Teams are preparing documents on reliability, EMC, asset management, system design, DC harmonics, testing, HVDC grids, VSC and LCC converter and insulation coordination for HVDC systems.

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[1] Numbers in square brackets refer to the Bibliography.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 316: Direct current by-pass switches and paralleling switches

1 Scope

This part of IEC 62271, which is a Technical Specification, is applicable to direct current (DC) by-pass switches (BPS) and paralleling switches (PS) designed for indoor or outdoor installation and for operation on HVDC transmission systems having direct voltages of 100 kV and above.

Switches other than mechanical switching devices used for the same applications specified here are not covered by this document.

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 60038:2009, *IEC standard voltages*

IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*, (available at www.electropedia.org)

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*, (available at www.electropedia.org)

IEC 60050-442, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories*, (available at www.electropedia.org)

IEC 60050-461, *International Electrotechnical Vocabulary (IEV) – Part 461: Electric cables*, (available at www.electropedia.org)

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Part 601: Generation, transmission and distribution of electricity – General*, (available at www.electropedia.org)

IEC 60050-614, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*, (available at www.electropedia.org)

IEC 60050-811, *International Electrotechnical Vocabulary (IEV) – Part 811: Electric traction*

IEC 60050-826:2022, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

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IEC 60068-2-17:1994, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60071-1:2019, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:2018, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60071-11:2022, *Insulation coordination – Part 11: Definitions, principles and rules for HVDC system*

IEC 60071-12:2022, *Insulation coordination – Part 12: Application guidelines for LCC HVDC converter stations*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60255-21-1:1988, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section One: Vibration tests (sinusoidal)*

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

IEC 60296, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF_6) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60417:2006, *Graphical symbols for use on equipment (available at http://www.graphical-symbols.info/equipment)*

IEC 60437, *Radio interference test on high-voltage insulators*

IEC 60480, *Specifications for the re-use of sulphur hexafluoride (SF_6) and its mixtures in electrical equipment*

IEC 60512-2-2, *Connectors for electronic equipment – Tests and measurements – Part 2-2: Electrical continuity and contact resistance tests – Test 2b: Contact resistance – Specified test current method*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60633:2019, *High-voltage direct current (HVDC) transmission – Vocabulary*

IEC TS 60815-4:2016, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 4: Insulators for DC systems*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

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IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-17:1999, *Electromagnetic compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-4-29, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on DC input power port immunity tests*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC TS 61245, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on DC systems*

IEC 61810-7:2006, *Electromechanical elementary relays – Part 7: Test and measurement procedures*

IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*
IEC 62271-1:2017/AMD1:2021

IEC 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for gases for insulation and/or switching*

IEC TS 62271-5:2024, *High-voltage switchgear and controlgear – Part 5: Common specifications for direct current switchgear*

IEC 62271-102:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*
IEC 62271-102:2018/AMD1:2022

IEC TS 62271-315:2024, *High-voltage switchgear and controlgear – Part 315: Direct current (DC) transfer switches*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 16-1 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

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CISPR TR 18-2, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-151, IEC 60050-441, IEC 60050-442, IEC 60050-461, IEC 60050-601, IEC 60050-614, IEC TS 62271-5 and IEC 60633, some of which are recalled hereunder, and the following apply.

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

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

NOTE Terms and definitions are classified in accordance with IEC 60050-441. Reference from other parts than IEC 60050-441 are classified so as to be aligned with the classification used in IEC 60050-441.

3.1 General terms and definitions

3.1.1
switchgear and controlgear
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 60050-441:1984, 441-11-01]

3.1.2
nominal direct voltage
mean value of the direct voltage required to transmit nominal power at nominal current

[SOURCE: IEC 60071-11:2022, 3.2, modified – Replacement of “DC” with “direct”.]

3.1.3
HVDC system
electrical power system which transfers energy in the form of high-voltage direct current between two or more AC buses

[SOURCE: IEC 60633:2019, 8.1]

3.1.4
HVDC transmission system
HVDC system which transfers energy between two or more geographic locations

[SOURCE: IEC 60633:2019, 8.2]

3.1.5
two-terminal HVDC transmission system
HVDC transmission system consisting of two HVDC substations and the connecting HVDC transmission line(s)

[SOURCE: IEC 60633:2019, 8.2.1]

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3.1.6
multiterminal HVDC transmission system
HVDC transmission system consisting of more than two separated HVDC substations and the interconnecting HVDC transmission lines

[SOURCE: IEC 60633:2019, 8.2.2]

3.1.7
HVDC system pole
part of an HVDC system consisting of all the equipment in the HVDC substations and the interconnecting transmission lines, if any, which during normal operation exhibit a common direct voltage polarity with respect to earth

[SOURCE: IEC 60633:2019, 8.5]

3.1.8
HVDC substation
HVDC converter station
part of an HVDC system which consists of one or more converter units installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary equipment

Note 1 to entry: An HVDC substation forming part of an HVDC transmission system may be referred to as an HVDC transmission substation.

[SOURCE: IEC 60633:2019, 8.12]

3.1.9
HVDC substation pole
part of an HVDC system pole which is contained within a substation

[SOURCE: IEC 60633:2019, 8.14]

3.1.10
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, etc.

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

3.1.11
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

[SOURCE: IEC 60050-614:2016, 614-03-03, modified – Addition of “parts of the”.]

3.1.12
degree of protection
extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and against mechanical impact

[SOURCE: IEC 60529:1989, 3.3, modified – Deletion of “verified by standardized test methods” and addition of “against mechanical impact” after “water and”.]

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3.1.13
IP code
coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection

[SOURCE: IEC 60529:1989, 3.4]

3.1.14
protection provided by an enclosure against access to hazardous parts
protection of persons against

– contact with hazardous low-voltage live parts;
– contact with hazardous mechanical parts;
– approach to hazardous high-voltage live parts below adequate clearance inside an enclosure

Note 1 to entry: This protection may be provided:

– by means of the enclosure itself;
– by means of barriers as part of the enclosure or distances inside the enclosure.

[SOURCE: IEC 60529:1989, 3.6]

3.1.15
IK code
coding system to indicate the degree of protection provided by an enclosure against harmful external mechanical impacts

[SOURCE: IEC 62262:2002, 3.3]

3.1.16
maintenance
combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required

Note 1 to entry: Management is assumed to include supervision activities.

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.1.17
visual inspection
visual investigation of the principal features of the switchgear and controlgear

Note 1 to entry: This inspection is generally directed toward pressures and/or levels of fluids, tightness, position of relays, pollution of insulating parts, but actions such as lubricating, cleaning, washing, etc. which can be carried out with the switchgear and controlgear in service are also included.

Note 2 to entry: Observations resulting from inspection can lead to the decision to carry out overhaul.

Note 3 to entry: This inspection can be used for determining the state of tested objects on e.g. cracks in solid insulators.

[SOURCE: IEC 62271-1:2017, 3.1.8]

3.1.18
diagnostic test
comparative test of the characteristic parameters of switchgear and controlgear to verify that it performs its functions, by measuring one or more of these parameters

Note 1 to entry: The result from a diagnostic test can lead to the decision to carry out overhaul.

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[SOURCE: IEC 62271-1:2017, 3.1.9]

3.1.19
overhaul
work performed with the objective of repairing or replacing parts which are found to be out of tolerance by inspection, diagnostic test, examination or as required by manufacturer's maintenance manual, in order to restore the component and/or the switchgear and controlgear to an acceptable condition (within tolerance)

[SOURCE: IEC 62271-1:2017, 3.1.10]

3.1.20
failure
loss of ability to perform as required

Note 1 to entry: A failure of an item is an event that results in a fault of that item: see fault (IEC 60050-192:2015, 192-04-01).

Note 2 to entry: Qualifiers, such as catastrophic, critical, major, minor, marginal and insignificant, can be used to categorize failures according to the severity of consequences, the choice and definitions of severity criteria depending upon the field of application.

Note 3 to entry: Qualifiers, such as misuse, mishandling and weakness, may be used to categorize failures according to the cause of failure.

[SOURCE: IEC 60050-192:2015, 192-03-01]

3.1.21
major failure
<of switchgear and controlgear> failure of switchgear and controlgear which causes the cessation of one or more of its fundamental functions

Note 1 to entry: A major failure may result in an immediate change in the system operating conditions, for example, the backup protective equipment will be required to remove the fault or will result in mandatory removal from service within 30 min for unscheduled maintenance.

[SOURCE: IEC 62271-1:2017, 3.1.12]

3.1.22
minor failure
<of switchgear and controlgear> any failure of a constructional element or a subassembly which does not cause a major failure of the switchgear and controlgear

[SOURCE: IEC 62271-1:2017, 3.1.13]

3.1.23
defect
imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time

[SOURCE: IEC 62271-1:2017, 3.1.14]

3.1.24
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.

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[SOURCE: IEC 60050-441:1984, 441-11-13]

3.1.25
monitoring
observation of the operation of a system or part of a system to verify correct functioning by detecting incorrect functioning, this being done by measuring one or more variables of the system and comparing the measured values with the specified values

Note 1 to entry: Some definitions are given for this term in IEC 60050 (all parts). They are related to different cases of application.

[SOURCE: IEC 62271-1:2017, 3.1.16]

3.1.26
supervision
activity, performed either manually or automatically, intended to observe the state of an item

Note 1 to entry: Automatic supervision may be performed internally or externally to the item.

[SOURCE: IEC 62271-1:2017, 3.1.17]

3.1.27
Unified Specific Creepage Distance
USCD
creepage distance of an insulator divided by the maximum operating voltage across the insulator.

Note 1 to entry: It is generally expressed in mm/kV.

[SOURCE: IEC TS 60815-4:2016, 3.1.1, modified – Removal of the note to entry.]

3.1.28
Reference DC Unified Specific Creepage Distance
RUSCDDC
value of Unified Specific Creepage Distance for a DC system at a pollution site determined from ESDD and NSDD value corrected for NSDD, CUR, etc. according to IEC TS 60815-4:2016

Note 1 to entry: This is generally expressed in mm/kV.

[SOURCE: IEC 60815-4:2016, 3.1.2, modified – Replacement of “this document” with “IEC 60815-4:2016”.]

3.1.29
Hydrophobicity Transfer Material
HTM
polymer materials which exhibit hydrophobicity and the capability to transfer hydrophobicity to the layer of pollution

Note 1 to entry: Further information on HTM is given in Annex A of IEC 60185-4:2016.

[SOURCE: IEC 60815-4:2016, 3.1.4, modified – Addition “of IEC 60815-4:2016” in Note 1 to entry.]

3.1.30
multi-part test
series of tests which adequately demonstrate the specified performance, in the case that this performance cannot be verified with a single test

Note 1 to entry: Multi-part tests are applicable for short-time withstand current and peak withstand current tests, as well as for short-circuit making and breaking tests.

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Note 2 to entry: Because of, for example, limitations of test field, maybe not all parameters concerning test current, test voltage or dissipated energy can be fulfilled in one test setup. In this case the test may be split in two or more parts with same current stress but different voltages stresses or different energy dissipation devices to cover all requirements. For each partial test of this series, the number of tests steps shall be the same as the number required for the respective test-duty.

3.1.101
switchgear and controlgear
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 60050-441:1984, 441-11-01]

3.1.102
indoor switchgear and controlgear
switchgear and controlgear designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost

[SOURCE: IEC 60050-441:1984, 441-11-04]

3.1.103
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 60050-441:1984, 441-11-05]

3.1.104
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device

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

[SOURCE: IEC 60050-441:1984, 441-11-13, modified – "or fuses" removed in note 1 to entry]

3.1.105
temperature rise
difference between the temperature of the part under consideration and the ambient air temperature

3.1.106
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, etc.

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

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3.1.107
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]

3.2 Assemblies of switchgear and controlgear

3.2.1
test object
equipment needed to represent the switchgear and controlgear for a particular type test

[SOURCE: IEC 62271-1:2017, 3.2.1]

3.3 Parts of assemblies

3.3.1
transport unit
part of switchgear and controlgear intended for transportation without being dismantled

[SOURCE: IEC 62271-1:2017, 3.3.1]

3.3.2
busbar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the busbar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.4 Switching devices

Various types of switching devices are used in HVDC substations as their examples are given in Annex A (informative). This subclause provides only the definitions of fundamental switching devices. Regarding each switching device, see IEC 60633, IEC TS 63014-1 and the relevant product standards.

3.4.1
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, SF_6, oil.

[SOURCE: IEC 60050-441:1984, 441-14-02]

3.4.2
DC circuit-breaker
type of switchgear used in an HVDC scheme, capable of making, carrying and breaking direct currents and also making, carrying for a specified time and breaking in specified time direct currents under specified abnormal circuit conditions such as those of short-circuit

3.4.3
disconnector
mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

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Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying currents for a specified time under abnormal conditions such as those of short-circuit.

[SOURCE: IEC 60050-441:1984, 441-14-05]

3.4.4
earthing switch
mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short circuit, but not required to carry current under normal conditions of the circuit

Note 1 to entry: An earthing switch may have a short-circuit making capacity.

[SOURCE: IEC 60050-441:1984, 441-14-11]

3.4.5
high-speed DC switch
type of switchgear used on an HVDC scheme, required to open or close rapidly (< 1 s), including in some cases the need to commutate load current into a parallel conducting path, but with no requirement to interrupt fault or load current

Note 1 to entry: DC switchgear is usually based on a single-phase unit of an AC circuit-breaker, appropriately modified for their DC applications. Their capabilities to perform faster opening and closing than disconnect switches are used but the function of breaking short-circuit currents is not required.

[SOURCE: IEC 60633:2019, 9.20]

3.4.6
DC transfer switch
high-speed DC switch used to transfer direct current from one return path to another return path

Note 1 to entry: High speed switch in DC transfer switch application will usually include an oscillating branch.

3.4.7
by-pass switch
BPS
high-speed DC switch connected across each converter valve group in HVDC schemes using more than one independent converter per pole, designed to close rapidly to by-pass a converter group that is being taken out of service and commutate the current back into a valve group that is being taken back in service

[SOURCE: IEC 60633:2019, 9.30]

3.4.8
paralleling switch
PS
mechanical switching device intended for rapid configuration of a HVDC system

Note 1 to entry: A PS can either be a converter paralleling switch or a line paralleling switch.

[SOURCE: IEC TS 62271-316:20—, 3.4.104]

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]

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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, for example, air, SF_6, oil.

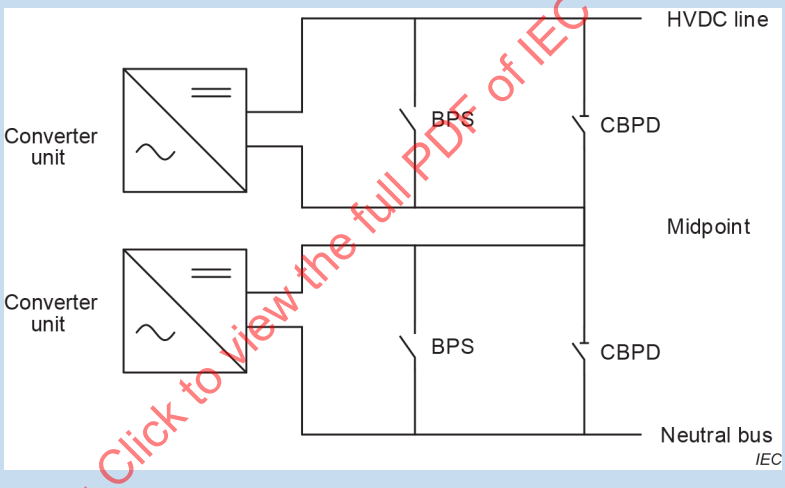
[SOURCE: IEC 60050-441:1984, 441-14-02]

3.4.103
by-pass switch
BPS
high-speed DC switch connected across each converter unit in HVDC schemes using more than one independent converter unit per pole, designed to close rapidly to bypass a converter unit that is being taken out of service and commutate the current back into a converter unit that is being taken back in service

Note 1 to entry: A BPS may also be used for prolonged shunting of the converter unit(s).

Note 2 to entry: Figure 1 illustrates the position of the BPS.

Note 3 to entry: BPS are most commonly used in LCC HVDC schemes.



Key

BPS By-pass switch

BPD By-pass disconnector

NOTE Figure 1 shows an example of the location of the BPS for one polarity only.

Figure 1 – Example of the location of BPSs in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.30, modified – The wording "converter valve group" and "group" replaced with "converter unit" in the definition; Notes 1 and 2 to entry changed; Note 3 to entry and Figure 1 added.]

3.4.104
paralleling switch
PS
mechanical switching device intended for rapid configuration of a HVDC system

Note 1 to entry: A PS can either be a converter paralleling switch or a line paralleling switch.

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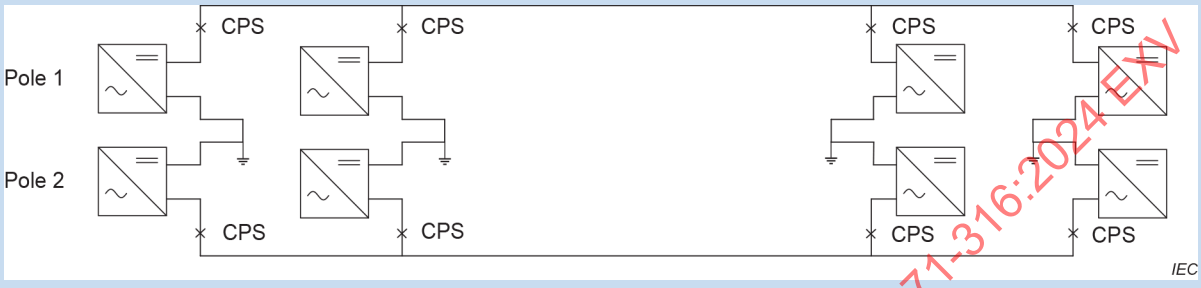
3.4.105
converter paralleling switch
CPS
high-speed DC switch connected in series with each converter at the high-voltage DC terminal in HVDC schemes where two or more converters are connected in parallel onto a common pole conductor, designed to allow additional converter(s) to be connected in parallel or disconnected without affecting the load current in the other converter

Note 1 to entry: Figure 2 illustrates the position of the CPS.



Key

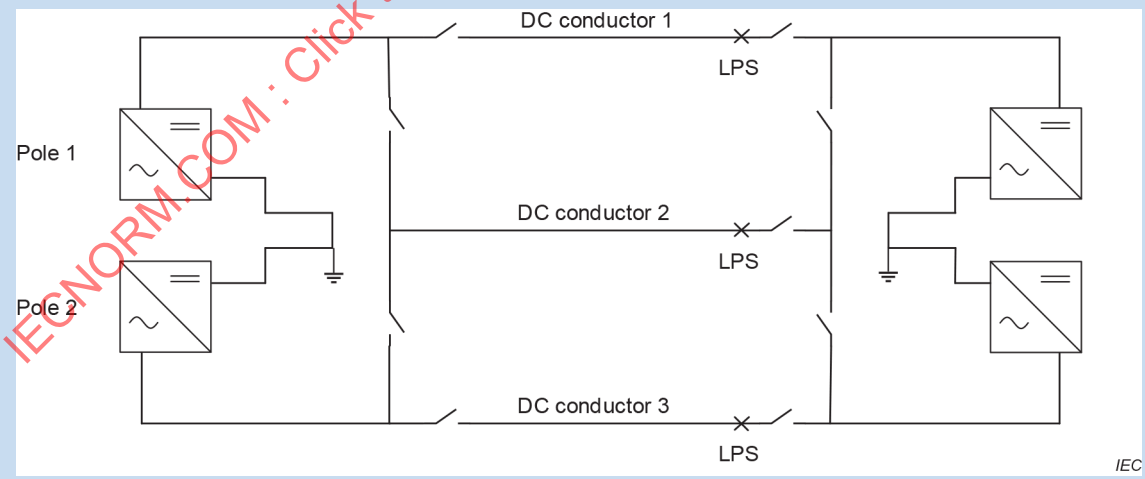
CPS Converter paralleling switch

Figure 2 – Example of the location of a CPS in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.28, modified – Note 1 to entry changed and Figure 2 added.]

3.4.106
line paralleling switch
LPS
DC commutation switch placed in series with one or more high-voltage pole conductors, allowing two or more lines to be connected in parallel or to revert to single-line operation while conducting load current

Note 1 to entry: Figure 3 illustrates the position of the LPS.



Key

LPS Line paralleling switch

Figure 3 – Example of the location of a LPS in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.29, modified – Note 1 to entry changed and Figure 3 added.]

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3.5 Parts of switchgear and controlgear

3.5.1
enclosure
housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: Enclosures provide protection of persons or livestock against access to hazardous parts. Barriers, shapes of openings or any other means (whether attached to the enclosure or formed by the enclosed equipment) suitable to prevent or limit the penetration of the specified test probes, are considered as a part of the enclosure, when they are secured in position either by means of interlocks, keys, or by hardware requiring a tool to be removed.

[SOURCE: IEC 60050-826:2022, 826-12-20, modified – Addition of Note 1 to entry.]

3.5.2
hazardous part
part that is hazardous to approach or touch

[SOURCE: IEC 60529:1989, 3.5]

3.5.3
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 60050-441:1984, 441-15-02]

3.5.4
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, the earthing 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 60050-441:1984, 441-15-04, modified – Addition of “earthing circuit”.]

3.5.5
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 60050-441:1984, 441-15-03]

3.5.6
contact
<of a 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 60050-441:1984, 441-15-05]

3.5.7
auxiliary contact
contact included in an auxiliary circuit and operated by the switching device

[SOURCE: IEC 60050-441:1984, 441-15-10, modified – Deletion of “mechanically”.]

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3.5.8
control contact
contact included in a control circuit of a switching device and operated by this device

[SOURCE: IEC 60050-441:1984, 441-15-09, modified – Deletion of “mechanical” and “mechanically”.]

3.5.9
auxiliary switch
<of a switching device> switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:1984, 441-15-11]

3.5.10
control switch
<for control and auxiliary circuits> mechanical switching device which serves the purpose of controlling the operation of switchgear or controlgear, including signalling, electrical interlocking, etc.

Note 1 to entry: A control switch consists of one or more contact elements with a common actuating system.

[SOURCE: IEC 60050-441:1984, 441-14-46]

3.5.11
connection
<bolted or the equivalent> two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

[SOURCE: IEC 62271-1:2017, 3.5.10]

3.5.12
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 60050-441:1984, 441-15-25]

3.5.13
monitoring device
device intended to observe automatically the status of an item

[SOURCE: IEC 62271-1:2017, 3.5.12]

3.5.14
pilot switch
non-manual control switch actuated in response to specified conditions of an actuating quantity

Note 1 to entry: The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

[SOURCE: IEC 60050-441:1984, 441-14-48]

3.5.15
partition
<of an assembly> part of an assembly separating one compartment from other compartments

[SOURCE: IEC 60050-441:1984, 441-13-06]

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3.5.16
actuator
part of the actuating system to which an external actuating force is applied

Note 1 to entry: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

[SOURCE: IEC 60050-441:1984, 441-15-22]

3.5.17
splice
connecting device with barrel(s) accommodating electrical conductor(s) with or without additional provision to accommodate and secure the insulation

[SOURCE: IEC 60050-581:2008, 581-24-19, modified – Addition of “electrical”.]

3.5.18
terminal
point of interconnection of an electric circuit element, an electric circuit or a network with other electric circuit elements, electric circuits or networks

Note 1 to entry: For an electric circuit element, the terminals are the points at which or between which the related integral quantities are defined. At each terminal, there is only one electric current from outside into the element.

Note 2 to entry: The term “terminal” has a related meaning in IEC 60050-151.

[SOURCE: IEC 60050-131:2002, 131-11-11]

3.5.19
terminal block
assembly of terminals in a housing or body of insulating material to facilitate interconnection between multiple conductors

[SOURCE: IEC 60050-581:2008, 581-26-26]

3.5.20
contactor
mechanical contactor
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:1984, 441-14-33, modified – Deletion of “Mechanical” in Note 1 to entry.]

3.5.21
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

Note 1 to entry: Starters may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:1984, 441-14-38]

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3.5.22
vacuum interrupter
component being part of a switching device in which electrical contacts operate in a highly evacuated, hermetically sealed environment

[SOURCE: IEC 62271-1:2017, 3.5.21]

3.5.23
operation counter
device indicating the number of operating cycles a mechanical switching device has accomplished

[SOURCE: IEC 62271-1:2017, 3.5.22]

3.5.24
coil
set of series-connected turns, usually coaxial

[SOURCE: IEC 60050-151:2001, 151-13-15]

3.5.25
auxiliary and control circuits
entity of

– control and auxiliary circuits, mounted on or adjacent to the switchgear or controlgear, including circuits in central control cubicles;
– equipment for monitoring, diagnostics, etc. that is part of the auxiliary circuits of the switchgear or controlgear;
– circuits connected to the secondary terminals of instrument transformers, that are part of the switchgear or controlgear

[SOURCE: IEC 62271-1:2017, 3.5.24]

3.5.26
subassembly
<of auxiliary and control circuits> part of auxiliary and control circuits, with regard to function or position, having its own interface and normally placed in a separate enclosure

[SOURCE: IEC 62271-1:2017, 3.5.25]

3.5.27
interchangeable subassembly
<of auxiliary and control circuits> subassembly which is intended to be placed in various positions within an auxiliary and control circuits, or intended to be replaced by other similar subassemblies

Note 1 to entry: An interchangeable subassembly has an accessible interface.

[SOURCE: IEC 62271-1:2017, 3.5.26]

3.5.28
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 60050-441:1984, 441-16-49]

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3.5.101
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 60050-441:1984, 441-15-02]

3.5.102
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 60050-441:1984, 441-15-07]

3.5.103
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 60050-441:1984, 441-15-08]

3.5.104
"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 60050-441:1984, 441-15-12]

3.5.105
"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 60050-441:1984, 441-15-13]

3.5.106
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 60050-441:1984, 441-15-17]

3.5.107
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 60050-441:1984, 441-15-18]

3.5.108
terminal
conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

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Note 1 to entry: The term "terminal" is also used for a connection point in circuit theory.

[SOURCE: IEC 60050-151:2001, 151-12-12]

3.5.109
enclosure
<of an assembly> part of an assembly providing a specified degree of protection 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

[SOURCE: IEC 60050-441:1984, 441-13-01]

3.5.110
operating mechanism
part of the BPS or PS that actuates the main contacts

3.6 Operational characteristics of switchgear and controlgear

3.6.1
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 60050-441:1984, 441-16-14]

3.6.2
stored energy operation
<of a mechanical switching device> operation by means of energy stored in the drive mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

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

– the manner of storing the energy (spring, weight, etc.);
– the origin of the energy (manual, electric, etc.);
– the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:1984, 441-16-15, modified – Addition of “drive”.]

3.6.3
independent unlatched operation
stored energy operation where energy is stored and released in one continuous operation such that the speed and force of the operation are independent of the rate of applied energy

Note 1 to entry: The energy stored for the operation may originate from the operator (manual) or a power source.

[SOURCE: IEC 62271-1:2017, 3.6.3]

3.6.4
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

Note 1 to entry: A positively driven operating device is made by the association of a moving part, linked mechanically to the main contact of the primary circuit, without the use of springs, and a sensing element. In the case of mechanical auxiliary contacts, this sensing element can be simply the fixed contact, directly connected to the secondary terminal. In the case where the function is achieved electronically, the sensing element can be a static transducer (optical, magnetic, etc.) associated with a static switch, or associated with an electronic or electro-optic transmitting element.

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[SOURCE: IEC 60050-441:1984, 441-16-12, modified – Addition of Note 1 to entry.]

3.6.5 Terms and definitions relative to pressure (or density)

3.6.5.1
filling pressure for insulation and/or switching
p_{re}
filling density for insulation and/or switching
ρ_{re}
pressure (in Pa), for insulation and/or for switching, 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, to which the assembly is filled before being put into service, or automatically replenished

[SOURCE: IEC 62271-1:2017, 3.6.5.1]

3.6.5.2
filling pressure for operation
p_{rm}
filling density for operation
ρ_{rm}
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, to which the energy storage device is filled before being put into service or automatically replenished

[SOURCE: IEC 62271-1:2017, 3.6.5.2]

3.6.5.3
alarm pressure for insulation and/or switching
p_{ae}
alarm density for insulation and/or switching
ρ_{ae}
pressure (in Pa), for insulation and/or for switching, 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 a monitoring signal may be provided

[SOURCE: IEC 62271-1:2017, 3.6.5.3]

3.6.5.4
alarm pressure for operation
p_{am}
alarm density for operation
ρ_{am}
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 a monitoring signal from the energy storage device may be provided

[SOURCE: IEC 62271-1:2017, 3.6.5.4]

3.6.5.5
minimum functional pressure for insulation and/or switching
p_{me}
minimum functional density for insulation and/or switching
ρ_{me}
pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute

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terms, at which and above which rated characteristics of switchgear and controlgear are maintained

[SOURCE: IEC 62271-1:2017, 3.6.5.5]

3.6.5.6
minimum functional pressure for operation
p_{mm}
minimum functional density for operation
ρ_{mm}
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 switchgear and controlgear 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 or lockout pressure.

[SOURCE: IEC 62271-1:2017, 3.6.5.6]

3.6.6 Terms and definitions relating to gas and vacuum tightness

3.6.6.1
controlled pressure system for gas
volume which is automatically replenished from an external compressed gas supply or internal gas source

Note 1 to entry: Examples of controlled pressure systems are air-blast circuit-breakers or pneumatic drive mechanisms.

Note 2 to entry: A volume may consist of several permanently connected gas-filled compartments.

[SOURCE: IEC 62271-1:2017, 3.6.6.1]

3.6.6.2
closed pressure system for gas
volume which is replenished when needed by manual connection to an external gas source

Note 1 to entry: Example of closed pressure systems are SF_6 single-pressure circuit-breakers.

[SOURCE: IEC 62271-1:2017, 3.6.6.2]

3.6.6.3
sealed pressure system
volume for which no further liquid, gas or vacuum processing is required during its expected operating duration

Note 1 to entry: Examples of sealed pressure systems are vacuum interrupters or some SF_6 circuit-breakers.

Note 2 to entry: Sealed pressure systems are completely assembled and tested in the factory.

Note 3 to entry: Expected operating duration starts when the device is sealed.

[SOURCE: IEC 62271-1:2017, 3.6.6.3]

3.6.6.4
absolute leakage rate of a gas
F
amount of gas escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in Pa × m^3 x s^{-1}.

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[SOURCE: IEC 62271-1:2017, 3.6.6.4]

3.6.6.5
permissible leakage rate of a gas
F_p
maximum permissible absolute leakage rate of gas specified for a part, a component or a sub-assembly, or by using the tightness coordination chart, for an arrangement of parts, components or subassemblies connected together in one pressure system

[SOURCE: IEC 62271-1:2017, 3.6.6.5]

3.6.6.6
relative leakage rate
F_{rel}
absolute leakage rate related to the total amount of gas in the system at filling pressure (or density)

Note 1 to entry: The relative leakage rate is expressed in percentage per year or per day.

[SOURCE: IEC 62271-1:2017, 3.6.6.6]

3.6.6.7
time between replenishments
t_r
time elapsed between two replenishments performed manually when the pressure (density) reaches the alarm level, to compensate the leakage rate F

Note 1 to entry: This value is applicable to closed pressure systems.

[SOURCE: IEC 62271-1:2017, 3.6.6.7]

3.6.6.8
number of replenishments per day of a gas
N
number of replenishments to compensate the leakage rate F

Note 1 to entry: This value is applicable to controlled pressure systems.

[SOURCE: IEC 62271-1:2017, 3.6.6.8]

3.6.6.9
pressure drop of a gas
Δp
drop of pressure in a given time caused by the leakage rate F, without replenishment

[SOURCE: IEC 62271-1:2017, 3.6.6.9]

3.6.6.10
tightness coordination chart
survey document supplied by the manufacturer, used when testing parts, components or sub-assemblies, to demonstrate the relationship between the tightness of a complete system and that of the parts, components or sub-assemblies

[SOURCE: IEC 62271-1:2017, 3.6.6.10, modified – Replacement of “and/or” with “or”.]

3.6.6.11
sniffing
action of slowly moving a leak meter sensing probe around an assembly to locate a gas leak

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[SOURCE: IEC 62271-1:2017, 3.6.6.11]

3.6.6.12
cumulative leakage measurement
measurement which takes into account all the leaks from a given assembly to determine the leakage rate

[SOURCE: IEC 62271-1:2017, 3.6.6.12]

3.6.7 Terms and definitions relating to liquid tightness

3.6.7.1
absolute leakage rate of a liquid
F_{liq}
amount of liquid escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in $cm^3 \times s^{-1}$.

[SOURCE: IEC 62271-1:2017, 3.6.7.1]

3.6.7.2
permissible leakage rate of a liquid
$F_{p(liq)}$
maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

[SOURCE: IEC 62271-1:2017, 3.6.7.2]

3.6.7.3
number of replenishments per day of a liquid
N_{liq}
number of replenishments to compensate the leakage rate F_{liq}

[SOURCE: IEC 62271-1:2017, 3.6.7.3]

3.6.7.4
pressure drop of a liquid
Δp_{liq}
drop in pressure in a given time caused by the leakage rate F_{liq} without replenishment

[SOURCE: IEC 62271-1:2017, 3.6.7.4]

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 BPS or PS, this may be a closing operation or an opening operation.

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

[SOURCE: IEC 60050-441:1984, 441-16-01, modified – "Circuit-breaker" in Note 1 to entry changed to "BPS or PS".]

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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 60050-441:1984, 441-16-02]

3.6.103
operating sequence
<of a mechanical switching device> succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:1984, 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 60050-441:1984, 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 60050-441:1984, 441-16-09]

3.6.106
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 60050-441:1984, 441-16-14]

3.6.107
stored energy operation
operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

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

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

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

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

[SOURCE: IEC 60050-441:1984, 441-16-15]

3.6.108
closed position
<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-22]

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3.6.109
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]

3.6.110
shunt release
release energised 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 60050-441:1984, 441-16-41]

3.6.111
anti-pumping device
device which
a) prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing
b) prevents re-opening after an open-close operation as long as the device initiating opening is maintained in the position for opening

[SOURCE: IEC 60050-441:1984, 441-16-48, modified – item b) added.]

3.6.112
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 60050-441:1984, 441-16-49]

3.6.113
switching
making and/or breaking operation of a mechanical switching device

3.7 Characteristic quantities

3.7.1
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.7.2
isolating distance
<of a mechanical switching device> clearance between open contacts meeting the withstand voltage requirements specified for disconnectors

[SOURCE: IEC 60050-441:1984, 441-17-35, modified – Deletion of “of a pole” from the term and replacement of “safety” with “withstand voltage”.]

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3.7.3
highest voltage for equipment
U_m
greatest value of pole-to-earth voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards

Note 1 to entry: Under normal service conditions specified by the relevant apparatus committee, this voltage can be applied continuously to the equipment.

[SOURCE: IEC 60050-614:2016, 614-03-01, modified — Replacement of “line-to-line voltage (RMS value)” with “pole-to-earth voltage”, and addition of Note 1 to entry.]

3.7.4
supply voltage
<of auxiliary and control circuits> RMS value or, if applicable, the DC value, of the voltage existing at a given instant at a point of supply, measured over a given time interval

Note 1 to entry: If a supply voltage is specified for instance in the supply contract, then it is called “declared supply voltage”.

Note 2 to entry: The supply voltage of auxiliary and control circuits is measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

[SOURCE: IEC 60050-614:2016, 614-01-03, modified – Addition of Note 2 to entry.]

3.7.5
diode bridge current feed for VSC converter
<HVDC substation using VSC> steady-state value of the short-circuit current supplied from AC system through VSC diode bridge before AC circuit-breaker opens

Figure 4, Figure 5 and Figure 6 illustrate some definitions of this subclause.

Time quantities, see definitions 3.7.106 through 3.7.113, are expressed in milliseconds.

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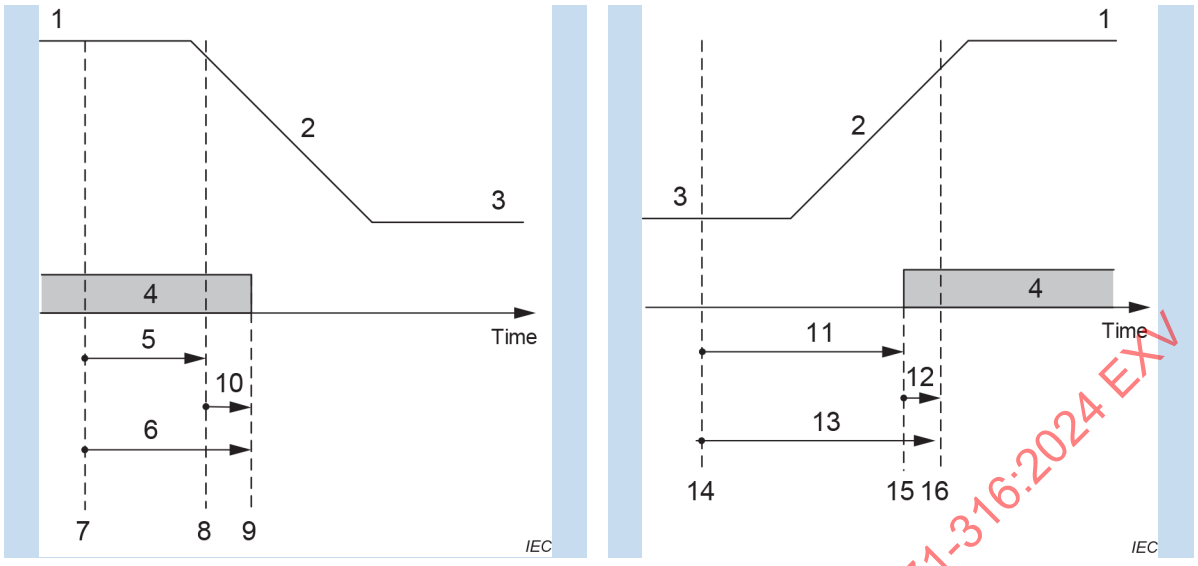

Opening operation | **Closing operation**

Key

1	Closed position	9	Instant of arc extinction
2	Contact travel	10	Arcing time,
3	Open position	11	Make-time, 3.7.110
4	Current flow	12	Pre-arcing time, 3.7.111
5	Opening time, 3.7.106	13	Closing time, 3.7.109
6	Commutation time, 3.7.108	14	Initiation of closing operation
7	Initiation of opening operation	15	Instant of start of current flow
8	Instant of separation of arcing contacts	16	Instant of contact touch

Figure 4 – BPS and PS – Opening and closing operations

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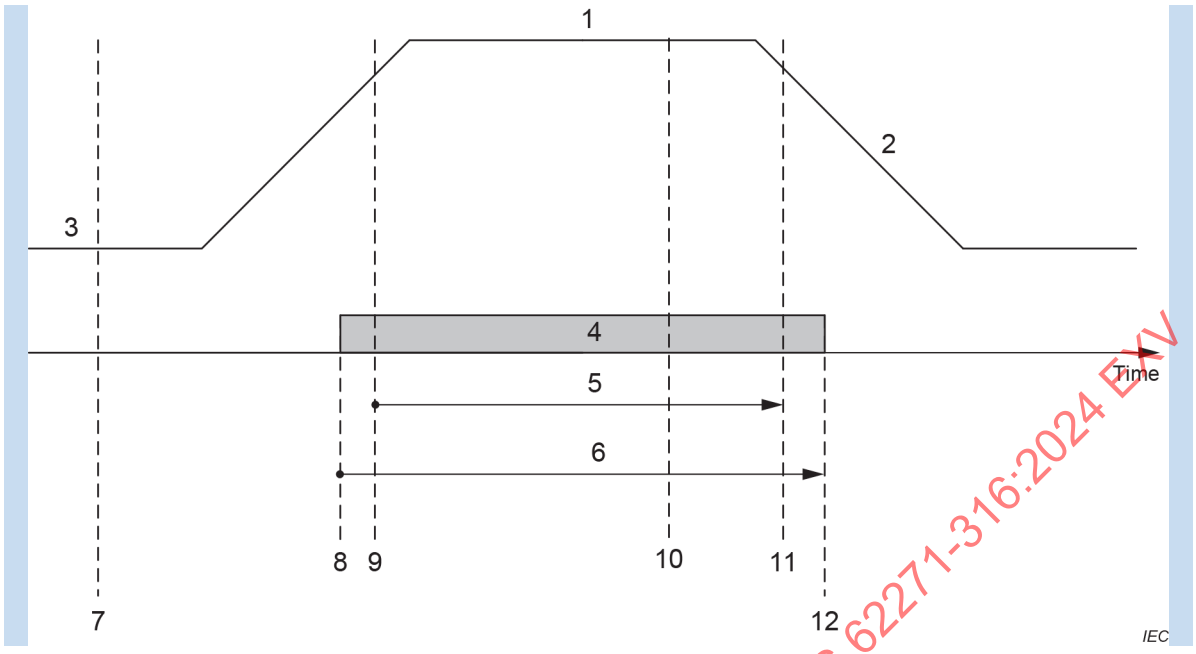

Key

1	Closed position	7	Initiation of closing operation
2	Contact travel	8	Instant of start of current flow
3	Open position	9	Instant of contact touch
4	Current flow	10	Initiation of opening operation
5	Close-open time, 3.7.112	11	Instant of separation of arcing contacts
6	Make-commutation time	12	Instant of arc extinction

Figure 5 – BPS and PS – Close-open cycle

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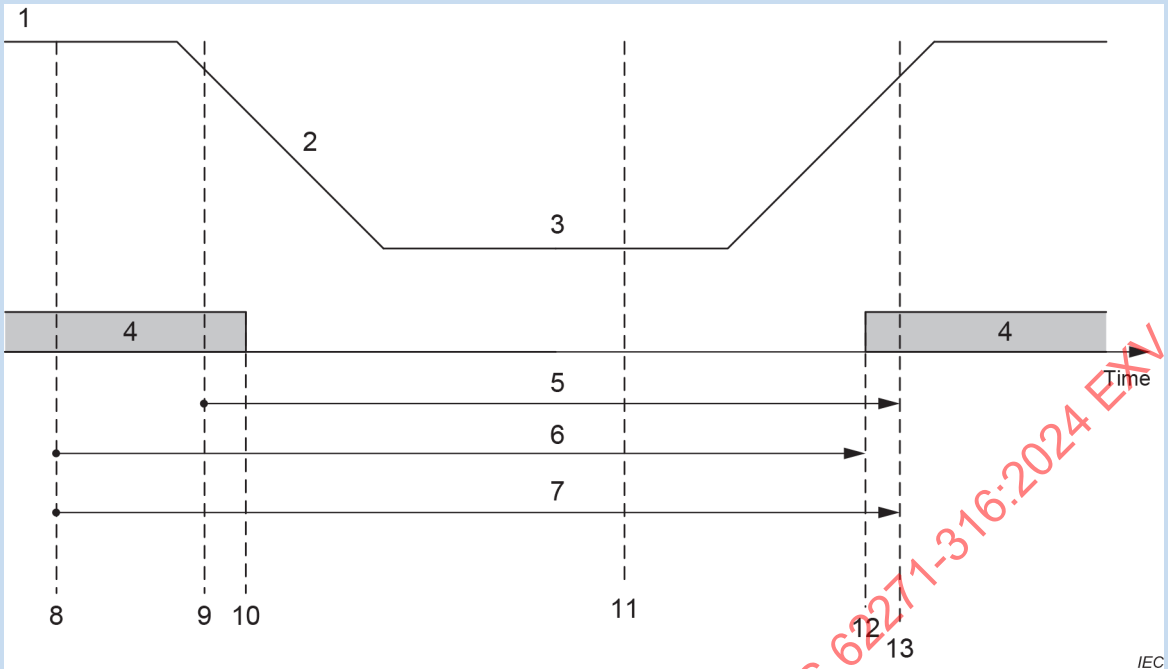

Key

1	Closed position	8	Initiation of opening release
2	Contact travel	9	Separation of arcing contacts
3	Open position	10	Arc extinction
4	Current flow	11	Initiation of closing circuit
5	Open-close time, 3.7.113	12	Instant of start of current flow
6	Re-make time	13	Contact touch
7	Reclosing time		

Figure 6 – BPS and PS – Open-close cycle

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

[SOURCE: IEC 60050-441:2000, 441-18-35, modified – Note 1 to entry deleted.]

3.7.102
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 60050-441:1984, 441-17-17]

3.7.103
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 60050-441:1984, 441-17-18]

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3.7.104
applied voltage
<for a switching device> voltage which exists across the terminals of a switching device just before the making of the current

[SOURCE: IEC 60050-441:1984, 441-17-24, modified – "of a pole" deleted from the definition.]

3.7.105
clearance
distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.7.106
opening time
<of a mechanical switching device> interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated

Note 1 to entry: The instant of initiation of the opening operation, i.e. the application of the opening command (for example energising the release, etc.) is given in the relevant specifications.

[SOURCE: IEC 60050-441:1984, 441-17-36, modified – "in all poles" deleted from the definition.]

3.7.107
arcing time
interval of time between the instant of the initiation of the arc and the instant of final arc extinction

[SOURCE: IEC 60050-441:1984, 441-17-37, modified – The domain "of a pole or a fuse" deleted, and "in a pole or a fuse" and "in that pole or that fuse" deleted from the definition.]

3.7.108
commutation time
interval of time between the beginning of the opening time of a mechanical switching device and the end of the arcing time

3.7.109
closing time
interval of time between the initiation of the closing operation and the instant when the contacts touch

[SOURCE: IEC 60050-441:1984, 441-17-41, modified – "in all poles" deleted from the definition.]

3.7.110
make-time
interval of time between the initiation of the closing operation and the instant when the current begins to flow in the main circuit

[SOURCE: IEC 60050-441:1984, 441-17-40]

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3.7.111
pre-arcing time
interval of time between the initiation of current flow during a closing operation and the instant when the contacts touch

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

3.7.112
close-open time
interval of time between the instant when the contacts touch during a closing operation and the instant when the arcing contacts have separated during the subsequent opening operation

[SOURCE: IEC 60050-441:2000, 441-17-42, modified – "in the first pole" and "in all poles" deleted from the definition.]

3.7.113
open-close time
interval of time between the instant when the arcing contacts have separated and the instant when the contacts touch during a reclosing operation

Note 1 to entry: Unless otherwise stated, it is assumed that the closing release incorporated in the BPS or PS is energised at the instant when the contacts have separated during opening. This represents the minimum open-close time.

3.7.114
continuous current
current that the main circuit is capable of carrying continuously under specified conditions of use and behaviour

3.7.115
temporary current
current that the main circuit is capable of carrying temporarily under specified conditions of use and behaviour

3.7.116
insulation level
set of withstand voltages specified which characterise the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016:2016, 614-03-23]

3.7.117
direct withstand voltage
value of direct voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

3.7.118
impulse withstand voltage
highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18]

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3.7.119
commutation
transfer of current between any two paths with both paths carrying current simultaneously during this process

Note 1 to entry: Commutation may occur between any two converter arms, including the connected AC phases, between a converter arm and a by-pass arm, or between any two paths in the circuit.

[SOURCE: IEC 60633:2019, 5.6]

3.7.120
initiation of (opening or closing) operation
instant of receipt of command for operation at the control circuit

3.8 Index of definitions

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4 Normal and special service conditions

4.1 Normal service conditions

4.1.1 General

Unless otherwise specified, high-voltage switchgear and controlgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal service conditions listed in 4.1.

Operation under normal service conditions is considered to be covered by the type tests according to this document and the relevant product standard.

4.1.2 Indoor switchgear and controlgear

The normal service conditions for indoor switchgear and controlgear are:

a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h does not exceed 35 °C. The ambient air temperature does not drop below -5 °C;

b) there is no influence from solar radiation;

c) the altitude does not exceed 1 000 m;

d) the ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt;

NOTE 1 Usually DC site severity is covered by a RUSCDDC between 20 mm/kV and 30 mm/kV (reference Annex B (informative)).

e) the conditions of humidity are as follows;

- the average value of the relative humidity, measured over a period of 24 h, does not exceed 95 %;
- the average value of the water vapour pressure, over a period of 24 h, does not exceed 2,2 kPa;
- the average value of the relative humidity, over a period of one month, does not exceed 90 %;
- the average value of the water vapour pressure, over a period of one month, does not exceed 1,8 kPa.

NOTE 2 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 3 High humidity can also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

f) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.1.3 Outdoor switchgear and controlgear

The normal service conditions for outdoor switchgear and controlgear are:

a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h, does not exceed 35 °C;

the ambient air temperature does not drop below -25 °C;

NOTE 1 Rapid temperature changes can occur, for example a hot sunny day followed by a sudden rain.

b) solar radiation does not exceed a level of 1 000 W/m^2;

NOTE 2 Details of global solar radiation are given in IEC 60721-2-4 [38].

c) the altitude does not exceed 1 000 m;

d) the ambient air can be polluted by dust, smoke, corrosive gas, vapours or salt;

NOTE 3 Usually DC site severity is covered by a RUSCDDC of 60 mm/kV for non-HTM insulators and 45 mm/kV for HTM insulators (reference Annex B (informative)).

e) ice coating does not exceed 20 mm;

f) the wind speed does not exceed 34 m/s;

NOTE 4 Characteristics of wind are defined in IEC 60721-2-2 [37].

g) the average humidity values given in 4.1.2 e) can be exceeded. Condensation or precipitation can occur;

NOTE 5 Characteristics of precipitation are defined in IEC 60721-2-2 [37].

NOTE 6 The conditions of humidity are always the effect of a combination of relative humidity with other environmental parameters, primarily temperature and rapid change of temperature.

h) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.2 Special service conditions

4.2.1 General

When high-voltage switchgear and controlgear is expected to be used under conditions different from the normal service conditions given in 4.1, the user's requirements should refer to standardized steps in 4.2.2 up to 4.2.7 if not provided by product standards.

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NOTE 1 Appropriate actions are also taken to ensure proper operation under such conditions of other components, such as relays.

NOTE 2 Detailed information concerning classification of environmental conditions is given in IEC 60721-3-3 [40] (indoor) and IEC 60721-3-4 [41] (outdoor).

4.2.2 Altitude

For altitudes higher than 1 000 m, the equation provided in 4.5.1.1 b) of IEC TR 62271-306:2012 [62] and in H.3.4 of IEC 60071-2:2018 shall be used, i.e. $k_{alt} = e^{m(H-1000/8150)}$, where H is the altitude above sea level in m. Conservative values for the exponent m are stated in Table 4 of IEC TR 62271-306:2012 [62]. For further details, see H.4 of IEC 60071-2:2018.

NOTE 1 For internal insulation, the dielectric characteristics are identical at any altitude and no special precautions are taken. For external and internal insulation, refer to IEC 60071-2:2018.

NOTE 2 For low-voltage auxiliary and control equipment, no special precautions are taken if the altitude is lower than 2 000 m. For higher altitudes, refer to IEC 60664-1 [31].

4.2.3 Exposure to pollution

For outdoor application ambient air that can be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds DC site severity covered by a RUSCDDC of 60 mm/kV for non-HTM insulators and 45 mm/kV for HTM insulators**, more information can be found in Annex B (informative)**.

For indoor application, ambient air that can be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds DC site severity covered by a RUSCDDC between 20 mm/kV and 30 mm/kV**, more information can be found in Annex B (informative)**.

4.2.4 Temperature and humidity

For installation at a location where the ambient temperature can be different from the normal service condition ranges stated in 4.1, the ranges of minimum and maximum temperature to be specified should be:

a) -50 °C to 40 °C for extremely cold climates;

b) -40 °C to 40 °C for very cold climates;

c) -30 °C to 40 °C for cold climates;

d) -25 °C to 40 °C for cold climates (indoor conditions);

e) -15 °C to 40 °C for moderate climates (indoor conditions);

f) -5 °C to 55 °C for very hot climates.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be up to 98 %.

NOTE 1 In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature and/or atmospheric pressure can occur.

NOTE 2 For special indoor conditions with power electronics, a temperature range of +5 °C to +60 °C and a very low humidity can be reasonable. Reference is made to IEC 111-1:2023, Table 2.

4.2.5 Exposure to abnormal vibrations, shock or tilting

Standard switchgear and controlgear is designed for mounting on substantially level structures, free from excessive vibration, shock, or tilting. Where any of these standard conditions do not exist, the requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level according to a relevant publication or specification should be specified by the user. In case of earthquake risk, the user should specify the operational requirements and admissible damage level.

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Installations with other unusual forms of vibration shall be identified, such as installations in close proximity to mine blasting or mobile applications.

NOTE Other relevant publications for seismic evaluations are IEEE 693 [68] and IEEE C37.81 [69].

4.2.6 Wind speed

If the wind speed is expected to be in excess of the normal service wind speed of 34 m/s, the user should specify the requirements for a particular application.

4.2.7 Other parameters

When special environmental conditions prevail at the location where switchgear and controlgear shall be placed in service, they should be specified by the user by reference to IEC 60721-1 [35], IEC 60721-2 (all parts) [36] and IEC 60721-3 (all parts) [39].

5 Ratings

5.1 General

Ratings define the common specifications of the switchgear and controlgear that are necessary for adequate selection and use in a particular network. Other important characteristics of the switchgear and controlgear are defined in Clause 9, some of which are included on the nameplate but are not ratings. Still other characteristics refer to installation, operation and maintenance; they are not considered as ratings since they are related to the technology used for switchgear and controlgear. Examples include normal filling level or filling / alarm pressure (density) of fluids and tightness for liquids, gas and vacuum systems.

5.1.101 By-pass switches (BPSs)

The characteristics used to determine rated values of a BPS and its operating mechanism and auxiliary equipment are the following:

a) direct voltage across the open BPS (BPS open). This voltage depends on the number of converter units in series;

   direct voltage from terminal to earth (BPS open). This voltage depends on the configuration of the BPS and its connection to the HVDC system. Examples of possible configurations are given in Annex C;

b) insulation level (U_{dd}, U_s, U_p). The considerations provided under a) also apply to the insulation level;

c) continuous current (I_{rd}) or its temporary current (I_t);

d) short-time withstand direct current (I_{kd});

e) peak withstand current (I_{pd});

f) duration of short-circuit (t_{kd});

g) supply voltage of auxiliary and control circuits (U_a);

h) supply frequency of auxiliary and control circuits.

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5.1.102 Parallelling switches (PSs)

The characteristics used to determine rated values of a PS and its operating mechanism and auxiliary equipment are the following:

a) direct voltage (U_{rd});

b) insulation level (U_{dd}, U_s, U_p);

c) continuous current (I_{rd});

d) short-time withstand direct current (I_{kd});

e) peak withstand current (I_{pd});

f) duration of short-circuit (t_{kd});

g) supply voltage of auxiliary and control circuits (U_a);

h) supply frequency of auxiliary and control circuits;

i) commutation current (for LPS only, see 3.4.106).

5.2 Rated direct voltage (U_{rd})

5.2.1 General

The rated direct voltage of HV switchgear and controlgear (U_{rd}) is the highest direct voltage pole to earth that include harmonics for which it is designed in respect of its insulation as well as other characteristics, to operate as specified for the service life (lifetime).

The typical system direct voltage ($U_{typ,d}$) is a system voltage in normal operation condition. This is a rounded value that is derived as an average from multiple projects and typical values are shown in Table 1. Depending on the configuration of the DC system, other values that do not exceed the rated direct voltage might be reasonable. Voltage ripple and harmonics of the system are included in the values given.

The rated direct voltage and the typical system direct voltage can differ from component-specific voltages, e.g. rated voltage for transfer switches and rated voltage for bypass switch can be different. Reference is made to IEC TS 62271-315 [3] and TS 62271-316 [4].

NOTE 1 The inclusion of voltage ripple and harmonics in the values is in line with CIGRE recommendations [75] and [73].

The rated direct voltages (U_{rd}) are given in 5.2.2 below.

NOTE 2 The term “rated maximum voltage” used in most IEEE switchgear standards has the same meaning as the term “rated direct voltage” as used in this document.

As BPSs are installed in parallel with a converter unit, the rated voltage of a BPS is different across open switch and to earth. Therefore, different rated voltages are defined for BPSs to earth in open position and across the open BPS.

PSs usually have same rated voltages across open switching device and to earth in both (open and closed) positions.

In some applications PSs not intended for rapid configuration of the HVDC system are connected in series with a disconnector that always operates and with a short time delay after the PS, to reduce the duration of voltage stress across the open PS. For such applications, a lower value of the rated direct voltage across the open PS can be chosen, whereby dielectric capabilities and creepage distance across open switching device are reduced.

Such applications are subject to agreement between user and manufacturer (see also Clause 9).

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5.2.101 Rated direct voltage to earth (U_{rde})

Subclause 5.2.2 of IEC TS 62271-5:2024 is applicable with the following addition.

For PS this rating is applicable for both open and closed position.

For BPSs this rating is applicable for the open position only and may be specified for one or both terminals. If the arrangement of the terminals is not symmetrical with respect to the frame, the rating is applicable for the terminal which is designed for the highest direct voltage to earth. The manufacturer must in this case specify which terminal the rating is assigned to.

5.2.102 Rated direct voltage across open switching device (U_{rdo})

Subclause 5.2.2 of IEC TS 62271-5:2024 is applicable.

5.2.2 Rated voltages

105 kV – 160 kV – 210 kV – 265 kV – 340 kV – 420 kV – 525 kV – 630 kV – 840 kV

NOTE Values for rated voltages lower than 100 kV cannot be defined adequately. The reason is the lack of applications or products. However, as an indication, for preferred voltages lower than 100 kV values are provided as a guide in Annex C (informative).

5.3 Rated insulation level (U_{dd}, U_p, U_s)

The insulation levels for rated voltages of 105 kV and above should be selected from the preferred rated values given in Table 1.

NOTE 1 Examples of preferred insulation levels for rated voltages lower than 105 kV are given in Annex C (informative).

Withstand values given in Table 1 cover the application of switchgear and controlgear under normal service conditions defined in 4.1 including altitudes from sea level up to 1 000 m. However, for testing purposes to verify a rating or capability, they shall be considered as insulation values at the standardized reference atmosphere temperature (20 °C), pressure (101,3 kPa) and humidity (11 g/m^3) specified in IEC 60071-1:2019, 5.9.2. For special service conditions, refer to IEC TR 62271-306 [62].

NOTE 2 The normal environmental conditions and the standard reference atmospheric conditions are currently not stated in IEC 60071-11:2022. In terms of these conditions, 5.9.1 and 5.9.2 of IEC 60071-1:2019 are applied in this document.

NOTE 3 The insulation levels in Table 1 are considered being applicable in the temperature range of -40 °C up to 40 °C for DC systems. Reference is made to IEC 60071-1:2019, 5.9.1 for AC systems.

The rated withstand voltage values for lightning impulse voltage (U_p), switching impulse voltage (U_s) (when applicable), and direct voltage (U_{dd}) shall be selected without crossing the horizontal marked lines in Table 1.

The superimposed voltage is a composite voltage consisting of the rated direct voltage U_{rd} and the lightning impulse voltage U_p or switching impulse voltage U_s, as shown in Figure 1.

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Table 1 – Preferred rated insulation levels

Typical system direct voltage $U_{typ,d}$ kV (NOTE 1)	Rated direct voltage U_{rd} kV (NOTE 2)	Rated direct withstand voltage U_{dd} kV	Rated switching impulse withstand voltage U_s kV (peak value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
		Pole-to-earth, across open switching device and/or isolating distance (NOTE 3)	Pole-to-earth and across open switching device (NOTE 4)	Across isolating distance[a]	Pole-to-earth (NOTE 4)	Across open switching device and/or isolating distance[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
100	105	160	--	--	380	380(+105)
150	160	240	--	--	450	450(+160)
200	210	315	550	550(+210)	550	550(+210)
					650	650(+210)
250	265	395	550	550(+265)	550	550(+265)
					650	650(+265)
			650	650(+265)	650	650(+265)
					750	750(+265)
320	340	505	650	650(+340)	650	650(+340)
					750	750(+340)
			750	750(+340)	750	750(+340)
					850	850(+340)
			850	850(+340)	850	850(+340)
					950	950(+340)
400	420	630	850	850(+420)	850	850(+420)
					950	950(+420)
			950	950(+420)	950	950(+420)
					1 050	1 050(+420)
					1 175	1 175(+420)
500	525[b]	790	950	950(+525)	950	950(+525)
					1 050	1 050(+525)
			1 050	1 050(+525)	1 050	1 050(+525)
					1 175	1 175(+525)
			1 175	1 175(+525)	1 175	1 175(+525)
					1 300	1 300(+525)
					1 425	1 425(+525)
600	630	945	1 175	1 175(+630)	1 175	1 175(+630)
					1 300	1 300(+630)
			1 300	1 300(+630)	1 300	1 300(+630)
					1 425	1 425(+630)
			1 425	1 425(+630)	1 425	1 425(+630)
					1 550	1 550(+630)

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Typical system direct voltage $U_{typ,d}$ kV **(NOTE 1)**	**Rated direct voltage U_{rd}** kV **(NOTE 2)**	**Rated direct withstand voltage U_{dd}** kV	**Rated switching impulse withstand voltage U_s** kV (peak value)		**Rated lightning impulse withstand voltage U_p** kV (peak value)	
		Pole-to-earth, across open switching device and/or isolating distance (NOTE 3)	**Pole-to-earth and across open switching device (NOTE 4)**	**Across isolating distance[a]**	**Pole-to-earth (NOTE 4)**	**Across open switching device and/or isolating distance[a]**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
800	840	1 260	1 550	1 550(+840)	1 550	1 550(+840)
					1 675	1 675(+840)
			1 675	1 675(+840)	1 675	1 675(+840)
					1 800	1 800(+840)
					1 950	1 950(+840)

NOTE 1 The typical system direct voltage values in column (1) are referred to IEC 60071-11:2022, Annex C.

NOTE 2 The rated direct voltage U_{rd} takes into account 5 % of ripple and harmonics to the typical system direct voltage, based on that the ripples and harmonics are in the range of 2 to 5 % of the typical system direct voltage. Reference is made to CIGRE Technical Brochure 684 [73].

NOTE 3 The rated direct withstand voltage U_{dd} is 150 % of the rated direct voltage U_{rd} of the HVDC system, reference is made to IEC TS 63014-1.

NOTE 4 The values in column (4) and (6) are mainly referred to IEC 60071-11:2022, Annex C.

[a] In column (5) and (7), values in brackets are the rated direct voltage applied to the opposite terminal (combined voltage). For multi-terminal grids or other system configurations, where the full direct voltage can occur at the opposite terminal, the 100 % rated direct voltage shall be applied. For typical two terminal DC systems, where no higher values can occur at the opposite terminal, the value of 10 % of rated direct voltage should be chosen. For equipment not subjected to direct voltage at the opposite terminal, columns (5) and (7) are not applicable.

[b] Instead of U_{rd} = 525 kV rated direct voltage, U_{rd} = 550 kV can also be reasonable. Reference is made to IEC 60071-11:2022, Annex C. In this case, the values in brackets of column (5) and (7) has to be adapted to the higher value of U_{rd} and the rated direct withstand voltage in column (3) shall be re-calculated according to NOTE 2.

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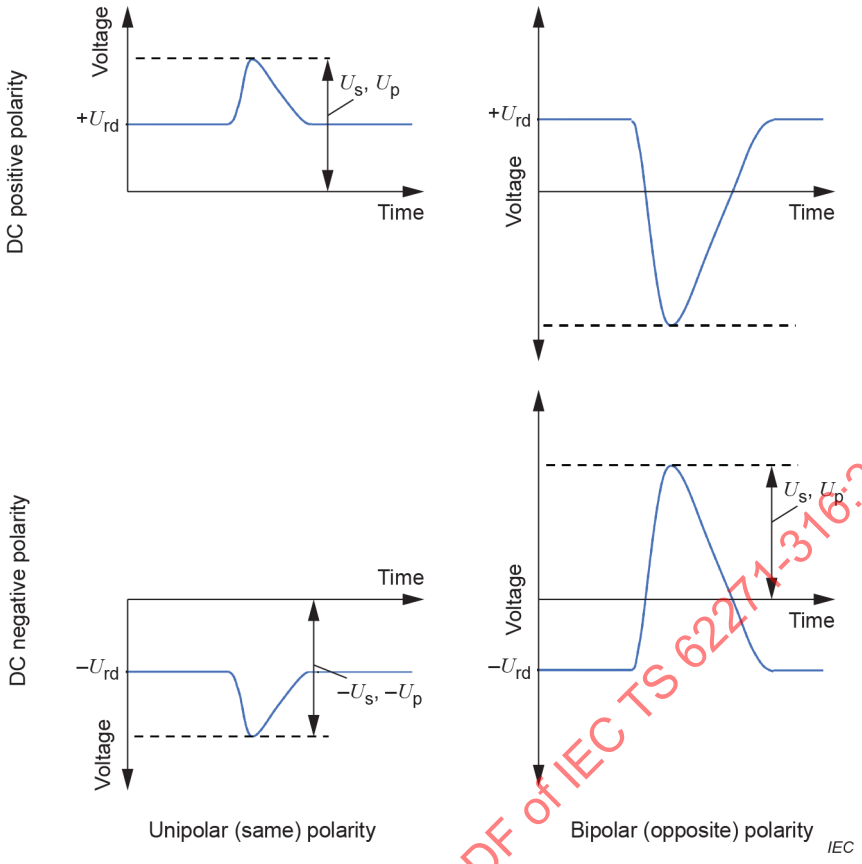

Figure 1 – Schematic representation of superimposed impulse voltage tests

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

The standard values of insulating levels for the rated voltage in 5.2.101 shall be selected in Table 1 of IEC TS 62271-5:2024.

For BPSs this rating is applicable for the open position only and may be specified for one or both terminals. If the arrangement of the terminals is not symmetrical with respect to the frame, the rating is applicable for the terminal which is designed for the highest direct voltage to earth. The manufacturer must in this case specify which terminal the rating is assigned to.

The insulating levels shall be selected from Columns (3), (4) and (6).

NOTE U_{dde} is the rated direct withstand voltage to earth, U_{pe} is the rated lightning impulse withstand voltage to earth and U_{se} is the rated switching impulse withstand to earth.

5.3.102 Rated insulation level across open switching device (U_{ddo}, U_{po}, U_{so})

The standard values of insulating levels for the rated voltage in 5.2.102 shall be selected in Table 1 of IEC TS 62271-5:2024.

The insulating levels shall be selected from Columns (3), (4) and (6).

NOTE U_{ddo} is the rated direct withstand voltage across open contacts, U_{po} is the rated lightning impulse withstand voltage across open contacts and U_{so} is the rated switching impulse withstand voltage across open contacts.

5.4 Rated continuous current (I_{rd})

This rating defines the value of the current the switchgear and controlgear can carry continuously for its service conditions (see Clause 4).

The values of rated continuous current should be selected from the R 10 series, specified in IEC 60059 [11].

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

NOTE 2 Continuous current defined in this document does not include any harmonics or induced current.

5.4.101 Rated temporary current (I_t)

The rated temporary current is the current a BPS can carry during 30 min under specific conditions.

NOTE In normal operation the BPS is not carrying any current, however in some cases a BPS can be designed to carry continuous current (for example when by-pass disconnectors are not used).

5.5 Rated values of short-time withstand current

5.5.1 Typical waveform of short-circuit current

Figure 2 shows typical waveforms of short-circuit current in an HVDC system.

– The current waveform in Figure 2a) corresponds to a typical half-bridge MMC (Modular Multilevel Converter), in a 2-terminal VSC HVDC and station switchgear in DC grids;

– The current waveform in Figure 2b) corresponds to a typical LCC (Line Commutated Converter), in a 2-terminal LCC HVDC; A special case of LCC under DC fault, that generally gives higher current stress, is discussed in Annex D (informative); This waveform also applies to 2-terminal, full-bridge MMC HVDC systems;

– The current waveform in Figure 2c) corresponds to a DC-line in HVDC system (2-terminal, multi-terminal or DC grid) with at least one DC CB installed.

Annex D (informative) gives further information on the circuit topologies, assumptions, and calculations.

In Figure 2c), the positive slope (S_p) is determined by the total series reactance in the fault path, as shown in Figure D.5. A typical value is 2 kA/ms < S_p < 10 kA/ms.

NOTE The definition of typical waveform for DC short-circuit currents is in the scope of IEC TC 73 (Short-circuit currents) activities. The definitions in 5.5 are provisionally provided by IEC TC 17 (High-voltage switchgear and controlgear) for the purpose of this document, and will be updated when definitions from TC 73 become available.

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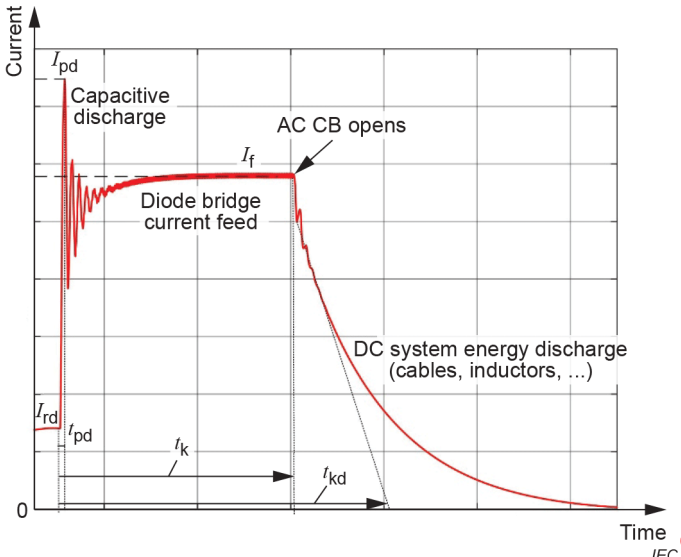
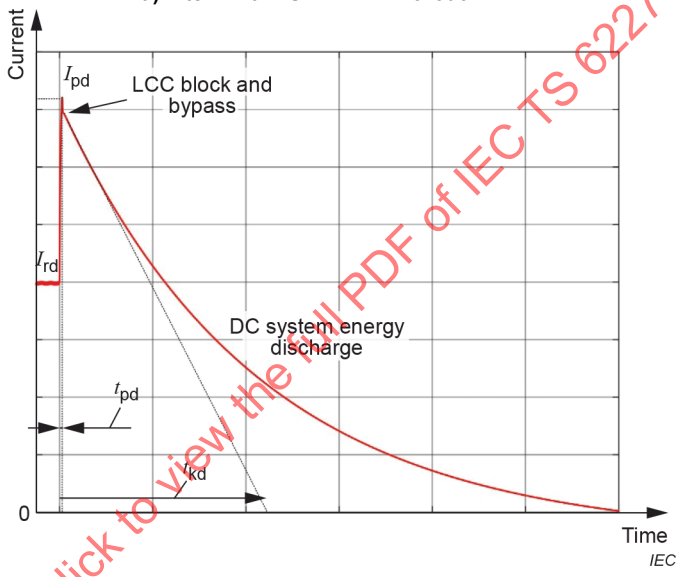
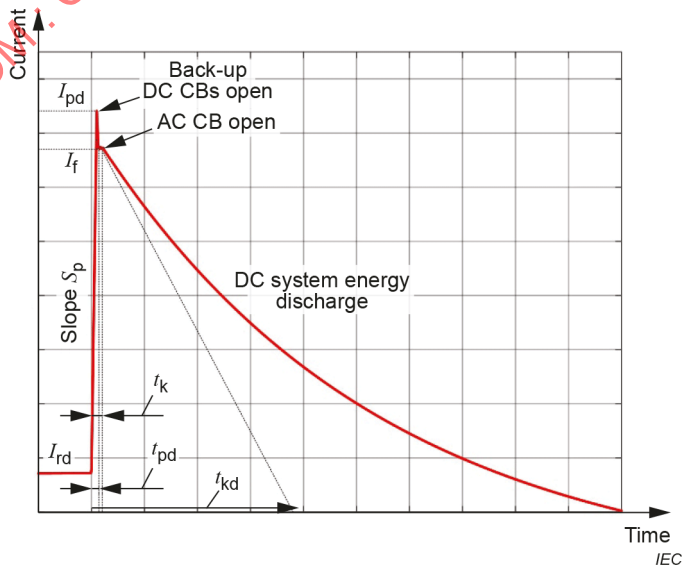


a) 2-terminal VSC HVDC without DC CB



b) 2-terminal LCC HVDC without DC CB



c) HVDC system (or DC grid) with DC CB

Figure 2 – Typical waveform of a short-circuit current in an HVDC system

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5.5.2 Rated short-time withstand direct current (I_{kd})

This rating defines the value of the short-circuit direct current that the switchgear and controlgear can carry in the closed position during its rated duration (see 5.5.4) under its service conditions (see Clause 4).

The value of rated short-time withstand direct current shall be determined so that it meets the necessary thermal withstand capability considering the type of waveform shown in Figure 2. D.4 gives the methodology for determining the value. The final value should be selected from the R 10 series specified in IEC 60059.

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

5.5.3 Rated peak withstand current (I_{pd})

This rating defines the peak value of the short circuit current. The value of rated peak withstand current depends on the type of waveform. Annex D (informative) gives the details.

The preferred value of rated peak withstand current is:

– for circuit in Figure 2a), 1,5 I_f;

– for circuit in Figure 2b), 2,0 I_{rd};

– for circuit in Figure 2c), S_p t_{pd}.

where I_f is diode bridge current feed for VSC converter in Figure 2a) (see D.1) and S_p and t_{pd} are positive slope and time to peak of short-circuit current time in Figure 2c), respectively (see D.3).

An alternative value higher than above may be chosen.

The time to peak short-circuit current is around 0,01 s for Figure 2a) and 0,07 s for Figure 2b) and 0,01 s for Figure 2c) but it will depend on the operating time of DC CB and protection (or back-up protection) time. D.4 gives further information.

5.5.4 Rated duration of short-circuit (t_{kd})

This rating defines the interval of time for which the switchgear and controlgear can carry, in the closed position, a current equal to its rated short-time withstand direct current.

The preferred value of rated duration of short circuit is:

– for circuit in Figure 2a), 0,7 s;

– for circuit in Figure 2b), 0,7 s; In case of full-bridge MMC HVDC a much smaller value may be chosen, depending on the DC circuit and the converter controller;

– for circuit in Figure 2c), 0,5 s.

An alternative value higher than above may be chosen.

5.6 Rated supply voltage of auxiliary and control circuits (U_a)

5.6.1 General

Several auxiliary voltages can be used on a single type of switchgear and controlgear.

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5.6.2 Rated supply voltage (U_a)

The rated supply voltage should be selected from the standard values given in Table 2 and Table 3.

Table 2 – Direct voltage of auxiliary and control circuits

U_a V
24
48
60
110
125
220
250

Table 3 – Alternating voltage of auxiliary and control circuits

Line number	Three-phase, three-wire or four-wire systems V	Single-phase, three-wire systems V	Single-phase, two-wire systems V
(1)	(2)	(3)	(4)
1	–	120/240	120
2	120/208	–	120
3	(220/380)	–	(220)
4	230/400	–	230
5	(240/415)	–	(240)
6	277/480	–	277
7	347/600	–	347

NOTE 1 The value 230/400 V indicated in line 4 of this table will be, in the future, the IEC standard voltage replacing the values 220/380 V and 240/415 V in lines 3 and 5. The voltage variations of existing systems at 220/380 V and 240/415 V will be brought within the range 230/400 V ± 23/40 V. The reduction of this range will be considered in the next and subsequent revisions.

NOTE 2 The lower values in the column (2) of this table are voltages to neutral and the higher values are voltages between phases. The lower value in the column (3) is the voltage to neutral and the higher value is the voltage between lines.

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5.7 Rated supply frequency of auxiliary and control circuits

When alternating current supply voltage is used, the preferred values of rated supply frequency are 50 Hz and 60 Hz.

5.8 Rated pressure of compressed gas supply for controlled pressure systems

The preferred values of rated pressure (relative pressure) are:

0,5 MPa – 1 MPa – 1,6 MPa – 2 MPa – 3 MPa – 4 MPa.

NOTE A example of controlled pressure systems is pneumatic drive mechanism.

5.101 Rated commutation current

At present there are no ratings available for the rated commutation current.

5.102 Rated operating sequence

The operating sequence of a BPS and PS is C – t – O – t" – C, where

O represents an opening operation;

C represents a closing operation;

Time t depends on the time used to reconfigure the HVDC system. This time can be anywhere between several seconds to several hours. For the purposes of standardisation, a value of 30 s is suggested;

Time t" is the time required to detect an unsuccessful commutation. t" is more than the open-close time and less than T_{aw} (see 6.102.7 of IEC TS 62271-315:2024).

NOTE The operating sequence is based on the assumption that the BPS or PS recloses after an unsuccessful commutation.

6 Design and construction

6.1 Requirements for liquids in switchgear and controlgear

The manufacturer shall specify the type and the required quantity and quality of the liquid used in switchgear and controlgear.

The manufacturer shall provide the user with necessary instructions for renewing the liquid and maintaining its required quantity and quality (refer to 11.5.2) except for sealed pressure systems.

For oil-filled switchgear and controlgear, insulating oil complying with IEC 60296 shall be used.

6.2 Requirements for gases in switchgear and controlgear

The manufacturer shall specify the type and the required quantity, and quality of the gas used in switchgear and controlgear.

The manufacturer shall provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality (refer to 11.5.2 and item a) of 11.5.3). This requirement does not apply to sealed pressure systems.

For sulphur hexafluoride (SF_6) filled switchgear and controlgear, SF_6 in accordance with IEC 60376 for new SF_6 and its mixture and IEC 60480 for reused SF_6 and its mixture shall be used. For gas handling of switchgear and controlgear with gas, reference is made to IEC 62271-4.

In order to prevent condensation, the maximum allowable humidity content within gas-filled switchgear and controlgear at the filling density for insulation shall be such that the dew point at filling pressure (density) for insulation is not higher than -5 °C for a measurement at 20 °C during service life, refer to 11.3.6.

6.3 Earthing of switchgear and controlgear

Switchgear and controlgear shall be provided with a reliable earthing point for connection of an earthing conductor suitable for specified fault conditions. The connecting point shall be marked with the “protective earth” symbol, as indicated by symbol IEC 60417-5019:2006-08.

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Conductive parts of the switchgear and controlgear intended to be connected to the earthing system, can be designed to be part of the earthing circuit.

All conductive components and enclosures that can be touched during normal operating conditions and are intended to be earthed shall be designed to carry 30 A (DC) with a voltage drop of maximum 3 V to the earthing point provided at the switchgear and controlgear.

NOTE For guidance on the connection of the earthing point of the switchgear and controlgear to the main station earth, Clause 10 of IEC 61936-1:2021 [58] and IEC 61936-2:2015 [59] applies.

6.4 Auxiliary and control equipment and circuits

– 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 BPS or PS 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 BPS or PS is open, the open release control contact is open and the close release control contact is closed;

– where auxiliary switches are used as position indicators, they shall indicate the end position of the BPS or PS at rest, open or closed. The signalling shall be sustained;

– connections shall withstand the stresses imposed by the BPS or PS, especially those due to mechanical forces during operations;

– where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, switching and/or insulating and operating media, and be able to switch the loads which are stated by the manufacturer of the BPS or PS;

– 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 media;

– where anti-pumping devices are part of the BPS or PS control scheme, they shall act on each control circuit, if more than one is installed.

6.4.1 General

Switchgear and controlgear include all auxiliary and control equipment and circuits, including but not limited to, electronic controls, supervision, monitoring and communication.

Auxiliary and control equipment and circuits shall operate normally when the voltage measured during operation at the supply terminals of the auxiliary and control equipment and circuits:

- is within 85 % to 110 % of rated supply voltage (U_a);
- in the case of DC, a ripple voltage is not greater than 5 % of U_a;
- is free of the voltage dips and interruptions which exceed the limits declared by the manufacturer according to IEC 61000-4-29 (DC supply voltage) and IEC 61000-4-11 (AC supply voltage).

In case of supply interruptions (also during operations) that exceed the duration limits declared by the manufacturer for normal operation:

- there shall be no false operation, false alarms or false remote signalling resulting from the interruption or re-instatement of the supply;
- the manufacturer shall state the behaviour of the device when the supply voltage gets interrupted (for example impact on internal energy storage);
- the manufacturer shall state the behaviour of the device when the supply voltage returns;

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- subsequent actions shall only be completed in response to a new valid operational command (where applicable).

The fulfilment of the above conditions can be demonstrated at any convenient dip duration that exceeds the declared limit.

NOTE 1 Possible actions can be:

a) completing the pending action without manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;

b) manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;

c) completing the action after giving another command for the same switching operation that was interrupted.

This choice can also be dependent on the duration of the interruption.

Specific conditions are given in 6.9 of IEC 62271-1:2017 for shunt closing releases, shunt opening releases and under-voltage releases.

For supply voltages lower than the minimum stated above, precautions shall be taken to prevent any damage to electronic equipment and/or unsafe operation.

Requirements for the interface with digital communication that ensure compliance with IEC 61850 (all parts) [57] are detailed in IEC 62271-3 [61].

NOTE 2 The logical nodes in IEC 62271-3:2015 (XCBR, XSWI) and their additional data objects described in Annex B of IEC 62271-3:2015 cover only some properties required by the electronic nameplates of some switchgear and controlgear of the IEC 62271 series of standards. The other properties required for the physical nameplate, tendering, quotation and ordering phases are not covered.

6.4.2 Protection against electric shock

6.4.2.1 Protection of auxiliary and control circuits from the main circuit

Auxiliary and control circuits that are installed on the frame of switchgear and controlgear shall be suitably protected against disruptive discharge from the main circuit. This is verified by dielectric type tests specified in 7.2, see 7.2.5 f).

6.4.2.2 Safety clearance during service

Auxiliary and control circuits to which access is required during service shall be accessible without the need to compromise clearances to hazardous parts.

6.4.3 Components installed in enclosures

6.4.3.1 Selection of components

All components used in the auxiliary and control circuits shall be designed or selected to be operational with their rated characteristics over the full range of service conditions inside auxiliary and control circuits enclosures. Suitable precautions (for example, heaters, ventilators, insulation, etc.) should be taken to ensure that those service conditions essential for proper operation of relays, contactors, low-voltage switches, meters, operation counters, push-buttons, etc. are maintained.

NOTE These internal conditions in control cabinet for auxiliary and control circuits can differ from the external service conditions specified in Clause 4.

The loss of “suitable precautions” shall not cause failure of the auxiliary and control circuits within the enclosure or untimely operation of the switchgear within the specified time. Selection of components should take into account the temperature obtained in the cabinet of the control and auxiliary circuit during a 2-hour period following the loss of the “suitable precautions” in order to ensure the proper operation of switchgear and controlgear until the end of this 2-hour period.

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After this 2-hour period non-operation is acceptable. If the loss of the “suitable precautions” is longer than 2 h but does not exceed 24 h in total, the functionality of the switchgear and controlgear shall come back to its original characteristics when the service conditions are recovered.

Where heating is essential for correct functioning of the equipment, monitoring of the heating circuit shall be provided.

In the case of switchgear and controlgear designed for outdoor installation, suitable arrangements (ventilation and/or internal heating, etc.) can be necessary to prevent harmful condensation in auxiliary and control circuit enclosures.

6.4.3.2 Accessibility

Closing and opening actuators and emergency shut-down system actuators shall be located between 0,4 m and 2 m above the floor, ground or operating platform normally used by operating personnel.

Other actuators should be located at such a height that they can be easily operated. Indicating devices should be located at such a height as to be readily legible.

Where a component needs adjustment during its service life, access shall be provided with protection level of at least IP XXB, refer to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

6.4.3.3 Identification

Identification of components installed in enclosures shall be in agreement with the indication on the wiring diagrams and drawings. If a component is of the plug-in type, an identifying mark should be placed on the component and on the fixed part where the component plugs in.

6.4.3.4 Requirements for auxiliary and control circuit components

6.4.3.4.1 General

The auxiliary and control circuit components shall comply with applicable IEC standards if one exists. Annex E (informative) is provided as a quick reference to many of the component standards.

6.4.3.4.2 Cables and wiring

Where a facility for external wiring is provided, it shall be through an appropriate connecting device, e.g. terminal blocks or plug-in terminations.

Polarity reversal at the interfacing point shall not damage auxiliary and control circuits.

Terminal blocks should be fixed. Cables between two terminal blocks shall have no intermediate splices or soldered joints.

Cables and wiring shall be adequately supported and shall not rest against sharp edges.

The available wiring space for external connection shall permit spreading of the cores of multi-core cables and the proper termination of the conductors without undue stresses.

Conductors connected to components mounted on doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these doors.

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6.4.3.4.3 Terminals

If facilities are provided for connecting incoming and outgoing neutral, protective and PEN (protective earthed neutral) conductors, they shall be situated in the vicinity of the associated phase conductor terminal.

6.4.3.4.4 Auxiliary switches

Auxiliary switches shall be suitable for the number of operating cycles specified for the high-voltage switching device to which they are linked.

Auxiliary switches which are operated in conjunction with the main contacts shall be positively driven in both directions. An auxiliary switch can consist of a set of two one-way positively driven auxiliary contacts (one for each direction).

6.4.3.4.5 Auxiliary and control contacts

Auxiliary and control contacts shall be suitable for the number of operating cycles specified for the switching device. This requirement is verified by the mechanical endurance test of the high-voltage switching devices to which they are linked.

The operational characteristics of the auxiliary contacts that are made available to the user shall comply with one of the classes shown in Table 4.

Examples of the use of the three contact classes are shown in Figure 3.

Table 4 – Auxiliary contact classes

Direct current				
Class	**Rated continuous current**	**Rated short-time withstand current**	**Breaking capacity**	
			U_a ≤ 48 V	110 V ≤ U_a ≤ 250 V
1	10 A	100 A/30 ms		440 W
2	2 A	100 A/30 ms		22 W
3	200 mA	1 A/30 ms	50 mA	

NOTE 1 Control contacts which are included in a control circuit of a mechanical switching device can be covered by this table.

NOTE 2 If insufficient current is flowing through the contact, oxidation can increase the resistance. Therefore, a minimum value of current is specified for class 1 contact.

NOTE 3 In the case of the application of solid state contacts, the rated short-time withstand current can be reduced if current-limiting equipment, other than fuses, is employed.

NOTE 4 For all classes, breaking capacity are based on a circuit time constant of 20 ms with a tolerance of $^{+20}_{0}$ %.

NOTE 5 An auxiliary contact which complies with class 1, 2 or 3 for DC is normally able to handle corresponding AC current and voltage.

NOTE 6 Breaking current at a defined voltage value between 110 V and 250 V can be deduced from the indicated power value for class 1 and class 2 contacts (for example, 2 A at 220 V DC for a class 1 contact).

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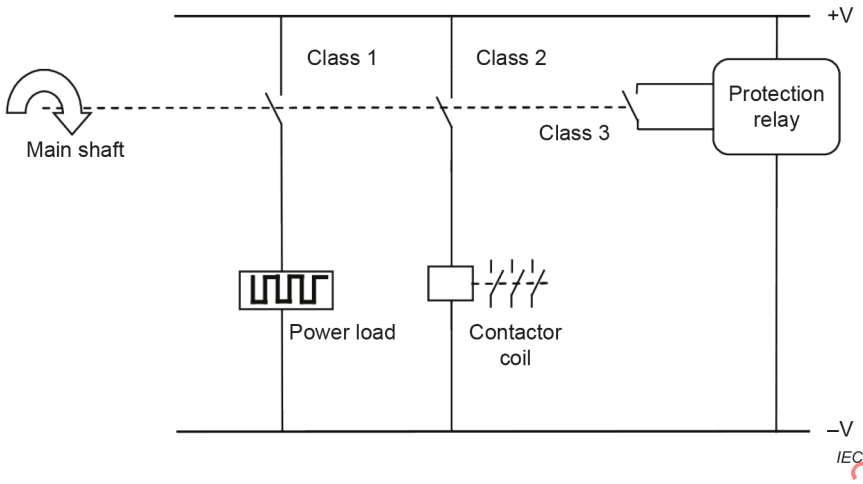

Figure 3 – Examples of classes of contacts

6.4.3.4.6 Heating elements

All heating elements shall be designed to prevent touching an electrically live part.

Where contact with a heater or shield can occur accidentally, the surface temperature shall not exceed the temperature limits for accessible parts not to be touched in normal operation, as specified in 7.4.6.

6.4.3.5 Operation counter

Operation counters shall be suitable for their intended duty in terms of environmental conditions and for the number of operating cycles specified for the switching devices.

6.5 Dependent power operation

A switching device arranged for dependent power operation with external energy supply shall be able to switch its rated making and/or breaking currents (if any) when the voltage or the pressure of the power supply of the operating device is at the lower of the limits specified under 6.4.1 and 6.6.2 (the term “operating device” here embraces intermediate control relays and contactors where provided).

Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner. The closed or open position of the main contacts shall not change as a result of loss of the energy supply or the re-application of the energy supply after a loss of energy, to the closing and/or opening device.

A BPS or PS arranged for dependent power opening with external energy supply shall also be capable of closing immediately (i.e. without additional delay) following the opening.

6.6 Stored energy operation

6.6.1 General

A switching device arranged for stored energy operation shall be capable of making and breaking all currents up to its rated values when the energy storage device is suitably charged. Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner, and not due to re-application of the energy supply after a loss of energy (electric power or pressure supply). A BPS or PS arranged for stored energy closing shall also be capable of closing immediately following the opening operation.

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A device indicating when the energy storage device is charged shall be mounted on the switching device except in the case of an independent unlatched operation.

It shall not be possible for the moving contacts to move from one position to the other, unless the stored energy is sufficient for satisfactory completion of the opening or closing operation. Stored energy devices shall be able to be discharged to a safe level prior to access.

6.6.2 Energy storage in gas receivers or hydraulic accumulators

When the energy storage device is a gas receiver or hydraulic accumulator, the requirements of 6.6.1 apply at operating pressures between the limits specified in items a) and b).

a) External pneumatic or hydraulic supply

   Unless otherwise specified by the manufacturer, the limits of the operating pressure are 85 % and 110 % of their specified rated pressure.

   These limits do not apply when the gas receivers also store compressed gas for interruption.

b) Compressor or pump integral with the switching device or the operating device

   The limits of operating pressure shall be stated by the manufacturer.

6.6.3 Energy storage in springs (or weights)

When the energy storage device is a spring (or weight), the requirements of 6.6.1 apply when the spring is charged (or the weight lifted).

6.6.4 Manual charging

If a spring (or weight) is charged by hand, the direction of motion of the handle shall be marked.

The manual charging facility shall be designed such that the handle is not driven by the operation of the switching device.

The maximum actuating force required for manually charging a spring (or weight) shall not exceed 250 N.

6.6.5 Motor charging

Motors, and their electrically operated auxiliary equipment for charging a spring (or weight) or for driving a compressor or pump, shall operate satisfactorily between 85 % and 110 % of the rated supply voltage (refer to 5.6), the frequency, in the case of AC, being the rated supply frequency (refer to 5.7).

For electric motors, the limits do not imply the use of non-standard motors but only the selection of a motor which at these values provides the necessary power, and the rated voltage of the motor does not need to be equal to the rated supply voltage of the auxiliary and control circuits.

6.6.6 Energy storage in capacitors

When the energy storage is a charged capacitor, the requirements of 6.6.1 apply when the capacitor is charged.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC TS 62271-5:2024 is not applicable as this type of operation is not used in HVDC systems.

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6.8 Manually operated actuators

Subclause 6.8 of IEC TS 62271-5:2024 is not applicable as this type of operation is not used in HVDC systems.

6.9 Operation of releases

6.9.1 General

See 6.4.1 for the basis of operation limits with respect to supply voltage.

6.9.2 Shunt closing release

A shunt closing release shall be able to operate within a voltage range of the power supply, measured at the input terminals, between 85 % and 110 % of the rated supply voltage of the closing device (refer to 5.6), the frequency, in the case of AC, being the rated supply frequency of the closing device (refer to 5.7).

6.9.3 Shunt opening release

A shunt opening release shall be able to operate under all operating conditions of the switching device up to its rated short-circuit breaking current (if any), and between 70 % in the case of DC – or 85 % in the case of AC – and 110 % of the rated supply voltage of the opening device measured at the input terminals (refer to 5.6), the frequency, in the case of AC, being the rated supply frequency of the opening device (refer to 5.7).

6.9.4 Capacitor operation of shunt releases

When a rectifier-capacitor combination is provided as an integral part of the switching device for stored energy of a shunt release, the charge of the capacitors derived from the voltage of the main circuit or auxiliary supply, shall be sufficient for satisfactory operation of the release 5 s after the voltage supply has been disconnected from the terminals of the combination and replaced by a short-circuiting link.

The voltages of the main circuit before disconnection shall be taken as the lowest voltage of the system associated with the rated voltage of the switching device. IEC 60038:2009 shall be referred to for the relation between “highest voltage for equipment” and system voltages.

6.9.5 Under-voltage release

When an under-voltage release is provided, it shall operate to open and prevent closing of the switching device for all values of the voltage at its terminals below 35 % of its rated supply voltage.

Between 70 % and 35 % of its rated supply voltage, the under-voltage release can operate, opening the switching device and preventing its closing.

On the other hand, the under-voltage release shall not operate to open the switching device when the voltage at its terminals exceeds 70 % (AC or DC) of its rated supply voltage.

The closing of the switching device shall be possible when the value of the voltage at the terminals of the release is equal to or greater than 85 % of its rated voltage.

6.10 Pressure/level indication

6.10.1 Gas pressure

Closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum functional pressure for insulation and/or operation above 0,2 MPa (absolute pressure), shall be provided with a device capable of monitoring the pressure (or density).

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The uncertainty of the gas monitoring device should be established and take into account pressure coordination (filling, minimum functional and alarm pressure) and leakage rate.

All BPSs or PSs having an energy storage in gas receivers or hydraulic accumulators (see 6.6.2 of IEC TS 62271-5:2024) and all BPSs or PSs except sealed pressure devices, using compressed gas for switching (see 6.103) shall be fitted with a locking device set to operate at, or within, the appropriate limits of pressure stated by the manufacturer.

6.10.2 Liquid level

A device for checking the liquid level, with indication of minimum and maximum limits permissible for correct operation, shall be provided. This requirement is not applicable to dashpots or shock-absorbers.

6.11 Nameplates

- The nameplates of a BPS or PS and their 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.

Table 1 – Nameplate information

	Abbreviation	Unit	BPS	PS	Operating device	Condition: Marking only required if
1	2	3	4	5	6	7
Manufacturer			X	X	X	
Type designation and serial number			X	X	X	
Rated direct voltage	U_{rd}	kV		X		
– To earth [a]	U_{rde}	kV	X	Y		Different from U_{rd}
– Across open switch	U_{rdo}	kV	X	Y		Different from U_{rd}
Rated lightning impulse withstand voltage	U_p	kV		X		
– To earth [a]	U_{pe}	kV	X	Y		Different from U_p
– Across open switch	U_{po}	kV	X	Y		Different from U_p
Rated switching impulse withstand voltage	U_s	kV		X		
– To earth [a]	U_{se}	kV	X	Y		Different from U_s
– Across open switch	U_{so}		X	Y		Different from U_s
Rated direct withstand voltage	U_{dd}	kV		X		
– To earth [a]	U_{dde}		X	Y		Different from U_{dd}
– Across open switch	U_{ddo}		X	Y		Different from U_{dd}
Rated continuous current	I_{rd}	A	Y	X		Rating is assigned
Rated temporary current	I_t	A	X			For BPSs when a temporary current is assigned
Duration of temporary current		min	X			Different from 30 min
Rated short-time withstand direct current	I_{kd}	kA	X	X		

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Rated peak withstand current	I_{pd}	kA	X	X		
Rated duration of short-circuit	t_{kd}	s	Y	Y		Different from 1 s
Rated supply voltage of auxiliary and control circuits Specify DC/AC (with rated frequency)	U_a	V Hz			(X)	
Filling pressure for operation	P_m	MPa			(X)	
Filling pressure for insulation and/or switching	P_e	MPa	(X)	(X)		
Mass	M	kg	Y	Y	Y	More than 300 kg
Type and mass of fluid (liquid or gas) for switching	M_f	kg	Y	Y		Contains fluid
Rated operating sequence			X	X		
Year of manufacture			X	X		
Minimum and maximum ambient air temperature			Y	Y	Y	Different from −5 °C and/or 40 °C
Reference to this document			X	X	X	

X = the marking of these values is mandatory; blanks indicate the value zero.

(X) = the marking of these values is optional.

Y = the marking of these values is in accordance with the conditions in column 7.

[a] For BPSs this rating applies to the open position only.

NOTE 1 The abbreviation 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.

NOTE 2 The BPS or PS can have different insulation levels to earth and across open contacts (see 6.101).

6.11.1 General

Switchgear and controlgear (and their operating devices where applicable) shall be provided with nameplates that contain the information required to identify the equipment, its ratings and appropriate operating parameters as specified in the relevant IEC standards.

6.11.2 Application

Table 5 shall be used where applicable if the product standard does not provide more specific information.

In particular, the terminology, symbols and units given in the table shall be used as appropriate. Annex F (informative) provides an extended list including non-rated values. The following recommendations should be considered as appropriate:

a) the type and mass of insulating fluid should be noted either on a nameplate or on a label placed in a visible location;

b) it should be stated whether pressures are absolute or relative values;

c) switchgear and controlgear installed outdoors or in high humidity should have nameplates and have methods of attachment that are weather-proof and corrosion-proof;

d) for an operating device combined with a switchgear device, it may be sufficient to use only one combined nameplate;

e) nameplates should be visible in the position of normal service and installation;

f) technical characteristics on nameplates and/or in documents which are common to several kinds of high-voltage switchgear and controlgear should be represented by the same symbols;

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g) since other characteristics (such as type of gas or temperature limits) are specialized, they shall be represented by the symbols which are used in the relevant standards.

Table 5 – Nameplate information

Item		Symbol	Unit	(**)	Condition: Marking only required if
(1)	(2)	(3)	(4)	(5)	(6)
1	Name of manufacturer			X	
2	Type designation and serial number			X	
3	Rated direct voltage	U_{rd}	kV	X	
4	Rated direct withstand voltage	U_{dd}	kV	X	
5	Rated lightning impulse withstand voltage	U_{p}	kV	X	
6	Rated switching impulse withstand voltage	U_{s}	kV	Y	rated direct voltage 210 kV and above
7	Rated continuous current	I_{rd}	A	X	
8	Rated short-time withstand direct current	I_{kd}	kA	X	
9	Rated peak withstand current	I_{pd}	kA	X	
10	Rated duration of short-circuit	t_{kd}	s	X	
11	Filling pressure for operation(*)	p_{rm}	MPa	X	
12	Filling pressure for insulation(*)	p_{re}	MPa	X	
13	Alarm pressure for insulation(*)	p_{ae}	MPa	X	
14	Alarm pressure for operation(*)	p_{am}	MPa	X	
15	Minimum functional pressure for insulation and/or switching(*)	p_{me}	MPa	X	
16	Minimum functional pressure for operation(*)	p_{mm}	MPa	X	
17	Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_{a}	V	X	
18	Type and mass of fluid (liquid or gas) for insulation	M_{f}	kg	X	
19	Mass of switchgear and controlgear (including any fluid)	M	kg	Y	more than 300 kg
20	Year of manufacture			X	
21	Minimum and maximum ambient air temperature		°C	Y	different from -5 °C and/or 40 °C

(*) Absolute pressure (abs.) or relative pressure (rel.) to be stated on the nameplate.

(**) X = the marking of these values is mandatory, where applicable.

Y = conditions for marking of these values are given in column (6).

NOTE 1 The symbol in column (3) can be used instead of the terms in column (2) to be stated on the nameplate.

NOTE 2 When terms in column (2) are used, the word “rated“ can be omitted.

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6.12 Locking devices

Switching devices, the incorrect operation of which can cause damage or which are used for assuring isolating distances, shall be provided with locking facilities (for example, provision for padlocks).

6.13 Position indication

Indication of the actual position of the main contacts of the switching devices shall be provided unless the contacts themselves are visible in all positions.

Requirements for position indicating devices are as follows:

- it shall be possible to read the position-indicating device when operating locally;
- all stable positions such as open, closed and test positions shall be clearly indicated.

Identification of the open, closed and where appropriate earthed positions should use symbols and/or colours defined by the relevant IEC publications: IEC 60073 [14] for colours, IEC 60417 [27] for symbols and IEC 60617 [30] for diagrams.

6.14 Degrees of protection provided by enclosures

6.14.1 General

The enclosures shall provide degrees of protection in accordance with 6.14.2 through 6.14.4.

6.14.2 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)

The degree of protection of persons and of equipment provided by an enclosure against access to hazardous parts of the main circuit, control and/or auxiliary circuits and to any hazardous moving parts and against ingress of solid foreign objects shall be at least IP1XB according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

6.14.3 Protection against ingress of water (IP coding)

For equipment of indoor installation, no minimum degree of protection against harmful ingress of water is specified, i.e. the second characteristic numeral of the IP code is X according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

Equipment for outdoor installation shall be at least IPX3 according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013. If it is provided with additional protection features against rain and other weather conditions (supplementary letter W), the performance refers to the situation with these features in place and shall be demonstrated according to Annex G (normative) (see 7.6.1).

6.14.4 Protection against mechanical impact under normal service conditions (IK coding)

For indoor installation, the preferred impact level is IK07 according to IEC 62262:2002 (2 J).

For outdoor installation without additional mechanical protection, the minimum impact level shall be IK10 according to IEC 62262:2002 (20 J).

Insulators and bushings of high-voltage switchgear and controlgear are not subjected to this requirement.

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6.15 Creepage distances for outdoor insulators

Annex B (informative) gives general rules (included RUSCDDC) that assist in choosing insulators which should give satisfactory performance under polluted conditions.

The general rules given in Annex B (informative) are applicable for glass, porcelain, composite and hybrid insulators.

For BPSs the creepage distance to earth and across open switching device shall be calculated based on the rated direct voltages as per 5.2.101 and 5.2.102, respectively. The creepage distance for a BPS terminal-to-earth shall be calculated from each terminal with the relevant rated voltage on the terminal and with the switch in open position.

6.16 Gas and vacuum tightness

6.16.1 General

The following specifications apply to all switchgear and controlgear that use vacuum or gas, other than ambient air, as an insulating, switching, combined insulating and switching, or operating medium.

For vacuum tightness no leakage rate F shall be specified, instead the level of vacuum and the expected operating duration shall be given.

NOTE 1 IEC TR 62271-306 [62] and CIGRE Brochure 430 [71] give some information, examples and guidance for tightness.

The absolute leakage rate F shall not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C.

An increased leakage rate at extreme temperatures is permissible, provided that this rate resets to a value not higher than the permissible value F_p at standardized ambient temperature of 20 °C. The increased temporary leakage rate shall not exceed the values given in 7.7.1.

NOTE 2 The average leakage rate observed during service life can be higher than the specified leakage rate due to the temporary increased leakage rate at temperatures above or below the standardized ambient temperature.

6.16.2 Controlled pressure systems for gas

The tightness of controlled pressure systems for gas is specified by the number of replenishments per day (N) or by the pressure drop per day (Δp). SF_6 gas and SF_6 mixtures are not applicable for controlled pressure systems.

NOTE Most controlled pressure systems use air as the gas; however, other gases can be used.

6.16.3 Closed pressure systems for gas

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment. The maximum value under the standardized ambient temperature of 20 °C is 0,5 % per year irrespective of gas type.

NOTE 1 A lower SF_6 leakage rate can apply to meet some local or governmental regulations, e.g. 0,1 % per year.

The tightness characteristic of a closed pressure system and the time between replenishments under normal service conditions shall be stated by the manufacturer. This time shall be at least 10 years for maintenance planning purposes. Means shall be provided to enable gas systems to be replenished while the equipment is in service.

NOTE 2 The term “in service” implies “under live conditions”.

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NOTE 3 Manufacturer's instructions and the user's operating practices provide guidance for replenishing gas.

6.16.4 Sealed pressure systems

The tightness of sealed pressure systems is specified by their expected operating duration. The expected operating duration shall be specified by the manufacturer and shall be at least 20 years. Other preferred values are 30 years and 40 years.

The tightness of gas insulated switchgear and controlgear shall be designed in a way to ensure that the minimum functional pressure (density) shall not be attained before the expected end of life. The manufacturer shall specify a permissible leakage rate.

NOTE 1 For some designs verification of an expected operating duration greater than 20 years can be impractical for a type or routine test.

NOTE 2 Sealed SF_6 switchgear and controlgear is considered to have insignificant SF_6 losses (less than 0,1 % per year) during their expected operating duration.

6.17 Tightness for liquid systems

6.17.1 General

The following specifications apply to all switchgear and controlgear that use liquids as insulating, or combined insulating and switching, or operating medium with or without permanent pressure.

6.17.2 Leakage rates

The permissible leakage rate $F_{p(liq)}$ for liquid shall be indicated by the manufacturer. A clear distinction shall be made between internal and external tightness where internal tightness refers to leakage between two compartments within a single closed system and external tightness refers to leakage outside of the closed system.

a) total tightness (sealed pressure system): no liquid loss can be detected;

b) relative tightness: slight loss is acceptable under the following conditions:

- the leakage rate, F_{liq} shall be less than the permissible leakage rate, $F_{p(liq)}$;
- the leakage rate, F_{liq} shall not increase with time or in the case of switching devices, with number of operations;
- the liquid leakage shall not cause malfunction of the switchgear or controlgear, nor cause any injury to operators in the normal course of their duty.

6.18 Fire hazard (flammability)

No technical requirement is defined for high-voltage switchgear and controlgear due to the large variety of designs and lack of acceptance criteria. The information below is provided for guidance.

IEC 60695-1 (all parts) [33] provides guidance for assessing the fire hazard of electrotechnical products.

IEC 60695-7 (all parts) [34] provides guidance on the minimization of toxic hazards due to fires involving electrotechnical products.

6.19 Electromagnetic compatibility (EMC)

Switchgear and controlgear shall be capable of satisfying the EMC tests specified in 7.8.

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6.20 X-ray emission

This subclause is applicable to vacuum interrupters used in switchgear and controlgear. Vacuum interrupters shall be designed in such a way that the acceptance criteria about X-ray emission levels specified in 7.10.3 are satisfied when subjected to the test specified in 7.10.

6.21 Corrosion

Due to the large number of parameters to be considered no standard requirements can be given. General recommendations are given in IEC TR 62271-306 [62].

6.22 Filling levels for insulation, switching and/or operation

The pressure (or density) or liquid mass shall be assigned by the manufacturer. The pressure (or density) of gas is referred to atmospheric conditions of 20 °C at which gas-filled switchgear is filled before being put into service.

In addition to the filling levels the following values shall be assigned by the manufacturer (when applicable):

– alarm pressure p_{ae} (or density ρ_{ae}) for insulation and/or switching;

– alarm pressure p_{am} (or density ρ_{am}) for operation;

– minimum functional pressure p_{me} (or density ρ_{me}) for insulation and/or switching;

– minimum functional pressure p_{mm} (or density ρ_{mm}) for operation.

6.101 Design of BPSs and PSs

6.101.1 BPSs

Figure 1 shows a case where two BPSs are installed to by-pass and insert two converter units.

In the case illustrated in Figure 1 the BPS bridges one converter unit. Figure 7 illustrates the case where two BPSs bridge two converter units of one pole. Each BPS consists of two switching units in series.

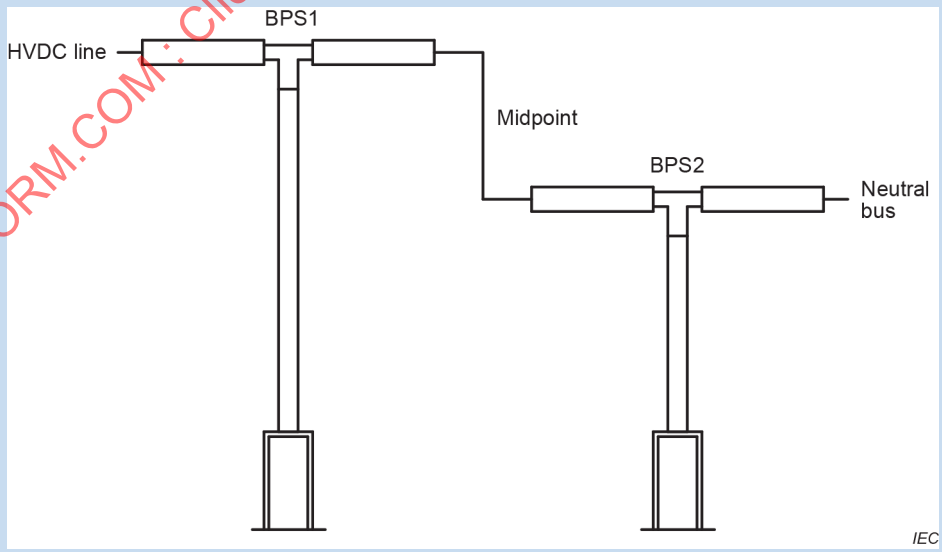

Figure 7 – Example of two series connected BPSs

In the case illustrated in Figure 7 the voltage between the HVDC line and the neutral bus is shared by four switching units.

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Grading elements, if used, can consist of resistors or a combination of resistors and capacitors, but not capacitors alone. They do not necessarily have to be fitted in the same enclosure (i.e. can be in separate units).

NOTE In case grading elements are used in Figure 7, the voltage across each BPS is 50 % of the voltage of the HVDC line and the voltage across the post insulator of BPS1 is 75 % of the voltage of the HVDC line, whereas the voltage across the post insulator of BPS2 is 25 % of the voltage of the HVDC line.

As can be seen, the voltage of a BPS depends on the voltage of the HVDC line, number of converter units per pole and number of series connected switching units.

6.101.2 PSs

PSs are used for rapid configuration of a multi-terminal HVDC transmission system. Examples are given in Figure 2 and Figure 3.

6.102 General requirement for operation

A BPS or PS, including its operating devices, shall be capable of completing its operating sequence given in 5.102 in accordance with the relevant provisions of 6.5 to 6.10 and 6.103 for the whole range of ambient temperatures within its minimum and maximum air temperature as defined in Clause 4 of IEC TS 62271-5:2024.

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

BPSs and PSs provided with heaters shall be designed to permit an opening or closing operation at the minimum ambient air temperature 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 BPS or PS 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).

6.104 Time quantities

Refer to Figure 4, Figure 5 and Figure 6.

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)
– commutation time (if applicable, see also 7.102).

Time quantities are based on:

– rated supply voltages of closing and opening devices and of auxiliary and control circuits (see 5.6);
– rated supply frequency of closing and opening devices and of auxiliary circuits (see 5.7);
– filling levels for insulation and/or operation (see 6.22);
– an ambient air temperature of 20 °C ± 5 °C.

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6.105 Static mechanical loads

Outdoor BPSs and PSs 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.

Some examples of static forces due to wind, ice and weight on flexible and tubular connected conductors are given as guidance in Table 2.

When calculating the stresses resulting from ice and wind, the ice coating and wind pressure shall be in accordance with 4.1 of IEC TS 62271-5:2024.

The tensile force due to the connected conductors is assumed to act at the outermost end of the BPS or PS terminal.

Table 2 – Examples of static horizontal and vertical forces for static terminal load

Rated voltage range	Rated current range	Static horizontal force F_{th}		Static vertical force
U_{rd}	I_{rd}	Longitudinal F_{thA}	Transversal F_{thB}	F_{tv}
kV	A	N	N	N
105 to 160	1 250 to 2 000	600	200	1 000
210 to 420	1 600 to 4 000	1 500	500	1 250
525 to 840	2 000 to 4 000	2 000	660	1 500

7 Type tests

7.1 General

7.1.1 Basics

The type tests are for the purpose of proving the ratings and characteristics of switchgear and controlgear, their operating devices and their auxiliary equipment. Each individual type test or type test sequence shall be made on test objects as defined in 3.2.1, in the condition as required for service (filled with the specified types and quantities of liquid or gas), with their operating devices and auxiliary equipment, all of which in principle shall be in, or restored to, a new and clean condition at the beginning of each type test or type test sequence.

Reconditioning during individual type tests or test sequence may be allowed, according to the relevant IEC product standards. The manufacturer shall provide a statement to the testing laboratory of those parts that may be renewed during the tests.

Tolerances on test quantities are listed in Table H.1.

Information regarding the extension of validity of type tests is given in Annex I (informative).

The type tests for BPSs or PSs are listed in Table 3.

Tolerances on test quantities are given in Annex A.

A new or refurbished BPS or PS may be used for each of the tests specified in Table 3.

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

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The expanded uncertainty of a complete measuring system for determination of the ratings shall be ≤ 5 %, evaluated with a coverage probability of 95 % corresponding to a coverage factor k = 2 under the assumption of a normal distribution.

NOTE Procedures for the determination of the uncertainty of measurements are given in ISO/IEC Guide 98-3 [1][2].

A change in the auxiliary and control circuit does not constitute an alternative operating mechanism.

Table 3 – Mandatory type tests

Preferred type tests [a]		Subclauses
Dielectric tests		7.2
Resistance measurement		7.3
Continuous current test (PS only)		7.4
Temporary current test (BPS only)		7.4.101
Short-time withstand current and peak withstand current tests		7.5
Additional tests on auxiliary and control circuits		7.9
Mechanical operation test at ambient temperature		7.101.2
Current commutation tests		7.102
[a] Mandatory type tests are required for all BPSs and PSs regardless of rated voltage, design or intended use. Other type tests are required for all BPSs and PSs where the associated rating is specified, for example RIV is required only for rated voltages of 210 kV and above.		
Type tests depending on requirements	**Condition requiring type test**	**Subclauses**
Electromagnetic compatibility tests (EMC)	U_{rd} ≥ 210 kV	7.8
Continuous current test	On BPSs when a continuous current rating is assigned	7.4
Verification of the protection	Assigned IP and IK class	7.6
Tightness test	Controlled, sealed or closed pressure systems	7.7
EMC tests	Electronic equipment or components are included in the auxiliary and control circuit	7.8
X-ray radiation test	Vacuum interrupters	7.10
Low and high temperature tests	If ambient air temperature is different from −5 °C and/or +40 °C	7.101.3
Humidity test	Insulation subject to voltage stress and condensation	7.101.4
Test to prove operation under severe ice conditions	Outdoor BPS or PSs with moving external parts	7.101.5

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7.1.2 Information for identification of test objects

The manufacturer shall submit to the testing laboratory, drawings and other data containing sufficient information to unambiguously identify by type the essential details and parts of the switchgear and controlgear presented for test. A summary list of the drawings and data schedules shall be supplied by the manufacturer and shall be uniquely referenced and shall contain a statement that the manufacturer guarantees that the drawings or data sheets listed are the correct version and represent the switchgear and controlgear to be tested.

The testing laboratory shall check that drawings and data sheets adequately represent the essential details and parts of the test object but is not responsible for the accuracy of the detailed information.

Particular drawings or data required to be submitted by the manufacturer to the test laboratory for identification of essential parts of test object are specified in Annex J (normative).

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2 Numbers in square brackets refer to the Bibliography.

7.1.3 Information to be included in type-test reports

The results of all type-tests shall be recorded in type-test reports containing sufficient data to prove compliance with the ratings and the test clauses of the relevant standards and sufficient information shall be included so that the essential parts of the test object can be identified. In particular, the following information shall be included:

– the manufacturer;
– the type designation and the serial number of the test object;
– the rated characteristics of the test object as specified in the relevant IEC standards.;
– the general description of the test object;
– the manufacturer, type, serial numbers and ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances);
– the general details of the supporting structure of the switching device or enclosed switchgear of which the switching device forms an integral part;
– the details of the operating-mechanism and devices employed during tests, where applicable;
– photographs to illustrate the condition of the test object before and after test;
– sufficient outline drawings and data schedules to represent the test object;
– the reference numbers of all drawings including revision number submitted to identify the essential parts of the test object;
– a statement that the test object complies with the drawings submitted;
– details of the testing arrangements (including diagram of test circuit);
– statements of the behaviour of the test object during tests, its condition after tests and any parts renewed or reconditioned during the tests;
– in case of breaking operations with some specific technologies, non-sustained disruptive discharge can occur during the recovery voltage period. Their number is of no significance to interpreting the performance of the device under test. They shall be reported in the test report only in order to differentiate them from restrikes;
– records of the test quantities during each test or test duty, as specified in the relevant IEC standards;
– the location, laboratory name where the tests were conducted and date of test.

Further details relating to records and reports of type tests are given in Annex B.

7.2 Dielectric tests

7.2.1 General

Dielectric tests shall be performed in compliance with IEC 60060-1, unless otherwise specified in this document.

No tests are required for the BPS in closed position.

NOTE When the BPS is in closed position, the voltage stresses are substantially lower than the ratings assigned in open position (since a converter unit is by-passed) and therefore the dielectric stresses terminal to earth in closed position are covered by the tests in open position.

7.2.2 Ambient air conditions during tests

Reference shall be made to IEC 60060-1 regarding standard reference atmospheric conditions and atmospheric correction factors.

For test objects where external insulation in ambient air is of principal concern, the atmospheric correction factor K_t shall be applied.

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The humidity correction factor k_2 shall be applied only for the dry tests where insulation in ambient air is of principal concern.

For test objects having external and internal insulation, the correction factor K_t shall be applied if its value is between 0,95 and 1,05. However, in order to avoid over-stressing of internal insulation, the application of the correction factor K_t may be omitted where the satisfactory performance of external insulation has been established.

If K_t is above 1,0 then to fully test the external insulation system, the internal insulation will be overstressed and steps may be necessary to prevent overstressing the internal insulation systems. If K_t is below 1,0 then to test the internal insulation system fully, the external insulation will be overstressed and steps may be necessary to prevent overstressing the external insulation systems. Some methods are discussed in IEC 60060-1.

For test objects having only internal insulation, the ambient air conditions are of no influence and the correction factor K_t shall not be applied.

For combined tests, parameter g shall be calculated considering the total test voltage value.

For cases where the equipment is installed where the maximum specified ambient air temperature exceeds 40 °C, test voltages shall be corrected for the most stringent combination of temperature and humidity. The combination of them provides the highest atmospheric correction among other possible combinations of temperature and humidity under service condition.

NOTE In valve halls, a combination of a high temperature and a very low humidity can happen (see 4.2.2). As an example, the most stringent combination of temperature and low humidity level can be such as 50 °C and 1 g/m^3. Other combinations are also possible.

7.2.3 Wet test procedure

When a wet test is required, the standard wet test procedure given in IEC 60060-1 shall be followed.

7.2.4 Arrangement of the equipment

Dielectric tests shall be made on switchgear and controlgear completely assembled, as in service with any supplementary insulation such as tape or barriers if stated in the installation instructions; the outside surfaces of insulating parts shall be in clean condition.

The test object shall be mounted for test with minimum clearances as specified by the manufacturer if such surrounding influences the performance.

NOTE Each HVDC system pole usually maintains a sufficient clearance from each other.

Tests shall be performed with the test object installed at a height above ground equal to or less than the height used in service.

If arcing horns or rings are part of the design for gradient distribution, they shall remain in position for the test. If they are proposed as overvoltage protection devices for the system, they are not part of the design of the test object and shall be not installed for tests.

For test objects using compressed gas for insulation, dielectric tests shall be performed at minimum functional pressure (density) for insulation. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

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For dielectric testing of switchgear and controlgear incorporating vacuum switching devices, precautions shall be taken to ensure that the level of possible emitted X-radiation during high-voltage testing is within safe limits (see 7.10). National regulations can influence the safety measures established.

7.2.5 Criteria to pass the test

a) Direct voltage tests

The test object shall be considered to have passed the test if no disruptive discharge occurs.

If during a wet test a disruptive discharge (as defined in IEC 60060-1) on external self-restoring insulation occurs, this test shall be repeated in the same test condition without intermediate cleaning and the test object shall be considered to have passed this test successfully if no further disruptive discharge occurs.

b) Impulse voltage tests

The test procedure B of 7.3.1.2 of IEC 60060-1, adapted for test objects that have self-restoring and non-self-restoring insulation, is the preferred test procedure. The test object has passed the impulse tests if the following conditions are fulfilled:

– each series has at least 15 impulses;

– the number of disruptive discharges does not exceed two for each complete series;

– no disruptive discharge on non-self-restoring insulation occurs. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge.

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

c) Superimposed impulse tests

The test object shall be considered to have passed the tests if the following conditions are fulfilled.

– pre-stress with rated direct voltage has been applied for 2 h, and no disruptive discharge occurs;

– the number of disruptive discharges does not exceed two for each complete series;

– no disruptive discharge on non-self-restoring insulation occurs. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge.

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

d) Polarity reversal tests

The test object shall be considered to have passed the test if no disruptive discharge occurs.

e) Voltage test as condition check

The test object shall be considered to have passed the test if no disruptive discharge occurs.

f) General comment

– When testing switchgear and controlgear, the part of equipment through which the test voltage is applied can be subjected to numerous test sequences to check the insulating properties of other downstream parts of equipment (circuit-breakers, disconnectors, other bays). It is recommended that parts be tested in sequence, starting with the first connected part. When this part has passed the test according to the above-mentioned criteria, its qualification is not impaired by possible disruptive discharges which could occur in it during further tests on other parts.

These discharges can have been generated by accumulation of discharge probability with the increased number of voltage applications or by reflected voltage after a disruptive discharge at a remote location within the equipment. To reduce the probability of occurrence of these discharges in gas-filled equipment, the pressure of compartments which are not subject of the test can be increased. Compartments at increased pressure should be clearly identified in the test report(s).

– A disruptive discharge to the auxiliary and control circuits shall be considered as a failure.

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For metal enclosed BPSs or PSs tested with test bushings that are not part of the BPS or PS, flashovers across the test bushings shall be disregarded, but each failed test shall be repeated. In case the test bushings continue to fail they shall be replaced.

7.2.6 Application of the test voltage and test conditions

7.2.6.1 General

Distinction shall be made between the general case, where the three test voltages (pole-to-earth, across open switching device and across the isolating distance) are the same and the special cases where the test voltages across the isolating distance is higher than the test-voltage pole to earth.

Some insulating materials retain a charge after a voltage application, and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of two impulses between 60 % and 80 % of the rated withstand voltage in the reverse polarity before the test, is recommended.

When testing switchgear incorporating an open vacuum interrupter, for each polarity a maximum of 25 preliminary impulses maybe performed at up to and including the rated withstand voltage. The number and level of preliminary impulses shall be stated by the manufacturer. Breakdowns that are observed during these preliminary tests shall be disregarded for the purpose of withstand statistics used to determine pass or fail performance of the equipment.

7.2.6.2 General case

Subclause 7.2.6.2 of IEC TS 62271-5:2024 is not applicable.

With reference to Figure 4, which shows a diagram of connection of a single pole switching device, the test voltage shall be applied according to Table 6, as applicable.

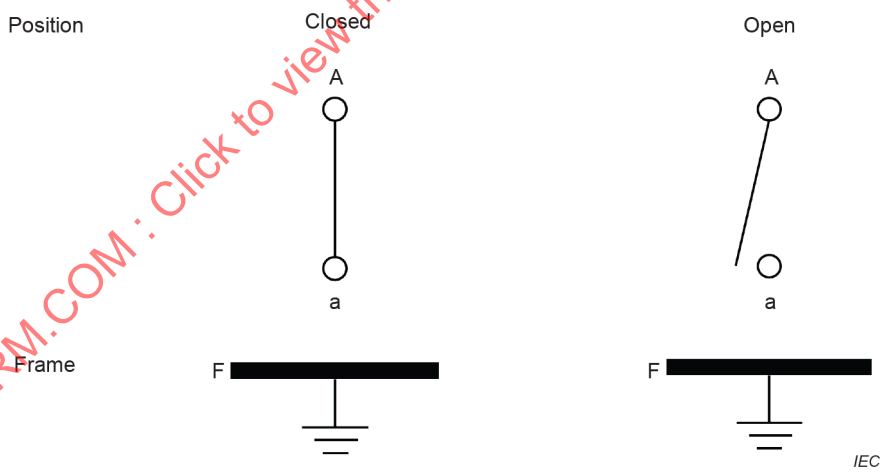

Figure 4 – Diagram of connections of a switching device

Table 6 – Test conditions in general case

Test condition	Switching device	Voltage applied to	Earth connected to
1	Closed	Aa	F
2	Open	A	aF
3	Open	a	AF
NOTE Test condition 3 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.			

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With reference to Figure 4 of IEC TS 62271-5:2024, which shows a diagram of connection of a single pole switching device, the test voltage shall be applied according to Table 4, Table 5 or Table 6 as applicable.

It is recognized that it might not be possible to perform tests on a BPS in a test laboratory which fully corresponds to service conditions. Therefore, alternatives for dielectric tests are provided for BPSs depending on the product configuration and the test setup of the laboratory.

Alternative 1 is a test setup to test the BPS using one voltage source only.

Alternative 2 is a test setup to test the relevant BPS by applying voltage to both terminals with one of the following methods:

a) Voltage distribution method. This is achieved by including the complete BPS configuration as seen between the pole bus and the neutral. This means that all BPSs for the relevant pole shall be included in the test set-up. If the BPSs are equipped with grading elements, it is permitted to replace the BPSs not subjected to type-test with its (their) grading elements or equivalent components to ensure that the applied voltage will stress both terminals correctly;
b) Method with two voltage sources. This is achieved by applying a voltage on both terminals using two separate voltage sources. In this case the main part applied consist of the rated withstand voltage to earth and the complementary part consist of a direct voltage, alternating voltage or impulse voltage with the same polarity as the main part.

Alternative 2 is not applicable for BPSs connected to the neutral.

It is allowed to perform the complete set of withstand tests with a combination of both alternatives, for example impulse voltage withstand tests according to Alternative 1 and direct voltage withstand tests according to Alternative 2.

Table 4 – Test conditions in general case for BPSs according to Alternative 1

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1 [a]	Open	A [b]	F	5.3.101 Rated withstand voltage to earth
2	Open	A	aF	5.3.102 Rated withstand voltage across open switching device
3 [c]	Open	A	AF	5.3.102 Rated withstand voltage across open switching device

[a] BPSs connected to the neutral may be tested as per test condition 2 but with terminal a connected to earth. In this case all other test conditions may be omitted.

[b] In test condition 1 terminal A defines the terminal assigned for the highest voltage to earth. Terminal a is in this test condition floating, i.e. not connected to a voltage source or earth. This test is a verification of the insulation terminal to earth based on the system insulating level and not intended to verify the insulation across the open switching device.

[c] Test condition 3 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.

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Table 5 – Test conditions in general case for BPSs according to Alternative 2

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1	Open	A and a [a]	F	5.3.101 Rated withstand voltage to earth
2	Open	A	AF	5.3.102 Rated withstand voltage across open switching device

[a] The test voltage to be applied on terminal a should be such that the voltage difference between terminals A and a is equal to the rated withstand voltage across open switching device.

Table 6 – Test conditions in general case for PSs

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1	Closed	Aa	F	5.3.101 Rated withstand voltage to earth
2	Open	A	aF	5.3.102 Rated withstand voltage across open switching device
3[a]	Open	A	AF	5.3.102 Rated withstand voltage across open switching device

[a] Test condition 3 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.

7.2.6.3 Special cases

Subclause 7.2.6.3 of IEC TS 62271-5:2024 is applicable to PSs only.

7.2.6.3.1 Impulse voltage tests across the isolating distance (or open switching device)

In case of impulse voltage tests across the isolating distance (or open switching device), the test voltage shall be applied according to Table 7, as applicable.

Table 7 – Test conditions in case of impulse voltage tests across the isolating distance (or open switching device)

Test condition	Main part	Complementary part	Earth connected to
	Voltage applied to		
1	A	a	F
2	a	A	F
NOTE Test condition 2 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.			

The rated impulse withstand voltage pole-to-earth constitutes the main part of the test voltage and is applied to one terminal; the complementary voltage is supplied by another voltage source of the opposite polarity and applied to the opposite terminal. This complementary voltage may be either another impulse voltage, the peak of a power-frequency voltage or a direct voltage. The sum of the impulse voltage peak and the complementary voltage at the instant of the peak

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of the impulse shall be equal to the total test voltage required with a tolerance of ±3 %. The frame is earthed.

NOTE To date, there is no design of disconnectors with solid insulating materials between the isolating distance. This means that surface and space charge effects can be largely excluded. Pre-stressing with direct voltage is not necessary.

7.2.6.3.2 Superimposed impulse tests

In case of superimposed impulse voltage tests, the voltage shall be applied according to Table 8, as applicable.

NOTE 1 This test applies to devices whose terminal is connected to high voltage side of grid system.

Table 8 – Test conditions in case of superimposed impulse voltage tests

Test condition	Switching device	Voltage applied to	Earth connected to
1	Closed	Aa	F

NOTE 2 To date, there is no design of disconnectors with solid insulating materials between the isolating distance. This means that surface and space charge effects can be largely excluded. Pre-stressing with direct voltage in open position is not necessary.

7.2.7 Tests of switchgear and controlgear

7.2.7.1 General

Subclause 7.2.7.1 of IEC TS 62271-5:2024 is not applicable.

The test voltage shall be applied according to Table 1 of IEC TS 62271-5:2024 based on the rated insulating levels assigned in 5.3.101 and 5.3.102.

The tests shall be performed with the test conditions stated in 7.2.7.2, 7.2.7.3 and 7.2.7.4, respectively.

7.2.7.2 Direct voltage tests

The test object shall be subjected to direct withstand voltage tests in accordance with IEC 60060-1. The test shall be carried out at rated direct withstand voltage and ambient temperature at positive and negative polarity. The test voltage shall be raised for each test condition to the test value and maintained for 1 h.

The tests shall be performed in dry conditions and also in wet conditions for outdoor switchgear and controlgear with external insulation.

The open switching device and/or isolating distance shall be tested in condition 2 and 3 of Table 6.

NOTE The direct voltage test is carried out to verify the withstand voltage under short-time loads. Possible DC charging effects are verified by dielectric tests specified by the relevant product standards.

The BPS and the PS shall be tested with the test conditions described in 7.2.6.2.

7.2.7.3 Switching impulse voltage tests

Switching impulse voltage tests are applicable for rated direct voltages U_{rd} of 210 kV and above. The test object shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse according to IEC 60060-1. For outdoor switchgear and controlgear with external insulation only, wet tests shall be performed and dry tests may be omitted.

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The open switching device shall be tested in condition 2 and 3 of Table 6. The isolating distance shall be tested in condition 1 and 2 of Table 7.

PSs shall be tested with the test conditions described in 7.2.6.2. For outdoor BPSs or PSs dry tests shall be performed using voltage of positive polarity only.

7.2.7.4 Lightning impulse voltage tests

The test object shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 µs according to IEC 60060-1.

The open switching device and/or isolating distance shall be tested in condition 1 and 2 of Table 7.

BPSs and PSs shall be tested as per 7.2.6.2. In addition, the open switching device shall be tested as per 7.2.6.3.1.

7.2.7.5 Superimposed impulse voltage tests

Subclause 7.2.7.5 of IEC TS 62271-5:2024 is not applicable.

7.2.7.6 Polarity reversal tests

Polarity reversal tests are applicable for LCC applications only. In case that there is no high stressed solid dielectric material, this test may be omitted with an agreement between user and manufacturer. The test object shall be subjected to polarity reversal tests in dry conditions and also in wet conditions for outdoor switchgear and controlgear with external insulation.

The open switching device and/or isolating distance shall be tested in conditions 2 and 3 of Table 6.

NOTE Superimposed impulse test on switchgear makes polarity reversal tests unnecessary.

Figure 5 shows the test sequence for polarity reversal test. The duration of pre-stress with -1,25 times of the rated direct voltage shall be t_1. After the polarity reversal, the duration of the opposite test voltage shall be t_1. After the complete procedure, an additional direct voltage stress -1,25 × U_{rd} shall be added with duration t_2. Preferred values for the durations of each step are given in Table 9. If, due to capacitance of the test object, polarity reversal cannot be achieved within 2 min, the duration for polarity reversals shall be agreed between user and manufacturer and the duration shall be stated in the test report.

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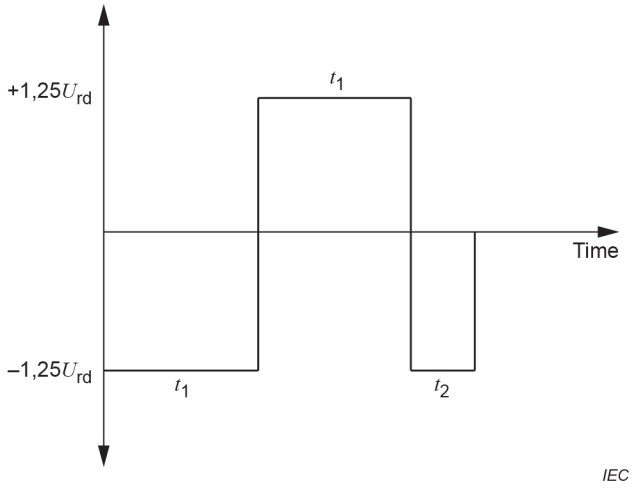

Figure 5 – Test sequence for polarity reversal tests

Table 9 – Test conditions for polarity reversal tests

Time	Value
t_1	90 min
t_2	45 min
Time duration for a polarity reversal	< 2 min

7.2.8 Artificial pollution tests for outdoor insulators

Artificial pollution tests are not required for insulators having creepage distances that are following the suggested values of 6.15 and Annex B (informative).

If the creepage distances differ from the suggested values given in Annex B (informative) artificial pollution tests shall be performed according to IEC TS 61245, using the rated voltage and the application factors given in IEC TS 60815-4:2016.

NOTE IEC TS 61245 describes the test procedure only for non-HTM insulators. No test procedure is available at present for HTM insulators.

7.2.9 Partial discharge tests

Unless otherwise specified by the relevant product standard, partial discharge tests are not required. When tests are required, the measurements shall be made according to IEC 60270.

7.2.10 Dielectric tests on auxiliary and control circuits

The dielectric test on auxiliary and control circuits are covered under 7.9.5.

7.2.11 Voltage test as condition check

When a dielectric test is required as condition check, a short-duration AC power-frequency withstand voltage test in dry condition shall be applied in accordance with IEC 60060-1. The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The test voltage shall be the following value:

– For isolating distances 100 % of the rated direct withstand voltages divided by $\sqrt{2}$;

– For other test situation 80 % of the rated direct withstand voltages divided by $\sqrt{2}$.

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The rated direct withstand voltages are specified in column 3 of Table 1.

NOTE The reduction of the test voltage is motivated by the insulation coordination margin in the rated withstand voltages, which takes ageing, wear and other normal deterioration into account, and by the statistical nature of the flashover voltage.

In the closed position, the tests shall be performed in condition 1 of Table 6. In the open position, the tests shall be performed in condition 2 and 3 of Table 6.

7.3 Resistance measurement

7.3.1 Measurement of the resistance of auxiliary contacts class 1 and class 2

One sample of each type of class 1 and class 2 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current of (10 ± 2) mA when energized by a source having an open circuit voltage of 6 V DC with a relative tolerance of $^{0}_{-15}$ % and the resistance measured according to IEC 60512-2-2.

The resistance of the closed class 1 and class 2 auxiliary contacts shall not exceed 50 Ω under these measuring conditions.

NOTE On contact materials, oxidation which decreases the effective current-carrying capabilities can occur. This results in an increased contact resistance or even no conduction at very low voltage while no problems are observed at higher voltage. This test is intended to verify the contact performance under these low-voltage conditions. The assessment criterion takes into account the non-linearity of the resistance. The 50 Ω value results from statistical considerations and has already been taken into account by users.

7.3.2 Measurement of the resistance of auxiliary contacts class 3

One sample of class 3 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current ≤ 10 mA when energized by a source having an open circuit voltage ≤ 30 mV DC and the resistance measured according to 4.12 of IEC 61810-7:2006.

The resistance of the closed class 3 auxiliary contacts shall not exceed 1 Ω.

7.3.3 Electrical continuity of earthed metallic parts test

Generally visual inspection is sufficient to assess compliance with requirements in 6.3.

However, as an alternative, the metallic components and enclosures that can be touched during normal operating conditions and are intended to be earthed may be tested at 30 A (DC) to the earthing point provided. The voltage drop shall be lower than 3 V.

NOTE Coating can be removed locally at measuring points.

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

7.3.4.1 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 contacts or connections being checked shall be measured before the test. The measuring test points shall be the nearest accessible points to and on either side of the contacts or connections in question. An average value of the resistance shall be calculated based on three measurements. If the test object comprises switching devices, one no-load open and close operation cycle shall be made on each device between each of the measurements. If the test object comprises removable elements, one remove / replace cycle shall be made between each of the measurements.

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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 In some designs only a few connections and/or contacts or complete pole are practically accessible for measurement in the main circuit.

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.

7.3.4.2 Making and breaking tests

For making and breaking tests of any switching device, the resistance condition check of the test sample after completion of the test is considered to be satisfactory if the resistance increase determined in 7.3.4.1 is not greater than 100 %.

NOTE The acceptance criterion of 100 % increase in resistance as a condition check after making and breaking test is a default value for this document. The criterion cannot be appropriate for all switchgear designs, e.g. designs with parallel arcing and main contacts. In such cases, the relevant product standards provide their own methods or criteria for a condition check.

7.3.4.3 Other tests

For tests other than making and breaking tests, the resistance condition check of the test object after completion of the test is considered to be satisfactory if the resistance increase determined in 7.3.4.1 is not greater than 20 %. If the resistance increase exceeds 20 % then a continuous current test (7.4) is applicable to determine if the test object can carry its rated continuous current.

NOTE The acceptance criterion of 20 % increase in resistance as a condition check after test is a default value for this document. The criterion cannot be appropriate for all switchgear designs, in which case, the relevant product standards provide their own methods or criteria for a condition check.

7.4 Continuous current tests

This test applies to PSs only and to BPSs to which a continuous current rating has been assigned.

7.4.1 Condition of the test object

The continuous current test of the main circuits shall be made on a test object, if applicable, with clean contacts and filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

7.4.2 Arrangement of the equipment

The test shall be made indoors in an environment substantially free from air currents, except those generated by heat from the test object. In practice, this condition is reached when the air velocity does not exceed 0,5 m/s.

For continuous current tests of parts other than auxiliary equipment, the test object and their accessories shall be mounted in all significant respects as in service, including all normal covers of any part of the test object (including any extra cover for testing purpose, for example cover

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surrounding a busbar extension), and shall be protected against undue external heating or cooling.

When the test object, according to the manufacturer's instructions, may be installed in different positions, the continuous current tests shall be made in the most unfavourable position.

These tests shall be made in principle on complete switchgear and controlgear but maybe made on a single unit provided the influence of the other units is negligible.

For particularly large test objects for which the insulation to earth has no significant influence on temperature rises, this insulation may be appreciably reduced.

Where temporary connections to the main circuit are used, they shall be such that there is no significant difference in heat conducted away from, or conveyed to, the test object compared to the connections intended to be used for service (see 7.4.4.2).

NOTE To make the continuous current test more reproducible, the type and/or sizes of the temporary connections can be specified in relevant standards.

7.4.3 Test current and duration

7.4.3.1 Test on main circuit

The test shall be made at the rated continuous current (I_{rd}) of the switchgear and controlgear. The supply current shall be direct current with a ripple coefficient that does not exceed 5 %.

The test shall be made over a period of time sufficient for the temperature rise to reach a stable value. This condition is deemed to be obtained when the variation of temperature rise does not exceed 1 K in 1 h. This criterion will normally be met after test duration of five times the thermal time constant of the test object.

The time for the whole test may be shortened by preheating the circuit with a higher value of current, provided that sufficient test data is recorded to enable calculation of thermal time constant.

For the convenience of testing, alternating current may be used alternatively. In such a case, the RMS value of the alternating current shall be equal to the rated continuous current (I_{rd}). Frequency of the test current shall be recorded in the test report. Alternating current test is applicable for devices except for semiconductor devices.

NOTE When using alternating current, the power losses during the entire test duration will be greater than the losses while tested with direct current. Measured temperature rise values by alternating current test is higher than these by direct current test caused by skin effect, by complex construction of switchgear and by material with iron component.

7.4.3.2 Test of the auxiliary and control equipment

The test is made with the specified supply voltage (AC or DC), and for AC at its rated frequency (tolerance $^{+2}_{-5}$ %).

The auxiliary equipment shall be tested at its rated supply voltage (U_a) or at its rated continuous current. The AC supply voltage shall be practically sinusoidal.

Coils rated for continuous duty shall be tested over a period of time sufficient for the temperature rise to reach a constant value. This condition is usually obtained when the temperature variation does not exceed 1 K in 1 h.

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For circuits energized only during operations, the tests shall be made under the following conditions.

a) When the operating device has an automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the circuit shall be energized 10 times, for either 1 s or until the automatic breaking device operates, the interval between the instant of each energizing being 10 s or, if the construction of the operating device does not permit this, the lowest interval possible.

b) When the operating device has no automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the test shall be made by energizing the circuit once for duration of 15 s.

7.4.4 Temperature measurement during test

7.4.4.1 Ambient air temperature

The ambient air temperature is the average temperature of the air surrounding the test object (for enclosed switchgear and controlgear, it is the air outside the enclosure). It shall be recorded during the tests by means of at least three thermometers, thermocouples or other temperature-measuring devices equally distributed around the test object at about the average height of its current-carrying parts and at a distance of about 1 m from the test object. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples maybe put into small bottles containing about 0,5 l of oil.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions of the test room, the temperature of an identical switchgear and controlgear under the same conditions, but without current, may be taken as a substitute for the ambient air temperature. This additional switchgear and controlgear shall not be subjected to an undue amount of heat.

The ambient air temperature during tests shall be more than 10 °C but shall not exceed 40 °C without the consent of the manufacturer. No correction of the temperature-rise values shall be made for ambient air temperatures within this range and above.

7.4.4.2 Temperature of test object

Precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the test object and the variations in the ambient air temperature.

For coils, the method of measuring the temperature rise by variation of resistance shall normally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point.

The surface temperature of a component immersed in a dielectric liquid shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

For measurement with thermometers or thermocouples, the following precautions shall be taken:

a) the bulbs of the thermometers or thermocouples shall be protected against cooling from outside (dry clean wool, etc.). The protected area shall, however, be negligible compared with the cooling area of the apparatus under test;

b) good heat conductivity between the thermometer or thermocouple and the surface of the part under test shall be ensured;

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c) when bulb thermometers are employed in places where there is any varying magnetic field, it is recommended to use alcohol thermometers in preference to mercury thermometers, as the latter are more liable to be influenced under these conditions.

Sufficient temperature measurements shall be made during the test, at time intervals not exceeding 30 min, in order to calculate the thermal time constant, and shall be recorded in the test document.

The temperatures at the terminals of the main circuit and at the temporary connections at a distance of 1 m from the terminals shall be measured. The difference in temperature rise shall not exceed 5 K.

However, if the temperature rise of the temporary connections at the distance of 1 m from the terminal of the main circuit exceeds by more than 5 K the temperature rise of the terminal, the test can be considered as valid if all criteria to pass the test defined in 7.4.6 are fulfilled.

7.4.5 Resistance of the main circuit

This subclause is only applicable for mechanical switching device.

A measurement of the resistance of the main circuit shall be made before the continuous current test, with the test object at the ambient air temperature according to the measurement procedure as defined in 7.3.4.

The resistance value measured before the continuous current tests is made for comparison between the switchgear and controlgear type tested for continuous current and all other switchgear and controlgear of the same type subjected to routine tests (see Clause 8).

7.4.6 Criteria to pass test

7.4.6.1 General

The test object has passed the test if the temperature rise of the parts of the test object for which limits are specified, has not exceeded the values specified in Table 10.

If the insulation of a coil is made of several different insulating materials, the permissible temperature rise of the coil shall be taken as that for the insulating material with the lowest limit of temperature rise.

If the test object is fitted with various equipment complying with particular standards (for example, rectifiers, motors, low-voltage switches, etc.), the temperature rise of such equipment shall not exceed the limits specified in the relevant standards.

In case alternating current is applied as a substitute of direct current, the test object is considered to pass the test if the temperature rise does not exceed the relevant temperature limit described in Table 10. Test results will be more severe when alternating current is used in comparison to direct current. If the test object fails to pass the test with an alternating current, the test may be repeated with a direct current; maintenance before repeating the test is allowed.

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Table 10 – Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.4.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
1 Contacts (refer to point 4)		
Bare-copper or bare-copper alloy		
– in OG (refer to point 5)	75	35
– in NOG (refer to point 5)	115	75
– in oil	80	40
Silver-coated or nickel-coated (refer to point 6)		
– in OG (refer to point 5)	115	75
– in NOG (refer to point 5)	115	75
– in oil	90	50
Tin-coated (refer to point 6)		
– in OG (refer to point 5)	90	50
– in NOG (refer to point 5)	90	50
– in oil	90	50
2 Connection, bolted or the equivalent (refer to point 4)		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
– in OG (refer to point 5)	100	60
– in NOG (refer to point 5)	115	75
– in oil	100	60
Silver-coated or nickel-coated (refer to point 6)		
– in OG (refer to point 5)	115	75
– in NOG (refer to point 5)	115	75
– in oil	100	60
Tin-coated		
– in OG (refer to point 5)	105	65
– in NOG (refer to point 5)	105	65
– in oil	100	60
3 All other contacts or connections made of bare metals or coated with other materials	(Refer to point 7)	(Refer to point 7)
4 Terminals for the connection to external conductors by screws or bolts (refer to points 8 and 14)		
– bare	100	60
– silver or nickel coated	115	75
– tin-coated	105	65
– other coatings	(Refer to point 7)	(Refer to point 7)
5 Oil for oil switching devices (refer to points 9 and 10)	90	50
6 Metal parts acting as springs	(Refer to point 11)	(Refer to point 11)

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Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.4.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
7 Materials used as insulation and metal parts in contact with insulation of the following classes (refer to point 12)		
– Y	90	50
– A	105	65
– E	120	80
– B	130	90
– F	155	115
– Enamel: oil base	100	60
synthetic	120	80
– H	180	140
– C other insulating material	(Refer to point 13)	(Refer to point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible surfaces	(Refer to point 15)	(Refer to point 15)
Surfaces of manual control components to be touched in normal operation:		
– Uncoated metal	55	15
– Coated metal	55	15
– Non metal	65	25
Other surfaces to be touched in normal operation but not to be held continuously in the hand:		
– Uncoated metal	65	25
– Coated metal	70	30
– Non metal	80	40
Surfaces not to be touched in normal operation:		
– Uncoated metal	80	40
– Coated metal	80	40
– Non metal	90	50

NOTE 1 The points referred to in this table are those in 7.4.6.2.

NOTE 2 For switchgear and controlgear with special service conditions including a maximum temperature different from 40 °C, the maximum values of temperature applies and the maximum values of temperature rise are calculated accordingly.

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7.4.6.2 Particular points of Table 10

The following points are referred to in Table 10 and complete it.

Point 1 According to its function, the same part can belong to several categories as listed in Table 10.

In this case the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.

Point 2 For vacuum switching devices, the values of temperature and temperature-rise limits do not apply to parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 10.

Point 3 Care shall be taken to ensure that no damage is caused to the surrounding insulating materials.

Point 4 When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be:

a) for contacts, those of the surface material having the lowest value permitted in item 1 of Table 10;

b) for connections, those of the surface material having the highest value permitted in item 2 of Table 10.

Point 5 NOG (Not Oxidizing Gases), for the purposes of this document, are non-reactive gases that are considered as not accelerating ageing of contacts by corrosion or oxidation, due to their chemical characteristics and demonstrated operational records.

Recognized NOG are SF_6, N_2, CO_2, CF_4. They can be used pure or as a mixture of various NOG.

OG (Oxidizing Gases), for the purposes of this document, are reactive gases that can accelerate ageing of contacts either by corrosion phenomena (presence of humidity) or by oxidation phenomena (mostly due to ambient air medium like oxygen). Gases classified as OG are ambient air, “dry” air, any gas not classified as NOG and any mixture including part of OG.

NOTE Some gases considered as OG in the classification above could be re-classified as NOG, in future revision of this document.

For description of these corrosion and oxidation phenomena, refer to IEC TR 60943 [45].

Due to the absence of corrosion and oxidation in NOG, a harmonization of the limits of temperature for different contact and connection parts in the case of gas insulated switchgear appears appropriate.

The permissible temperature limits for bare copper and bare copper alloy parts are equal to the values for silver-coated or nickel-coated parts in the case of NOG atmospheres.

In the particular case of tin-coated parts, due to fretting corrosion effects, an increase of the permissible temperatures is not applicable, even under the corrosion and oxidation free conditions of NOG. Therefore, the values for tin-coated parts are lower.

Point 6 The quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area:

a) after the making and breaking test (if any);

b) after the short-time withstand current test;

c) after the mechanical endurance test.

According to the relevant standard for each equipment. Otherwise, the contacts shall be regarded as “bare”.

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Point 7 When materials other than those given in Table 10 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.

Point 8 The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.

Point 9 The temperature shall be measured at the upper part of the oil.

Point 10 Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.

Point 11 The temperature shall not reach a value where the elasticity of the material is impaired.

Point 12 Classes of insulating materials are those given in IEC 60085.

Point 13 The temperature is limited only by the requirement not to cause any damage to surrounding parts.

Point 14 These values do not take into account any influence on insulation of cable or cable termination.

Point 15 For further details regarding temperature limits for hot surfaces to be touched, refer to IEC Guide 117 [67].

7.4.101 Temporary current test

Subclause 7.4 of IEC TS 62271-5:2024 is applicable with the following addition.

This test applies to BPSs to which a temporary current has been assigned.

The duration of the test is determined by the time it takes to close the by-pass disconnector (BPD in Figure 1), a typical value is 30 min.

The test shall be performed in accordance with IEC TS 62271-5:2024, 7.4. The current shall be the temporary current and the duration of the test shall be 30 min.

The BPS is considered having passed the test if the temperature rise does not exceed the relevant temperature limits described in IEC TS 62271-5:2024, Table 10.

7.5 Short-time withstand current and peak withstand current tests

7.5.1 General

The tests apply to the main circuits and where applicable, to the earthing circuits of the test object to demonstrate their ability to carry their rated peak withstand current and their thermal withstand capability for their rated duration of short-circuit.

The test may be performed at any convenient ambient temperature.

7.5.2 Arrangement of the equipment and of the test circuit

The test object shall be mounted on its own support(s) or on (an) equivalent support(s) and installed with its own operating device(s) as far as necessary to make the test representative for checking mechanical and thermal effects of the test currents. It shall be in the closed position, where relevant.

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Each test shall be preceded by a no-load opening operation of the mechanical switching device(s) (if any) and, with the exception of earthing switches, by measurement of the resistance of the main circuit according to 7.3.4. The no-load opening operation shall be carried out at the rated value of the supply voltage in the case of power operated devices and the force/torque shall be measured in the case of dependent manually operated devices.

The distance between the terminals and the nearest supports of the conductors or the nearest clamping points of cable on both sides of the test object shall be in accordance with the instructions of the manufacturer.

The test arrangement shall be noted in the test report.

The use of insulating fluid is not mandatory for short-time withstand current and peak withstand current tests. Air or N_2 may be used as an alternative to gases with high global warming potential. There is also no requirement of minimum pressure for insulation and/or switching.

7.5.3 Test current and duration

The peak current shall be not less than the rated peak withstand current (I_{pd}) and shall not exceed it by more than 5 % without the consent of the manufacturer. The value of Joule integral $\int I^2 dt$ of the test current shall not be less than the specified value calculated by the specified waveform, peak current and duration, and shall not exceed by more than 10 % without the consent of the manufacturer.

NOTE The value of the Joule integral can be calculated by the specified waveform, peak current, and duration by equations indicated in D.6.

The following deviations are permitted:

a) if the decrement of the short-circuit of the test laboratory is such that the specified Joule integral value cannot be obtained for the specified duration without applying initially an excessively high current, the duration of the test may be increased appropriately to obtain the specified joule integral value, provided that the value of the peak current is not less than that specified and the duration is not extended to more than 5 s;

b) if, in order to obtain the required peak current, the Joule integral value of the current is increased above the specified value, the duration of the test may be reduced accordingly;

c) multi-part test such as separation of the peak withstand current test and the short-time withstand current test is permissible:

   – for the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0,3 s;

   – for the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the specified duration. However, deviation in time according to item a) is permitted;

   – for switching devices the test object shall be kept in closed position between the tests.

For the convenience of testing, AC test current may be used alternatively. In such case, the tests shall be made under the following conditions:

a) AC peak current shall be not less than the rated peak withstand current (I_{pd}) and shall not exceed it by more than 5 % without the consent of the manufacturer;

b) The value of the Joule integral $\int I^2 dt$ of AC current shall be not less than the specified value of DC Joule integral value and shall not exceed it by more than 10 % without consent of the manufacturer.

The following deviations are permitted:

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a) if the decrement of the short-circuit of the test laboratory is such that the specified Joule integral value cannot be obtained within the specified duration without applying initially an excessively high current, the RMS value of the test current may be permitted to fall below the specified value during the test and the duration of the test may be increased appropriately, provided that the value of the peak current is not less than that specified and the time is not extended to more than 5 s;

b) if, in order to obtain the required peak current, the Joule integral value of the current is increased above the specified value, the duration of the test may be reduced accordingly;

c) separation of the peak withstand current test and the short-time withstand current test is permissible:

- for the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0,3 s;
- for the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the specified duration. However, deviation in time according to item a) is permitted;
- for switching devices the test object shall be kept in closed position between the tests.

7.5.4 Conditions of the test object after test

After the test, the test object shall not show significant deterioration, shall be capable of operating normally and carrying its rated continuous current.

If the mechanical switching device has a rated making and/or breaking capacity, then the condition of the contacts shall not be such as to affect the performance materially at any making and/or breaking current up to its rated value.

The following steps are used to check these requirements:

a) a no-load opening operation of the mechanical switching device shall be performed in the same conditions as stated in 7.5.2 immediately after the test, and the contacts shall open at the first attempt;

b) except for earthing switches, the variation of the resistance of the main circuit shall be checked according to 7.3.4;

c) visual inspection of the test object and the contacts (if not detrimental).

NOTE For semiconductor devices, reference is made to IEC 62501, 4.4.2 and 11 [64].

7.6 Verification of the protection

7.6.1 Verification of the IP coding

In accordance with the requirements specified in Clauses 11, 12, 13 and 15 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013, tests shall be performed, to demonstrate performances as required in 6.14, on the enclosures of switchgear and controlgear fully assembled as under service conditions. As real cable connections entering the enclosures are not normally installed for type tests, corresponding filler pieces shall be used. Transport units of switchgear shall be closed for the tests by covers providing identical protection qualities as for the joints.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts as deemed necessary.

When the supplementary letter W is used, test method given in Annex G (normative) shall be applied.

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7.6.2 Verification of the IK coding

The requirements specified in 6.14.4 shall be demonstrated according to IEC 62262:2002; tests shall be performed on the enclosures of switchgear and controlgear fully assembled as under service conditions.

After the test, the enclosure shall show no breaks and the deformation of the enclosure shall not affect the normal function of the equipment, reduce the insulating and/or creepage distances or reduce the specified degree of protection against access to hazardous parts below the permitted values. Superficial damage, such as removal of paint, breaking of cooling ribs or of similar parts, or depression of small dimension can be ignored.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts deemed necessary.

Auxiliary equipment such as meters, relays etc., which can form part of the enclosure is exempted from receiving impacts in this test.

7.7 Tightness tests

7.7.1 General

The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C. Acceptable test condition is an ambient temperature in a range of 15 °C up to 30 °C.

If tightness tests at the temperature limits of the service condition are required in the relevant product standards, an increased leakage rate is permissible. The increased temporary leakage rate shall not exceed the values given in Table 11.

Tightness test shall be performed with the same fluid and under the same pressure (density) as used in service. If the fluid itself is not traceable additional traceable fluids may be added, for example helium. The leakage test method shall have sufficient sensitivity; reference is made to IEC TR 62271-306 [62].

Where possible, the tests should be performed on a complete system. If this is not practical, the tests may be performed on parts, components or subassemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart (refer to IEC TR 62271-306 [62]). The possible leakages between subassemblies of different pressures shall also be taken into account.

The tightness test of switchgear and controlgear containing a mechanical switching device shall be performed both in the closed and open position of the device, unless the leakage rate is independent of the position of the main contacts.

Cumulative leakage measurement, which takes into account all the leaks from a given assembly to determine the leakage rate, shall be used in the calculation of leakage rates.

The type test report should include such information as:

– description of the object under test, including its internal volume and the nature of the filling gas or liquid;
– whether the object under test is in the closed or open position (if applicable);
– the pressures and temperatures recorded at the beginning and end of the test and the number of replenishments (if applicable);
– the value of the ambient temperature during the test.

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– the cut-in and cut-off pressure settings of the pressure (or density) control or monitoring device;
– an indication of the calibration of the meters used to detect leakage rates;
– the results of the measurements;
– the test gas and if applicable the conversion factor to assess the results.

In general, for the application of an adequate test method, reference is made to IEC 60068-2-17:1994.

Table 11 – Permissible leakage rates for gas systems

Temperature °C	Permissible leakage rate
Maximum service temperature (≥ 40 °C)	$3F_p$
Standardized ambient temperature (20 °C)	F_p
Minimum service temperature (any value down to and including -40 °C)	$3F_p$
Minimum service temperature (any value below -40 °C)	$6F_p$

7.7.2 Controlled pressure systems for gas

Preferred method for checking the relative leakage rate F_{rel} is by measuring the pressure drop Δp over a time period t that is of sufficient duration to permit a determination of the pressure drop (within the filling and replenishing pressure range). A correction shall be made to take into account the variation of ambient air temperature during the course of the test. During this period the replenishment device shall be inoperative.

$$F_{rel} = \frac{\Delta p}{p_r} \times \frac{24}{t} \times 100 \text{ (\% per day)} \quad (1)$$

$$N = \frac{\Delta p}{p_r - p_m} \times \frac{24}{t} \quad (2)$$

where

t is the test duration (h);
p_r is the filling pressure (Pa);
p_m is the replenishing pressure t (Pa);
Δp is the pressure drop after time t (Pa);
N is the number of replenishments per day.

NOTE The linearity of the formula is considered to be maintained provided that Δp is of the same order of magnitude as $p_r - p_m$.

7.7.3 Closed pressure systems for gas

The test Q_m (Test method 1: cumulative test) described in IEC 60068-2-17:1994 is the preferred method to determine the relative leakage rate F_{rel} in gas systems and calculate the time

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between replenishments t_r. Detailed information about test procedure, sensitivity of measurement and example of calculation are also given in IEC TR 62271-306 [62].

Alternative methods of leak detection are also given in IEC TR 62271-306 [62] that may be used to measure the leakage rate, which allows in combination with the tightness coordination chart, the calculation of:

– the relative leakage rate;
– the time between replenishments (without considering extreme temperature conditions of number of operations).

The tightness test is considered to be successful when the measured leakage rate does not exceed the permissible leakage rate stated in Table 11 within the limits of +10 %. This inaccuracy of the measurement shall be taken into account when calculating the period of time between replenishments.

7.7.4 Sealed pressure systems

Tightness tests on sealed pressure systems shall be as follows

a) Switchgear using gas

The tests shall be performed according to the preferred method of 7.7.3.

b) Switchgear using vacuum interrupters

No specific tightness tests are required for vacuum interrupters since their tightness is verified during manufacturing process and because they are considered to have a zero leakage rate during their life. Nevertheless, instead of a tightness test, the vacuum integrity shall be verified where specific standards ask for a tightness test as condition check (for example mechanical test, low and high temperature tests, etc.).

The integrity of the vacuum can be verified by the dielectric condition check test, refer to 7.2.11.

7.7.5 Liquid tightness tests

The purpose of liquid tightness tests is to demonstrate that the total system leakage rate F_{liq} does not exceed the specified value $F_{p(liq)}$.

The object under test shall be as in service conditions with all its accessories and its normal fluid, mounted as close as possible as in service.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) and/or during operations is acceptable, provided that this rate resets to the initial value after the temperature is returned to normal ambient air temperature and/or after the operations are performed. The increased temporary leakage rate shall not impair the safe operation of the switchgear and controlgear.

The switchgear shall be observed over a period sufficient to determine a possible leak or the pressure drop Δp_{liq}. In this case, the calculations given in 7.7.2 are valid.

As an alternative, using liquids different from those in service or gas for the test is possible but requires justification by the manufacturer.

The test report shall include such information as:

– a general description of the object under test;
– the number of operations performed;
– the nature and pressure(s) of the liquid;

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– the ambient air temperature during test;
– the results with the switchgear device in closed and in open position (where applicable).

7.8 Electromagnetic compatibility tests (EMC)

7.8.1 Emission tests

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

Radio interference voltage tests apply only to switchgear and controlgear having a rated direct voltage of 210 kV and above, when specified in the relevant product standard.

Test object shall be installed as stated in 7.2.4.

The test voltage shall be direct voltage and applied as follows.

a) in closed position, between the terminals and the earthed frame;
b) in open position, if any, between one terminal and the other terminal connected to the earthed frame and then with the connections reversed if the switching device is not symmetrical.

The case, tank, frame and other normally earthed parts shall be connected to earth.

The test object shall be dry and clean and at approximately the same temperature as the room in which the test is made. During the tests the test object shall be equipped with all accessories such as grading elements, corona rings, high-voltage connectors, etc. which may influence the radio interference voltage.

The measuring circuit (refer to Figure 6) shall comply with CISPR TR 18-2. The measuring circuit shall preferably be tuned to a frequency within 10 % of 0,5 MHz, but other frequencies in the range 0,5 MHz to 2 MHz may be used, the measuring frequency being recorded. The results shall be expressed in µV.

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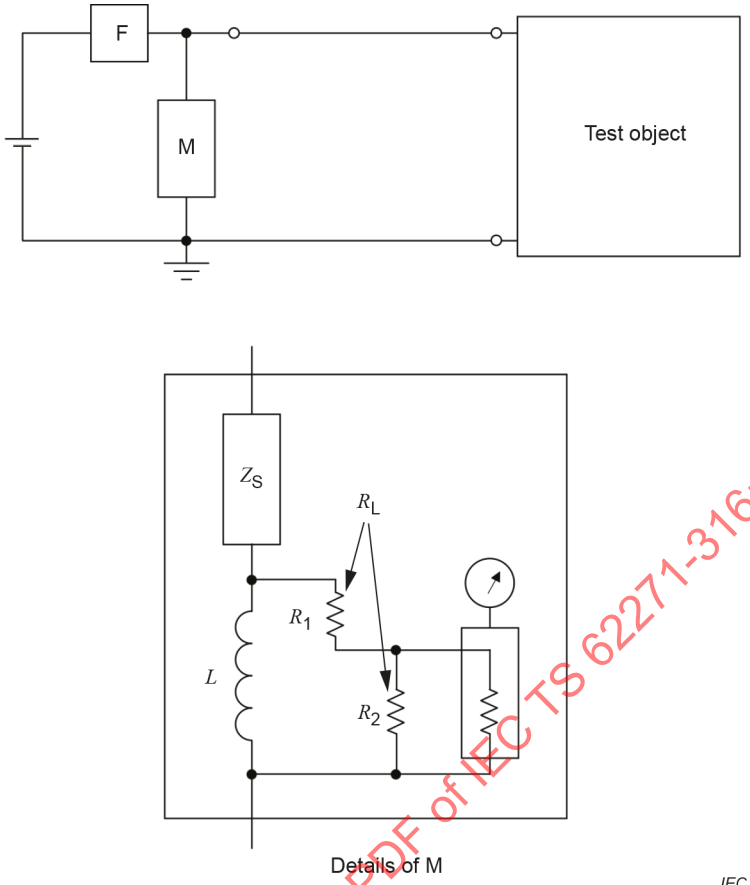

Key

F	Filter
R_L	The equivalent resistance of R_1 in series with the parallel combination of R_2 and the equivalent resistance of the measuring set
Z_S	Either a capacitor or a circuit composed of a capacitor and an inductor in series
L	The inductance used to shunt harmonic currents and to compensate for stray capacitance at the measuring frequency

Figure 6 – Diagram of a test circuit for the radio interference voltage test

The preferred measuring impedances are those specified in CISPR publications. If measuring impedances different from those specified in CISPR publications are used as an alternative, they shall be from 30 Ω up to 600 Ω; in any case the phase angle shall not exceed 20°. The equivalent radio interference voltage referred to 300 Ω can be calculated, assuming the measured voltage to be directly proportional to the resistance, except for test pieces of large capacitance, for which a correction made on this basis can be inaccurate. Therefore, a 300 Ω resistance is recommended for switchgear and controlgear with bushings with earthed flanges (for example dead tank switchgear and controlgear).

The filter F shall have high impedance at the measuring frequency, so that the impedance between the high-voltage conductor and earth is not shunted as seen from the switchgear and controlgear under test.

NOTE 1 This filter also reduces circulating radiofrequency currents in the test circuit, generated by the high-voltage transformer or picked up from extraneous sources. A suitable value for its impedance has been found to be 10 000 Ω to 20 000 Ω at the measuring frequency.

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It shall be ensured by suitable means that the radio interference background level (radio interference level caused by external field and by the high-voltage transformer when magnetized at the full test voltage) is at least 6 dB below the specified radio interference level of the test object. Calibration methods for the measuring instrument and for the measuring circuits are given in CISPR 16-1 (all parts) and CISPR TR 18-2 respectively.

The following test procedure shall be followed.

Unless otherwise specified by the relevant product standard, direct voltage of 1,1 × U_{rd}, U_{rd} being the rated direct voltage of the switchgear and controlgear, shall be applied to the test object with both polarities and maintained for at least 5 min. A much longer test time than 5 min is also applicable by agreement between user and manufacturer.

NOTE 2 The test time of 5 min is based on IEC TS 63014-1. However, RIV behaviour and physical mechanisms (space charges, ozone generation, etc.) with a DC applied voltage can be slightly different from that with an AC applied voltage, especially for the polymeric insulated part subjected to direct voltage. In some cases, a long-time such as one hour or three hours test is possible.

As alternative method, RIV tests may be performed using an alternating voltage source as described in IEC 60437, instead of direct voltage. In this case, the RMS value of the alternating voltage shall be the direct test voltage divided by $\sqrt{2}$.

The test is passed, if the radio interference level does not exceed 2 500 µV. In a long-time test, the test is passed if no more than 30 RIV pulses exceeding 2 500 µV are recorded during any 30-min period of the test. RIV pulses that are proven to be external to the test object shall be disregarded.

As the radio interference level can be affected by fibres or dust settling on the insulators, it is permitted to wipe the insulators with a clean cloth before taking a measurement. The atmospheric conditions during the test shall be recorded. If the measured RIV value is above the limit and the relative humidity is above 80 %, the test is not conclusive and shall be repeated with a relative humidity lower than 80 %.

PSs shall be tested with the test conditions described in Table 6 in 7.2.6.3.

BPSs shall be tested in open position only with test condition 1 described Table 4 or Table 5 in 7.2.6.3.

7.8.1.2 Emission tests from the auxiliary and control circuits

Auxiliary and control circuits of switchgear and controlgear shall be subjected to electromagnetic emission tests if they include electronic equipment or components. In other cases, no tests are required.

For auxiliary and control circuits of switchgear and controlgear, the EMC requirements and tests specified in this document have precedence over other EMC specifications.

The test shall be performed only on a representative auxiliary and control circuit, because the single components are tested according to their relevant standards, if any.

Electronic equipment, which is part of the auxiliary and control circuits, shall fulfil the requirements with regard to radiated emission, as defined in CISPR 11:2015 for group 1, class A equipment. No other tests are specified. A 10 m measuring distance may be used instead of 30 m, by increasing the limit values by 10 dB.

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7.8.2 Immunity tests on auxiliary and control circuits

7.8.2.1 General

Auxiliary and control circuits of switchgear and controlgear shall be subjected to electromagnetic immunity tests if they include electronic equipment or components. In other cases no tests are required.

The tests shall be performed on a typical auxiliary and control circuit. Components shall comply with their relevant standards, if any.

The following immunity tests are specified:

– electric fast transient/burst test (refer to 7.8.2.2). The test simulates the conditions caused by switching in the auxiliary and control circuit;

– oscillatory wave immunity test (refer to 7.8.2.3). The test simulates the conditions caused by switching in the main circuit.

NOTE Other EMC immunity tests do exist, but are not specified in this case.

Electromagnetic immunity tests shall be made on complete auxiliary and control circuits or subassemblies. The tests can be made on

– the complete auxiliary and control circuits;

– subassemblies, such as central control cubicle, drive mechanism cubicle, etc.;

– subassemblies within a cubicle, such as metering or monitoring system.

Individual testing of subassemblies is strongly recommended in cases where long lengths of interconnections are required, or where significant interference voltages are expected between the subassemblies. Individual testing is mandatory for each interchangeable subassembly.

The test voltage shall be applied to the interface of the auxiliary and control circuits or tested subassembly.

The type test report shall clearly state what system or subassembly has been tested.

7.8.2.2 Electrical fast transient/burst test

An electrical fast transient/burst test shall be performed in accordance with IEC 61000-4-4, with a repetition rate of 5 kHz. The ports and interfaces shall be chosen in accordance with IEC 61000-6-2. The test voltage and coupling shall be chosen according to Table 12.

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Table 12 – Application of voltages at the fast transient/burst test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	AC and DC power lines	2	CDN
Cabinet earth port		2	CDN
Signal port	Shielded and unshielded lines, carrying analogue and/or digital signals control lines communication lines (for example data buses) measuring lines (for example current transducers, voltage transducers)	2	CCC or equivalent coupling methods
Key CDN Coupling decoupling network. CCC Capacitive coupling clamp.			

7.8.2.3 Oscillatory wave immunity test

An oscillatory wave immunity test shall be performed, with shape and duration of the test voltage in accordance with IEC 61000-4-18.

The ports and interfaces shall be chosen in accordance with IEC 61000-6-2.

Damped oscillatory wave tests shall be made at 100 kHz and 1 MHz, with a relative tolerance of ±30 %.

Tests shall be made for both common and differential mode. The test voltage and coupling method shall be chosen according to Table 13.

Table 13 – Application of voltage at the damped oscillatory wave test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	AC and DC power lines	Differential mode: 1,0 Common mode: 2,5	CDN CDN
Signal port	Shielded and unshielded lines, carrying analogue and/or digital signals control lines communication lines (for example data buses) measuring lines (for example: current transducers, voltage transducers)	Differential mode: 1,0 Common mode: 2,5	CDN CDN Or equivalent coupling method
Key CDN Coupling decoupling network.			

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7.8.2.4 Behaviour of the secondary equipment during and after tests

The auxiliary and control circuits shall withstand each of the tests specified in 7.8.2.2 and 7.8.2.3 without permanent damage. After the tests it shall still be fully operational. Temporary loss of parts of the functionality is permitted according to Table 14.

Table 14 – Assessment criteria for transient disturbance immunity

Function	Criterion
Protection, tele protection	A
Alarm	B
Supervision	B
Command and control	A
Measurement	B
Counting	A
Data processing for high-speed protective system for general use	 A B
Information	B
Data storage	A
Processing	B
Monitoring	B
Man-machine interface	B
Self-diagnostics	B
Processing, monitoring and self-diagnostic functions which are on-line connected, and are part of command and control circuits, shall fulfil criterion A.	
Key A Normal performance within the specification limits; B Temporary degradation or loss of function or performance which is self-recoverable.	

7.8.3 Additional EMC tests on auxiliary and control circuits

7.8.3.1 General

The objective of the tests described below is to qualify the whole assembly without repeating individual test on components. Therefore, tests on components which comply with their relevant IEC standards and with relevant rated values do not need to be repeated.

7.8.3.2 Ripple on DC input power port immunity test

This test shall be performed according to IEC 61000-4-17:1999. The test level shall be level 2, and the frequency of the ripple is equal to three times the rated frequency of auxiliary and control circuits.

The assessment criterion is: “normal performance within the specification limits” (criterion A).

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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 BPS or PS equipped with its entire control unit, the ripple on DC input power port immunity test according to subclause 7.8.3.2 of IEC TS 62271-5:2024 is regarded as being covered and additional tests are not required. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

Where electronic components are used, tests according to 7.8.3.2 of IEC TS 62271-5:2024 on the individual components are sufficient.

This subclause is applicable to both complete electronic boards (for example control modules) and devices containing at least one electronic component (for example electronic timing relays).

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

Voltage dips, short interruptions and voltage variations tests on AC power ports shall be performed according to IEC 61000-4-11 and on DC power ports according to IEC 61000-4-29.

The relevant acceptance criteria are present in 6.4.1.

7.9 Additional tests on auxiliary and control circuits

7.9.1 General

Tests on components, which comply with their relevant IEC standards and with relevant rated values, shall not be repeated.

7.9.2 Functional tests

A functional test of all auxiliary and control circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device. They shall be performed with the upper and lower value limits of the supply voltage defined in 6.4.1.

For auxiliary and control circuits, sub-assemblies and components, operation tests can be omitted if they have been fully performed during a test applied to the whole switchgear and controlgear or in relevant circumstances.

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete BPS or PS equipped with its entire control unit, the functional tests according to subclause 7.9.2 of IEC TS 62271-5:2024 are regarded as covered and additional tests are not required and may be omitted. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

7.9.3 Verification of the operational characteristics of auxiliary contacts

7.9.3.1 General

Auxiliary contacts, which are contacts included in auxiliary circuits, shall be submitted to the following tests unless the equipment has passed the whole type tests as a functional unit.

7.9.3.2 Auxiliary contact rated continuous current

This test verifies the rated value of current which a previously closed auxiliary contact is capable of carrying continuously.

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The circuit shall be closed and opened by means independent from the contact under test. Test procedures are described in 7.4.3.2. The contact shall carry its class rated continuous current according to Table 4 without exceeding the temperature rise in Table 10 based on the contact material and the working environment.

7.9.3.3 Auxiliary contact rated short-time withstand current

This test verifies the value of current which a previously closed auxiliary contact is capable of carrying for a specified short period.

The circuit shall be closed and opened by means independent from the contact under test. The contact shall carry its class rated short-time withstand current according to Table 4 for 30 ms, with a resistive load. The current value to be obtained shall be reached within 5 ms after current initiation. The tolerance on the test current amplitude is $^{+5}_{0}$ % and the tolerance on the test current duration is $^{+10}_{0}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The contact resistance value shall be taken before and after the tests at 50 % of the rated continuous current in Table 4, with the contacts at ambient temperature for both measurements.

The test is passed:

– if the resistance increase is less than 20 %;
– or, when the increase exceeds 20 %, if the continuous current test according to 7.4.3.2 is performed successfully.

7.9.3.4 Auxiliary contact breaking capacity

This test verifies the breaking capacity of an auxiliary contact.

The circuit shall be closed by means independent from the contact under test. The contact shall carry for 5 s and shall break the current associated with its class according to Table 4, with an inductive load. The tolerance on the test voltage is $^{+10}_{0}$ % and the tolerance on the test current amplitude is $^{+5}_{0}$ %.

For all classes, the circuit time constant shall be 20 ms with a tolerance of $^{+20}_{0}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The recovery voltage shall be maintained during each 1 min interval and for 300 ms ± 30 ms after the last operation. The contact resistance value shall be taken before and after the tests at 50 % of the rated continuous current in Table 4, with the contacts at ambient temperature for both measurements. The resistance increase shall be less than 20 %. If the increase exceeds 20 % then the continuous current test according to 7.4.3.2 shall be performed.

7.9.4 Environmental tests

If the mechanical operation test at ambient air temperature in accordance with 7.101.2, the low and high temperature tests in accordance with 7.101.3 and, if applicable, the humidity test in accordance with 7.101.4 are performed on the complete BPS or PS equipped with its entire control unit or in case of the humidity test on the control equipment respectively, the environmental tests according to of IEC TS 62271-5:2024, 7.9.4 are regarded as covered and additional tests can be omitted. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

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Seismic tests are not covered. If a seismic test is requested, it should be performed in accordance with IEC TR 62271-300 by agreement between manufacturer and user.

7.9.4.1 General

Heating elements, if any, shall be ready to operate except where otherwise stated.

The following tests are independent type tests.

Auxiliary and control circuits shall be energised and shall remain in the operating condition during and after the test until the functional checks have been performed. At the end of the test duration, except for the vibration response test, auxiliary and control circuits shall be checked to ascertain whether they are capable of functioning in accordance with their design intent.

If other environmental tests than indicated under 7.9.4 are requested, due to special environmental conditions, then these tests should be performed according to IEC 60068-2 (all parts) [13] where applicable.

7.9.4.2 Cold test

A cold test shall be performed according to test Ad of IEC 60068-2-1:2007, under the service conditions specified in Clause 4. The test temperature shall be the minimum ambient air temperature and the test duration shall be 16 h.

7.9.4.3 Dry heat test

A dry heat test shall be performed according to test Be of IEC 60068-2-2:2007 according to the configuration of auxiliary circuits, under the service conditions specified in Clause 4. The test temperature shall be the maximum ambient air temperature and the test duration shall be 16 h.

7.9.4.4 Cyclic humidity test

A cyclic humidity test shall be performed according to test Db of IEC 60068-2-30:2005. The upper temperature shall be the maximum ambient air temperature specified in Clause 4 and the number of temperature cycles shall be two. Variant 2 may be used for the temperature fall period and recovery shall take place under standard atmospheric conditions. No special precautions shall be taken regarding the removal of surface moisture.

7.9.4.5 Vibration tests

Vibrations due to operation of the associated switchgear or controlgear are checked as follows.

– A test is performed according to IEC 60255-21-1:1988. Vibration response test parameters are those corresponding to severity class 1;
– or the auxiliary and control equipment assembly is subjected to the relevant mechanical endurance tests in the complete switchgear and controlgear.

The auxiliary and control circuits shall withstand the vibration response test without permanent damage. After the test, it shall still be fully operational. Temporary loss of parts of the functionality is permitted during the test according to criteria stated in Table 13.

7.9.4.6 Condition check

The power-frequency voltage withstand tests according to 7.9.5 shall be performed after each type test, to confirm that there has been no reduction of performance during testing.

In the case the type tests of 7.9.4 are performed as test sequence on the same test object, this condition check may be performed only once at the end.

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7.9.5 Dielectric test

Auxiliary and control circuits of switchgear and controlgear shall be subjected to short-duration power-frequency voltage withstand tests. Each test shall be performed:

a) between the auxiliary and control circuits connected together as a whole and the frame of the switching device;

b) if practicable, between each part of the auxiliary and control circuits, which in normal use can be insulated from the other parts, and the other parts connected together and to the frame.

The power frequency tests shall be performed according to IEC 61180. The test voltage shall be 2 kV with duration of 1 min.

A DC test is acceptable by agreement of the manufacturer, the test voltage shall be 2,8 kV, with a duration of 1 min.

The auxiliary and control circuits of switchgear and controlgear shall be considered to have passed the tests if no disruptive discharge occurs during each test.

If motors and other devices such as electronic equipment used in the auxiliary and control circuits have already been tested in accordance with their own specification, they shall be disconnected for these tests.

The dielectric test shall be performed on auxiliary and control circuits that are in new condition.

7.10 X-radiation test for vacuum interrupters

7.10.1 General requirements

7.10.1.1 Condition of interrupter to be tested

Tests on the X-radiation emission levels shall be performed on new vacuum interrupters.

There is no requirement to test switchgear and controlgear for X-radiation emission, where the vacuum interrupter type has been successfully tested as a component.

7.10.1.2 Mounting of specimen

The interrupter shall be mounted in a test fixture, designed so that the open contact spacing can be set at the minimum distance when installed in the switchgear and controlgear. Interrupters designed for operation in an insulating medium other than air (such as oil or SF_6) may be tested in such a medium, if necessary, to withstand the test voltage.

The container for the insulating medium shall be of an insulating material having radiation attenuation no greater than that afforded by 9,5 mm thick methyl methacrylate. The insulating medium between the interrupter and radiation survey instrument shall be the minimum required for dielectric purposes.

7.10.1.3 Radiation survey instrument

A radiofrequency shielded radiation survey instrument having the following minimum specifications shall be used.

– accuracy: capable of measuring from 5 µSv/h up to 150 µSv/h with an accuracy of ±25 % along this range and with a response time not to exceed 15 s;

– energy response range: at least 25 keV to 0,5 MeV.

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NOTE The selection of the radiation survey measuring instrument is related to the test voltage and sensitivity of the detector across the specified energy response range.

7.10.1.4 Location of radiation survey instrument

The sensing element of the radiation survey instrument shall be positioned in the plane of the separable contacts and pointed at the contacts. The preferred distance between the measuring instrument and the wall of the vacuum interrupter is 1 m. However, any distance up to 15 m may be used in which case the instrument reading shall be adjusted by applying the inverse square law as follows:

$$R(1\ \text{m}) = R(d) \times d^2 \tag{3}$$

where $R(d)$ is the radiation level measured, at the distance d (in m) from the external surface of the vacuum interrupter.

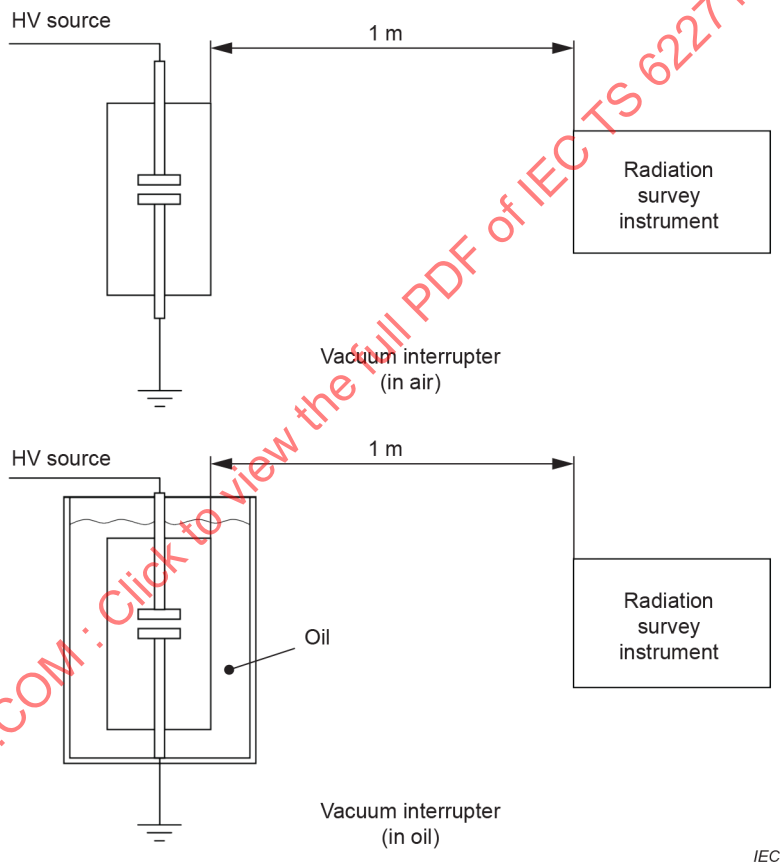

Figure 7 – Test location of radiation survey instrument

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7.10.2 Test voltage and measurement procedure

With the interrupter mounted in a test fixture, with the contacts blocked open at the minimum contact spacing specified, and with the radiation survey instrument in place (refer to Figure 7), a voltage shall be applied across the interrupter contacts equal the rated direct voltage U_{rd} of the switchgear and controlgear. After a minimum of 15 s, the X-radiation level on the radiation survey instrument shall be according to 7.10.3.

Next, the voltage across the interrupter contacts shall be raised to a value equal to the rated direct withstand voltage U_{dd} shown in Table 1 as appropriate. After a minimum of 15 s, the X-radiation level on the radiation survey instrument shall be recorded in the test report.

7.10.3 Acceptance criteria

The X-radiation emitted from vacuum interrupters shall not exceed 5 µSv/h at 1 m distance at the rated direct voltage U_{rd}.

For vacuum interrupters used in switchgear and controlgear that have a rated direct withstand voltage less than or equal to 240 kV, the X-radiation emitted at the rated direct withstand voltage U_{dd} shall not exceed 150 µSv/h at 1 m distance.

For vacuum interrupters in switchgear and controlgear that have a rated direct withstand voltage greater than 240 kV, the X-radiation emitted at the rated direct withstand voltage U_{dd} shall be measured. If the measured value exceeds 150 µSv/h at 1 m distance, then the actual value shall be declared by the manufacturer.

NOTE 1 The declared value can be used to develop a safe working environment in accordance with local regulations when performing a power frequency withstand test across open contact gaps of vacuum interrupters.

NOTE 2 The test duration can be longer than the voltage applied time in actual use.

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 BPS or PS shall be established (see Annex D). IEC TR 62271-306 [2] 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 BPS or PS. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical and switching type tests behave mechanically in a similar way, i.e. within the tolerances specified by the manufacturer. 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 are examples of operating characteristics that can be recorded:

– no-load travel curves;
– closing and opening times.

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

7.101.1.2 Component tests

When testing of a complete BPS or PS is not practicable, component tests may be accepted as type tests. The manufacturer should determine the components which are suitable for testing.

Components are separate functional sub-assemblies which can be operated independently of the complete BPS or PS (for example, switching 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 BPS or PS is tested. Component tests shall cover all different types of components of the complete BPS or PS, 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 BPS or PS.

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Parts of auxiliary and control equipment which 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 BPS or PS shall be verified.

7.101.1.3 Characteristics and settings of the BPS or PS 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 (if applicable);
d) recharging time and consumption of the operating device;
e) consumption of the control circuit, if applicable;
f) consumption of the auxiliary circuit;
g) duration of opening and closing command;
h) tightness, if applicable;
i) gas densities or pressures, if applicable;
j) resistance of the main circuit;
k) mechanical travel characteristics (if applicable);
l) 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 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 filling pressure for operation.

7.101.1.4 Condition of the BPS or PS during and after the tests

During and after the tests, the BPS or PS shall be in such a condition that it is capable of operating normally, carrying its rated continuous or temporary current and withstanding the voltage values according to its rated insulation level.

In general, these requirements are fulfilled if

– during the tests, the BPS or PS 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, 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 7.4) does not exceed the value permitted for bare contacts;
– during and after the tests, it shall be possible to fit any defined replacement part according to the manufacturer's instructions;
– after the tests the insulating properties of the BPS or PS in the open position shall be in essentially the same condition as before the tests. Visual inspection of the BPS or PS after the tests is usually sufficient for verification of the insulating properties. In the case of BPSs or PSs with sealed-for-life interrupters, a voltage test as a condition check in accordance with 7.2.11 replaces this visual inspection;

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– for sealed-for-life switches, the increase of the resistance of the main circuit shall be less than or equal to 20 %. If the increase in resistance exceeds 20 % then a continuous current test according to 7.4 is applicable to determine if the test object can carry its rated continuous current without exceeding the temperature limits given in Table 10 of IEC TS 62271-5:2024 by more than 10 K;
– for other BPS or PS types, the resistance condition check of the test object is satisfactory if the resistance increase determined in 7.3.4.1 of IEC TS 62271-5:2024 is not greater than 20 %. If the resistance increase exceeds 20 % a visual inspection shall be performed.

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 should 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, insulation capability of the auxiliary circuits, of the auxiliary switches and of the control equipment shall not be impaired. In case of doubt, the dielectric tests according to 7.10.5 of IEC TS 62271-5:2024 shall be performed;
– during and after the tests, the contact resistance of the auxiliary switches shall not be affected adversely.

7.101.2 Mechanical operation test at ambient air temperature

7.101.2.1 General

The mechanical operation test shall be carried out 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 cycles in accordance with 7.101.2.3.

A BPS or PS 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 5.6 and 5.7. 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 Annex D.

7.101.2.2 Condition of the BPS or PS before the test

The BPS or PS for test shall be completely mounted on its own support and its operating mechanism shall be operated in the specified manner. It shall be tested according to its type as follows:

Tests shall be conducted at the filling pressure for insulation and/or switching.

7.101.2.3 Operating sequence

The BPS or PS shall be tested in accordance with Table 7.

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Table 7 – Number of operating sequences

Operating sequence	Supply voltage	Operating pressure	Number of operating sequences
C – t_a – O	Minimum	Minimum functional	500
	Rated	Filling pressure	500
	Maximum	Filling pressure	500
C – t_a – O – t_b – C – t_a – O	Rated	Filling pressure	250

O opening;

C closing;

t_a time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the BPS or PS (this time can be different according to the type of operation).

t_b shortest time between an O and subsequent C operation such that the BPS or PS reaches the fully open position prior to closing.

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

7.101.2.4 Acceptance criteria for the mechanical operation tests

a) Before and after the total test programme, the following operations shall be performed:

- five operating cycles at the rated supply voltage of closing and opening devices and of auxiliary and control circuits and/or the filling pressure for operation;
- five operating cycles at the minimum supply voltage of closing and opening devices and of auxiliary and control circuits and/or the minimum pressure for operation;
- five operating cycles at the maximum supply voltage of closing and opening devices and of auxiliary and control circuits and/or the filling pressure for operation.

During these operating cycles, the operating characteristics (see 7.101.1.3) shall be recorded. 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:

- 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 mechanical endurance tests shall be within the tolerances given by the manufacturer.

b) After the total test programme the condition of the BPS or PS shall be in accordance with 7.101.1.4.

7.101.3 Low and high temperature tests

7.101.3.1 General requirements

It is not necessary to perform the two tests in succession, and the order in which they are carried out is arbitrary. If the minimum ambient air temperature of indoor and outdoor switches is higher than or equal to −5 °C, no low temperature test is required. If maximum ambient air temperature is not higher than +40 °C, no high temperature test is required.

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

Liquid or gas supplies for BPS or PS operation are to be at the test air temperature unless the BPS or PS design requires a heat source for these supplies.

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No maintenance, replacement of parts, lubrication or readjustment of the BPS or PS is permissible during the tests.

The BPS or PS has passed the test if the conditions stated in 7.101.1.4 and 7.101.1.5 are fulfilled. Furthermore, the conditions in 7.101.3.4 and 7.101.3.5 shall be fulfilled and the leakage rates recorded shall not exceed the limits given in Table 15 of IEC TS 62271-5:2024. In the test report the testing conditions and the condition of the BPS or PS before, during and after the test shall be reported. The recorded quantities shall be presented. To reduce the number of oscillograms in the test report, a single representative oscillogram of every relevant type of operation under each specified testing condition shall be included.

A BPS or PS 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 5.6 and 5.7. It is not necessary to test these variants if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

The conditions during and after the tests are given in 7.101.3.6.

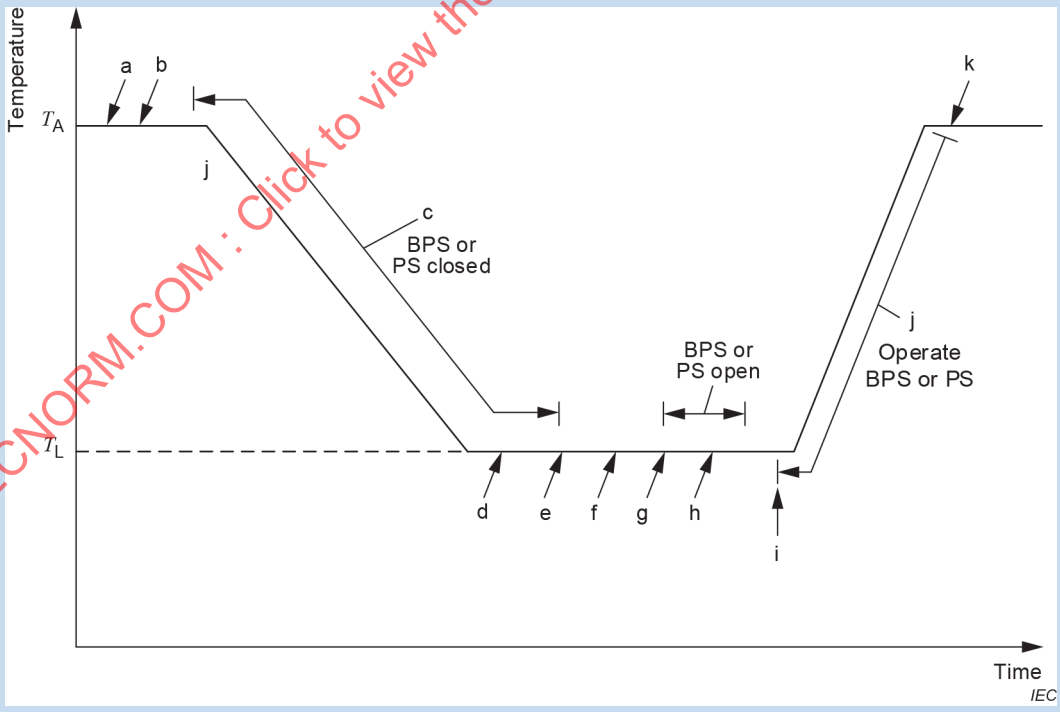
7.101.3.2 Measurement of ambient air temperature

The ambient air temperature of the immediate test environment shall be measured at half the height of the BPS or PS and at a distance of 1 m from the BPS or PS.

The maximum temperature deviation over the height of the BPS or PS shall not exceed 5 K.

7.101.3.4 Low temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 8.



NOTE Letters a through k identify application points of tests specified in 7.101.3.4.

Figure 8 – Test sequence for low temperature test

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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) in the following list are omitted.

a) The test BPS or PS shall be prepared and adjusted in accordance with the manufacturer's instructions;

b) Characteristics and settings of the BPS or PS shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of 20 °C ± 5 °C (T_A). The tightness test (if applicable) shall be performed according to 7.7;

c) With the BPS or PS in the closed position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the minimum ambient temperature specified as given in 4.1.2, 4.1.3 and 4.2.4 of IEC TS 62271-5:2024. The BPS or PS shall be kept in the closed position for 24 h after the ambient air temperature stabilises at T_L;

d) During the 24 h period with the BPS or PS 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 BPS or PS 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 TS 62271-5:2024;

e) After 24 h at temperature T_L, the BPS or PS shall be opened, closed and opened at rated values of supply voltage and operating pressure. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances;

f) The low temperature behaviour of the BPS or PS 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 an 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 mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances.

The manufacturer shall state the value of t_x (not less than 2 h) up to which the BPS or PS 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;

g) The BPS or PS shall be opened and left in the open position for 24 h;

h) During the 24 h period with the BPS or PS 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 BPS or PS 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 TS 62271-5:2024;

i) At the end of the 24 h period, 50 closing and 50 opening operations shall be made at rated values of supply voltage and operating pressure with the BPS or PS at temperature T_L. At least a 3 min interval shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. Following the first opening operation (O) and the first closing operation (C), three OC operating cycles shall be performed. The additional operations shall be carried out by performing O – t_a – C – t_a operating sequences (t_a is defined in Table 7);

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 BPS or PS 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 should be carried out at 30 min intervals so that the BPS or PS will be in open and in closed position for 30 min periods between the operating sequences;

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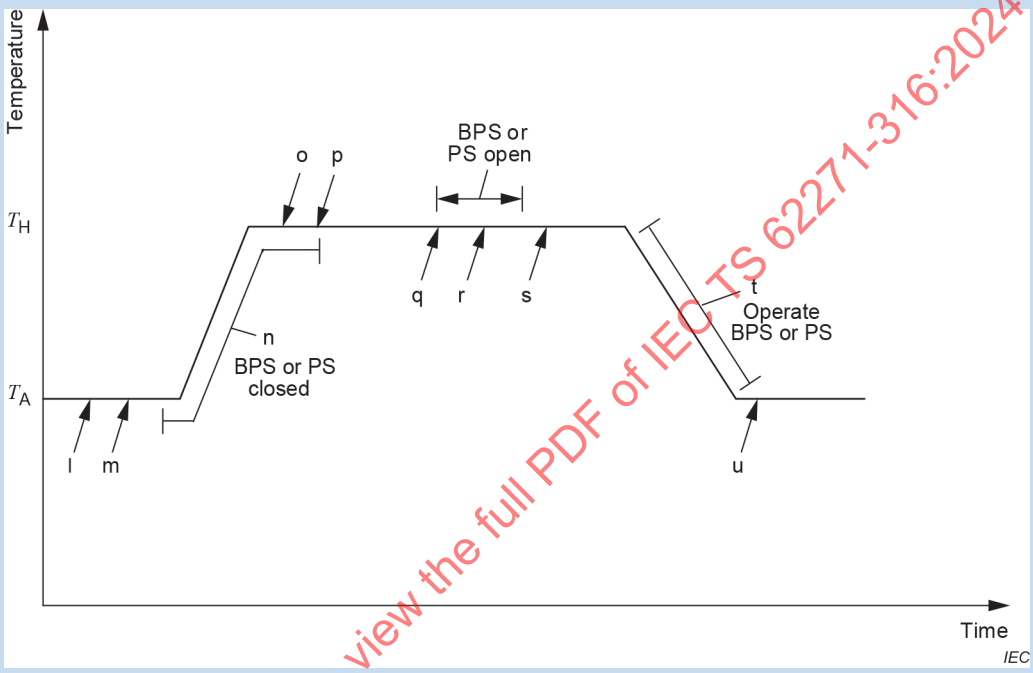
k) After the BPS or PS has stabilised thermally at ambient air temperature T_A, a recheck shall be made of the BPS or PS settings. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. The tightness test shall be repeated as in item b) and the leakage rate shall remain within the limits stated in 7.7.

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).

7.101.3.5 High temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 9.



NOTE Letters l through u identify application points of tests specified in 7.101.3.5.

Figure 9 – Test sequence for high temperature test

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 BPS or PS shall be prepared and adjusted in accordance with the manufacturer's instructions;

m) Characteristics and settings of the BPS or PS shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of 20 °C ± 5 °C (T_A). The tightness test (if applicable) shall be performed according to 7.7;

n) With the BPS or PS in the closed position, the air temperature shall be increased to the appropriate, maximum ambient air temperature (T_H), according to the upper limit of ambient air temperature as given in 4.1.2, 4.1.3 and 4.2.4 of IEC TS 62271-5:2024. The BPS or PS shall be kept in the closed position for 24 h after the ambient air temperature stabilises at T_H;

o) During the 24 h period with the BPS or PS 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 BPS or PS 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 TS 62271-5:2024;

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p) After 24 h at the temperature T_H, the BPS or PS shall be opened and closed at rated values of supply voltage and operating pressure. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances;

q) The BPS or PS shall be opened and not operated for 24 h at the temperature T_H;

r) During this 24 h period at 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 BPS or PS 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 TS 62271-5:2024;

s) At the end of the 24 h period, 50 closing and 50 opening operations shall be carried out at rated values of supply voltage and operating pressure with the BPS or PS at the temperature T_H. An interval of at least 3 min shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances.

Following the first closing or opening operation, three O – t_b – C operating cycles shall be performed. The additional operations shall be carried out by performing O – t_a – C – t_a operating sequences (t_a and t_b are defined in Table 7);

t) After completing the tests indicated in s), 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 BPS or PS shall be subjected to alternate C – t_a – O – t_a – C and O – t_a – C – t_a – O operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences should be carried out at 30 min intervals so that the BPS or PS will be in the open and closed positions for 30 min periods between the operating sequences;

u) After the BPS or PS has stabilised thermally at ambient air temperature T_A, a recheck shall be made of the BPS or PS settings. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. The tightness test shall be repeated as in item m) and the leakage rate shall remain within the limits stated in 7.7.

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

7.101.4 Humidity test

7.101.4.1 General

The humidity test does not apply to equipment which is designed to be directly exposed to precipitation, for example primary parts of outdoor BPSs or PSs. The test shall be performed on BPSs or PSs or on BPS or PS components, where due to sudden changes of the temperature, condensation may occur on insulating surfaces which are continuously stressed by voltage. This is mainly the insulation of the secondary wiring of indoor installed BPSs or PSs. The humidity test is also not necessary where effective means against condensation are provided, for example control cubicles with anti-condensation heaters.

Applying the test procedure described in 7.101.4.2, the withstand of the test object, primarily BPS or PS components, to humidity effects, which may produce condensation on the surface of the test object, is determined in an accelerated manner.

7.101.4.2 Test procedure

The test object shall be arranged in a test chamber containing circulating air and in which the temperature and humidity shall follow the cycle given in the following paragraph:

During about half of the cycle the surfaces of the test object shall be wet, and dry during the other half. To obtain this result the test cycle consists of a period t_4 with low air temperature

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(T_{min} = 25 °C ± 3 °C) and a period t_2 with high air temperature (T_{max} = 40 °C ± 2 °C) inside the test chamber. Both periods shall be equal in time. The generation of fog shall be maintained for that half of the cycle (see Figure 10) in which the low air temperature is applied.

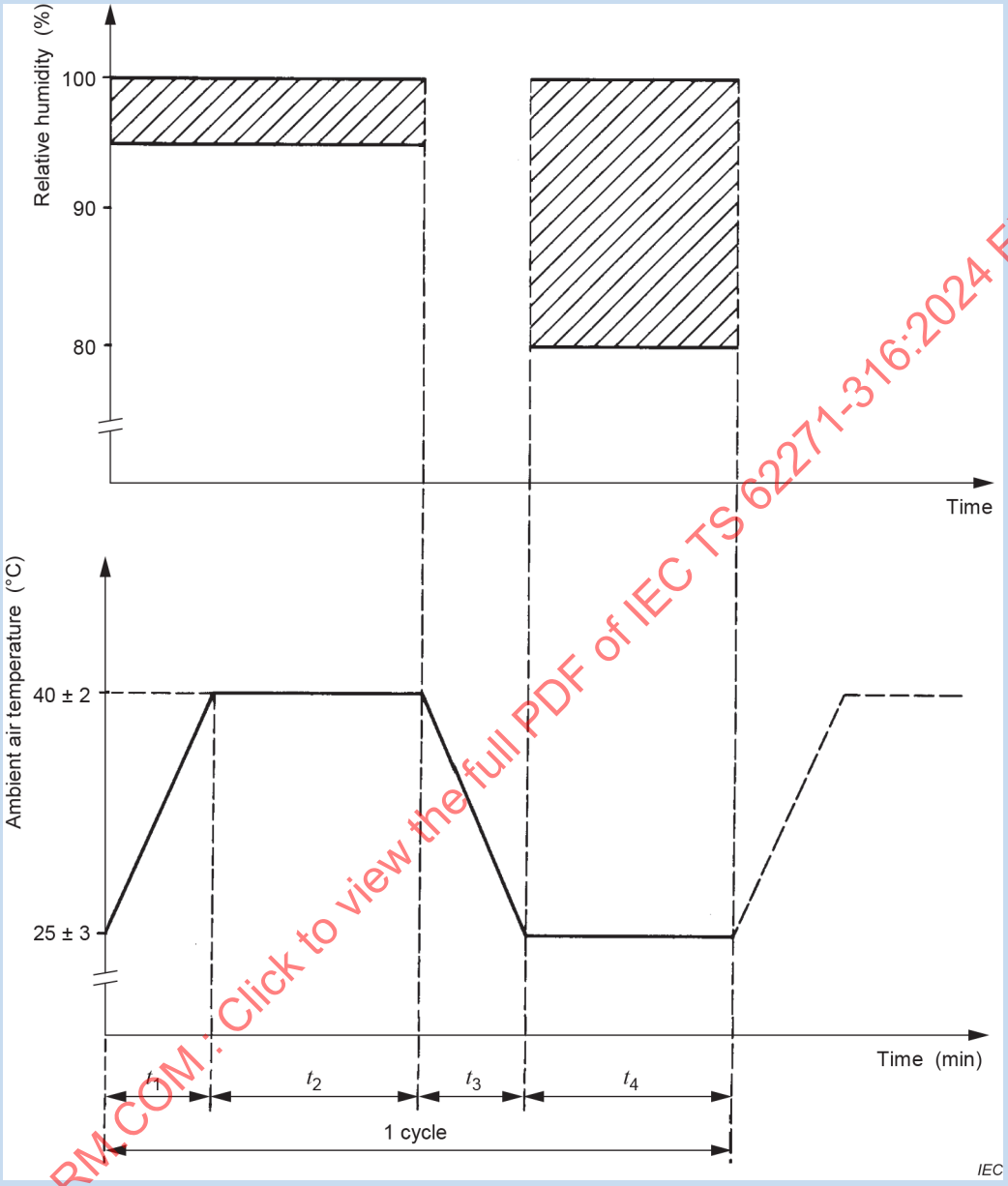

Figure 10 – Humidity test

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The beginning of fog generation coincides in principle with the beginning of the low air temperature period. However, to wet the vertical surfaces of materials with a high thermal time constant, it is allowed to start the fog generation later within the low air temperature period.

The duration of the test cycle depends on the thermal characteristics of the test objects, and shall be sufficiently long, both at high and low temperature, to cause wetting and drying of all insulation surfaces. In order to obtain these conditions, steam should be injected directly into the test chamber or heated water should be atomised; the rise from 25 °C to 40 °C may be obtained with the provision of heat coming from the steam or atomised water or, if necessary, by additional heaters. Preliminary cycles shall be carried out with the test object placed in the test chamber in order to observe and to check these conditions.

For low-voltage components of BPS and PSs, usually having time constants smaller than 10 min, the duration of the time intervals given in Figure 10 are: t_1 = 10 min, t_2 = 20 min, t_3 = 10 min and t_4 = 20 min.

The fog is obtained by the continuous or periodical atomisation of 0,2 l to 0,4 l of water (with the resistivity characteristics given below) per hour and per cubic metre of test chamber volume. The diameter of the droplets shall be less than 10 µm; such a fog may be obtained by mechanical atomisers. The direction of the spraying shall be such that the surfaces of the test object are not directly sprayed. No water shall drop from the ceiling upon the test object. During the fog generation the test chamber shall be closed, and no additional forced air-circulation is permitted.

The water used to create the humidity shall be such that the water collected in the test chamber has a resistivity equal to or greater than 100 Ωm and contains neither salt (NaCl) nor any corrosive element.

The temperature and the relative humidity of the air in the test chamber shall be measured in the immediate vicinity of the test object and shall be recorded for the whole duration of the test. No value of relative humidity is specified during the drop in temperature; however, the humidity shall be above 80 % during the period when the temperature is maintained at 25 °C. The air shall be circulated in order to obtain uniform distribution of the humidity in the test chamber.

The number of cycles shall be 350.

During and after the test, the operating characteristics of the test objects shall not be affected. This is proven by the dielectric withstand test on the auxiliary and control circuits in accordance with 7.2.11. The degree of corrosion, if any, should be indicated in the test report.

7.101.5 Test to prove the operation under severe ice conditions

The test under severe ice conditions is applicable only to outdoor BPSs or PSs having moving external parts. The test shall be performed according to IEC 62271-102:2018.

7.102 Current commutation test

This test applies to BPSs and LPSs. Currently no laboratory test procedures and test circuits are available. Requirements for testing and test parameters will be added once TC 115 has provided more relevant data.

8 Routine tests

8.1 General

The routine tests are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practicable at the manufacturer's' works on each apparatus manufactured. By agreement, any routine test may be made on site.

The routine tests given in this document comprise:

a) dielectric test on the main circuit in accordance with 8.2;

b) tests on auxiliary and control circuits in accordance with 8.3;

c) measurement of the resistance of the main circuit in accordance with 8.4;

d) tightness test in accordance with 8.5;

e) design and visual checks in accordance with 8.6.

Additional routine tests can be specified in the relevant IEC standards.

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When switchgear and controlgear is not completely assembled before transport, separate tests shall be made on all transport units. In this event, the manufacturer shall demonstrate the validity of this test (for example, leakage rate, test voltage, resistance of part of the main circuit).

Test reports of the routine tests are not required unless otherwise agreed upon between the manufacturer and the user.

8.2 Dielectric test on the main circuit

It is preferred to carry out the test at short-duration AC power-frequency voltage. Alternatively, a dry, short-duration direct voltage test may be applied. The test duration shall be 1 min. The test procedure shall be according to IEC 60060-1 and to 7.2, except that each pole or transport unit shall be tested. For sealed pressure systems, the test shall be made at the filling pressure for insulation.

The test voltage shall be the rated direct withstand voltage divided by $\sqrt{2}$ for AC power-frequency tests or the rated direct withstand voltage for DC tests. The rated direct withstand voltages are specified in column 3 of Table 1.

When the insulation of switchgear and controlgear is provided only by solid-core insulators and air at ambient pressure, the voltage withstand test may be omitted if the dimensions between the conductive parts – across open switching devices and between conductive parts and the frame – are checked by dimensional measurements.

Bases for the checking of dimensions are the dimensional (outline) drawings, which are part of the type test report (or are referred to in it) of the particular switchgear and controlgear. Therefore, in these drawings all information necessary for dimensional checking including the permissible tolerances shall be given.

The dielectric test across the open contacts may be performed on the complete BPS or PS or on single switching units, if the BPS or PS is constructed by assembling identical switching units in series (see also Figure 7, where BPS1 and BPS2 consist of two series connected switching units).

When performing dielectric tests on single units, the test voltage to be applied across each single unit shall be that of the most stressed unit. This test voltage is the higher fraction of the total withstand voltage with the BPS or PS in the open position and one terminal earthed. The test voltage shall be applied to one side of the switching unit with the other terminal earthed.

For BPSs or PSs using compressed gas for insulation and/or switching, the gas pressure during the dielectric test, the main circuit shall be set at the minimum filling pressure for insulation and/or switching. For sealed pressure systems, the gas pressure shall be the filling pressure for insulation and/or switching.

In case of BPSs or PSs using a gas mixture such as SF_6/N_2, the test may be performed using the declared gas mixture at the minimum filling pressure for insulation and/or switching or pure SF_6 at a total absolute pressure not exceeding the equivalent gas pressure (P_{test}) as calculated by the following equation (see Figure 4.1 of CIGRE TB 163 [3]): $P_{test} = P_{SF_6} + 0{,}7 \times P_{add\ N_2}$. The equation is valid for mixtures having at least 30 % of SF_6 gas volume (see note);

where

P_{test}	is the total absolute SF_6 pressure at T = 20 °C during routine dielectric test on the main circuit;
P_{SF6}	is the partial pressure of SF_6 at T = 20 °C at the minimum functional pressure for switching according to the declared gas mixture;

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$P_{add\ N2}$ is the partial pressure of N_2 at T = 20 °C at the minimum functional pressure for switching according to the declared gas mixture.

NOTE See CIGRE TB 163 [3] for mixtures having less than 30 % SF_6.

8.3 Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to the circuit diagrams and wiring diagrams

The nature of the materials, the quality of assembly, the finish and, if necessary, the protective coatings against corrosion shall be checked. A visual inspection is also necessary to check the satisfactory installation of the thermal insulation, if any.

A visual inspection of actuators, interlocks, locks, etc., shall be made.

Components for auxiliary and control circuits inside enclosures shall be checked for proper mounting. The location of the means provided for connecting external wiring shall be checked to ensure that there is sufficient wiring space for spreading of the cores of multi-core cables and for the proper connection of the conductors.

The conductors and cables shall be checked for proper routing. Special attention shall be given to ensure that no mechanical damage can occur to conductors and cables due to the proximity of sharp edges or heating elements, or to the movement of moving parts.

Furthermore, the identification of components and terminals and, if applicable, the identification of cables and wiring shall be verified. In addition, the conformity of auxiliary and control circuits to the circuit diagrams and wiring diagrams shall be checked.

8.3.2 Functional tests

Functional tests are specified, where relevant, in the relevant IEC product standards. When specified, they shall be made on all auxiliary and control circuits to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device.

Operation tests on auxiliary and control circuits, subassemblies and components may be omitted if they have been fully tested during a test applied to the whole switchgear and controlgear.

8.3.3 Verification of protection against electrical shock

Protection against direct contact with the main circuit and safe accessibility to the auxiliary and control equipment parts liable to be touched during normal operation shall be checked. The preferred method is by visual inspection.

Where visual inspection cannot provide confirmation of the electrical continuity of earthed metallic parts, the alternative procedure defined in 7.3.3 shall be applied.

8.3.4 Dielectric tests

Only power frequency tests shall be performed. This test shall be made under the same conditions as those detailed in 7.9.5.

The test voltage shall be 1 kV with duration of 1 s.

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8.4 Measurement of the resistance of the main circuit

This subclause is only applicable for mechanical switch parts.

For the routine test, the direct voltage drop or resistance of the main circuit shall be measured under conditions as nearly as possible similar, with regard to ambient air temperature and points of measurement, to those under which the corresponding measurement before the continuous current test was made. The test current shall be within the range stated in 7.3.4.

The measured resistance shall not exceed 1,2 × R_u, where R_u is equal to the resistance measured before the continuous current test.

In the case of assemblies, it is possible to calculate the expected resistance based on relevant type tests.

8.5 Tightness test

8.5.1 General

Routine tests shall be performed to demonstrate the tightness criteria according to 6.16 at ambient temperature with the switchgear parts, components or subassemblies at or above the minimum functional pressure (or density) for insulation.

8.5.2 Controlled pressure systems for gas

The test procedure corresponds to 7.7.2.

8.5.3 Closed pressure systems for gas

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and subassemblies.

For parts or subassemblies tested in factory, the cumulative test is the preferred method.

For gas-filled systems tested in factory, the probing test using a sniffing device may be used. If any leak is detected, the test shall be considered to be failed or the leak shall be quantified by using a cumulative method.

For routine tests at site, the probing test using a sniffing device is the preferred method.

The sensitivity of the sniffing device shall be at least 10^{-8} Pa × m^3/s.

8.5.4 Sealed pressure systems

Depending on the insulation medium two situations are considered:

a) Switchgear and controlgear using gas

   The preferred test procedure corresponds to 7.7.4, item a).

   An alternative test procedure corresponds to the sealing tracer gas test with mass spectrometer, refer to IEC 60068-2-17:1994.

b) Switchgear and controlgear using vacuum interrupters

   The vacuum tightness shall be demonstrated by a dielectric test according to 7.2.11 carried out after the mechanical routine test specified in the relevant product standards.

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8.5.5 Liquid tightness tests

Routine tests shall be performed at normal ambient air temperature with the completely assembled switchgear and controlgear device. Testing of subassemblies is also permissible. In this case, a final check shall be performed at site.

The test methods correspond to those of the type tests (refer to 7.7.5).

8.6 Design and visual checks

The switchgear and controlgear shall be checked to verify its compliance with the purchase specification, if any.

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 filling 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 filling pressure for operation (if applicable):
   – five O - t'' - C operating cycles, where t'' is specified in 5.102.

Mechanical operating tests should be carried out on the complete BPS or PS. However, when BPSs or PSs 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 BPS or PS. Guidance for commissioning tests is given in 11.3.101.

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 pressure difference.

Proof shall be given that the mechanical behaviour conforms to that of the test object used for type testing. For example, a no-load operating cycle, as described in 7.101.1.1, may 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 characteristic, as defined in 7.101.1.1, from the instant of contact separation to the end of the contact travel for an opening operation and from start of movement to contact touch for a closing operation. See also Annex D.

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Where the mechanical routine tests are performed on sub-assemblies, the reference mechanical 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 can be different, and the comparison of the instantaneous contact stroke may be impossible to achieve.

If applicable, the mechanical characteristics can be recorded directly, using a travel transducer or similar device on the BPS or PS 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 characteristics shall preferably be a continuous curve. Where the measurements are taken on site, other methods may be applied which record points of travel during the operating period.

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 BPS or PS;
– all auxiliary equipment shall operate correctly at the limits of 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;
– inspections 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 of the operating mechanism;
– operation of electrical, mechanical, pneumatic or hydraulic interlocks and signalling devices;
– operation of anti-pumping device;
– general performance of equipment within the required tolerance of the supply voltage;
– inspection of earthing terminals of the BPS or PS.

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9 Guide to the selection of switchgear and controlgear (informative)

9.1 General

Clause 9 gives general guidance on the appropriate selection of ratings and parameters depending on the application to be covered by high-voltage switchgear and controlgear. A summary of the considerations for specifying the ratings of switchgear and controlgear is provided in Annex L (informative).

A BPS or PS suitable for a given duty in service is best selected by considering the individual rated values required by load conditions and fault conditions.

The complete list of rated characteristics is given in Clause 5. The following individual ratings are dealt with in this Clause 9.

Type of rating and/or characteristics:

– Voltage, see 5.2;
– Insulation level (can be different to earth and across open contacts), see 5.3;
– Continuous current, see 5.4;
– Temporary current, see 5.4.101;
– Duration of short-circuit, see 5.5;
– Operating sequence, see 5.102.

For rated characteristics not dealt with in Clause 9, reference should, if applicable, be made to Clause 5 as follows:

Other parameters to be considered when selecting a BPS or PS are, for example:

– Local atmospheric and climatic conditions, see 9.2.105;
– Use at high altitudes, see 9.2.106;
– Opening and/or closing time.

9.2 Selection of rated values

The rated values should be chosen in accordance with this document having regard for the characteristics of the system as well as its anticipated future system development. A list of ratings is given in Clause 5.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltage, the type of earthing of the system and the type of overvoltage limiting devices. Other parameters, such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m, should also be considered.

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the switchgear and controlgear is located in the system.

9.2.101 Selection of rated voltage

The rated voltage of the BPS or PS should be chosen so as to be at least equal to the highest voltage of the system at the point where the BPS or PS is to be installed.

NOTE 1 Reference is made to Annex C for BPSs.

NOTE 2 In some applications PSs are connected in series with a disconnector that always operates and with a short time delay after PS, to reduce the duration of voltage stress across the open PS. For such applications, a lower value of the rated direct voltage across the open PS can be chosen, whereby dielectric capabilities and creepage distance across open switching device are reduced.

The rated voltages of a BPS or PS according 5.2.101 and 5.2.102 should be selected from the values given in 5.2 of IEC TS 62271-5:2024.

9.2.102 Insulation coordination

The rated insulation level of a BPS or PS should be selected according to 5.3.

The values in the tables stated there apply to both indoor and outdoor BPSs and PSs. It should be specified in the enquiry whether the BPS or PS is to be of indoor or outdoor type.

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The insulation coordination in an electrical system serves to minimise damage to the electrical equipment due to overvoltages and tends to confine flashovers (when these cannot be economically avoided) to points where they will cause no damage.

In accordance with IEC TS 60071-11 and IEC TS 60071-12 precautions should be taken to limit the overvoltages on the terminals of the BPS or PS to stated values below the insulation level.

Where a BPS or PS is required for a position necessitating a higher insulation level, this should be specified in the enquiry (see 10.101).

9.2.103 Selection of rated continuous current

The continuous current of a PS should be selected from the standard values given in 5.4.

It should be noted that PSs have no specified continuous overcurrent capability. When selecting a PS therefore, the rated continuous current should be such as to make it suitable for any load current that may occur in service. Where intermittent over-currents are expected to be frequent and severe, the manufacturer should be consulted.

9.2.104 Selection of temporary current

The temporary current of a BPS and its duration should be specified by the user. The duration depends on the time it takes to close the by-pass disconnector. A typical value for the duration is 30 min.

9.2.105 Local atmospheric and climatic conditions

The normal atmospheric and climatic conditions for BPSs and PSs are given in Clause 4.

For outdoor BPSs and PSs, the atmospheric conditions in certain areas are unfavourable due to smoke, chemical fumes, salt-laden spray and the like. Where such adverse conditions are known to exist, special consideration should be given to the design of those parts of the BPS or PS, especially the insulators, normally exposed to the atmosphere.

The performance of an insulator in such atmospheres also depends on the frequency of washing or cleaning operations and on the frequency of natural washing by rain. Since the performance of an insulator under such conditions is dependent on so many factors, it is not possible to give precise definitions of normal and heavily polluted atmospheres. Experience in the area where the insulator is to be used is the best guide.

The manufacturer should be consulted when the BPS or PS is to be located where the wind speed exceeds 34 m/s.

If a BPS or PS is to be located where an ice-coating exceeding 20 mm is expected, agreement should be reached between manufacturer and user as to the ability of the BPS or PS to perform correctly under such conditions.

Where applicable, the seismic qualification level should be specified by the user. Subclause 4.2.5 of IEC TS 62271-5:2024 should be taken into account.

For indoor installations, the humidity conditions are given in 4.1.2 e) of IEC TS 62271-5:2024. When selecting the BPS or PS for service, it is recommended to indicate the cases where the high values of humidity are expected and condensation can occur.

BPSs and PSs installed in indoor installations can be exposed to high ambient temperatures and low humidity.

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For outdoor BPSs or PSs, the manufacturer should be consulted for any special service conditions, for example when chemical fumes, aggressive atmosphere, salt laden spray, etc., are present.

9.2.106 Use at high altitudes

The normal service conditions specified in Clause 4 of IEC TS 62271-5:2024 provide for BPSs and PSs intended for use at altitudes not exceeding 1 000 m.

For installation at altitudes above 1 000 m, 4.2.2 of IEC TS 62271-5:2024 is applicable.

9.2.107 Operating sequence in service (not a rating)

The operating sequence of a BPS or PS is given in 7.102.

When the operating sequence in service is more severe than that which is provided for in this document, this should be specified by the user in their enquiry and/or order in such a way that the manufacturer can modify the rating of the BPS or PS appropriately.

9.2.108 Selection of rated duration of short-circuit

The standard value of rated duration of short-circuit is given in 5.5.4 of IEC TS 62271-5:2024.

For short-circuit durations greater than the rated duration, the relation between current and time, unless otherwise stated by the manufacturer, is in accordance with the equation:

$$I^2 \times t = \text{constant}$$

9.3 Cable-interface considerations

For connection to cables, the maximum temperature at the terminals at full continuous current should be below the temperature limits of the cable insulation and cable termination.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC TS 62271-5:2024 is not applicable.

9.5 Environmental aspects

9.5.1 Service conditions

Selected switchgear and controlgear and its associated operating devices and auxiliary equipment should be designed and validated to comply with at least the specific service conditions required by the user or appropriate arrangements should be made.

9.5.2 Clearances affected by service conditions

Where clearances can be compromised by environmental related changes in the service access level (for example accumulation of snow, sand, etc.) the use of increased clearances should be considered.

9.5.3 High humidity

For the normal service conditions present in 4.1.2 e), condensation can occasionally occur on, or in, indoor switchgear and controlgear.

To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions should be used.

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Condensation can be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear.

High humidity can also be due to ground level rainwater or for cable-connected applications of underground network applications from incoming cable raceways connected to switchgear.

9.5.4 Solar radiation

Under certain levels of solar radiation, appropriate measures, for example roofing, forced ventilation etc., should be taken, or derating can be used, in order not to exceed the specified temperature and pressure rise limits. Tests with simulated solar gain can be used to demonstrate if measures or derating are required.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

The intention of this clause is to define information, which is necessary to enable the user to make an appropriate enquiry for equipment and to enable the supplier to give an adequate tender.

Furthermore, it enables the user to make a comparison and evaluation of offers from different suppliers.

NOTE The supplier can either be a manufacturer or a contractor.

When enquiring about or ordering an installation of switchgear and controlgear the following information as a minimum should be supplied by the enquirer.

Annex L (informative) provides similar information items in a tabular form for ease of use.

10.2 Information with enquiries and orders

The following information listed below, if applicable, should be given by the enquirer / user.

a) Particulars of the system as defined in Clause 3:

   Nominal and highest voltage, normal current and maximum fault current. Unusual characteristics of the system in which the equipment to be installed should be noted;

b) Service conditions if different from normal (refer to Clause 4):

   Any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment.

   In this case high-voltage switchgear and controlgear and associated operating devices and auxiliary equipment should be designed and validated to comply with any special service conditions required by the user, or appropriate arrangements should be made.

c) Particulars of the installation and its components:

   1) indoor or outdoor installation;
   2) unidirectional or bidirectional;
   3) number of busbars, as shown in the single-line diagram;
   4) rated direct voltage;
   5) rated insulation level (U_{dd}, U_p, U_s when applicable);
   6) rated continuous currents of busbars and feeder circuits;
   7) rated short-time withstand direct current (I_{kd});

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8) rated peak withstand current (I_{pd});

9) rated duration of short-circuit (t_{kd}) (if different from the preferred values given in 5.5.4);

10) rated values of components (e.g. for DCVTs or DCCTs in an assembly, for individual functional units of an assembly.);

11) degree of protection for the enclosure and partitions;

12) circuit diagrams.

d) Particulars of the operating devices:

1) type of operating devices;

2) rated supply voltage (if any);

3) rated supply frequency (if any);

4) rated supply pressure (if any);

5) special interlocking requirements;

6) number of available auxiliary contacts required (the user should state the contact performance required).

In addition to these items the enquirer should indicate every condition which might influence the tender or the order, for example special mounting or installation conditions, the location of the external high-voltage connections or any specific rules for pressure vessels, requirements for cable testing and, if applicable, whether functionality shall be maintained after a seismic event or during and after a seismic event.

Information should be supplied if type test reports or any other conformity assessment related document are requested.

When enquiring for or ordering a BPS or PS, the following particulars should be supplied by the enquirer:

a) particulars of systems, i.e. nominal and highest voltages;

b) service conditions including minimum and maximum ambient air temperatures, altitude if over 1 000 m and any special conditions likely to exist or arise, for example unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 9.2.105 and 9.2.106);

c) characteristics of the BPS or PS.

The following information should be given:

Type of information	Reference
1) indoor or outdoor	9.2.105
2) voltage	9.2.101
3) insulation level: where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, the desired insulation level	9.2.102
4) continuous current	9.2.103
5) temporary current	9.2.104
6) operating sequence	9.2.107
7) the type tests specified under special request (for example artificial pollution and radio interference, etc.)	7.2.8, 7.8
The following information should be given, if the required performance is other than standard	
8) desired duration of short-circuit	9.2.108
The following information should be given in the case of applicability	
9) any test exceeding the standardised type, routine and commissioning tests	

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d) characteristics of the operating mechanism of BPS or PS and associated equipment, in particular:

1) method of operation, whether manual or power;
2) number and type of spare auxiliary switches;
3) rated supply voltage and rated supply frequency;
4) number of releases for tripping, if more than one;
5) number of releases for closing, if more than one.

e) 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

The following information listed below, if applicable, should be given by the manufacturer with descriptive material and drawings.

a) Rated values and characteristics as enumerated in item c) of 10.2.

b) Constructional features, for example:
   1) mass of the heaviest transport unit;
   2) overall dimensions of the installation;
   3) arrangement of the external connections;
   4) future extensions if applicable;
   5) facilities for transport and mounting;
   6) mounting provisions;
   7) accessible sides;
   8) instructions for installation, operation and maintenance;
   9) type of gas-pressure or liquid-pressure system;
   10) filling level /pressure and minimum functional level / pressure;
   11) volume or mass of fluid for the different compartments;
   12) specification of fluid;
   13) number of units in series, or, in parallel;
   14) minimum clearance in air and safety boundaries in operation;
   15) any special arrangements (cooling system, for example) to maintain the rated characteristics of the equipment at the required temperatures of the ambient air.

c) Particulars of the operating devices:
   1) types and rated values as enumerated in item d) of 10.2;
   2) current or power for operation;
   3) operating times.

d) List of recommended spare parts that should be procured by the user.

e) Any other document or information requested in the enquiry.

When the enquirer requests technical particulars of a BPS or PS, the following information (those which are applicable) should be given by the manufacturer, with the descriptive matter and drawings:

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a) rated values and characteristics:

Type of information	Reference
1) indoor or outdoor, temperature, ice-coating	9.2.105
2) voltage	9.2.101
3) insulation level	9.2.102
4) rated continuous current	9.2.103
5) temporary current and duration	9.2.104
6) short-time withstand current	9.2.108
7) operating sequence	9.2.107
8) opening time and closing time	6.104
9) the type tests specified under special request (for example artificial pollution and radio interference, etc.)	7.2.8, 7.8
The following information should be given if the required performance is other than standard:	
10) rated duration of short-circuit	9.2.108
The following information should be given in the case of applicability	
11) any test exceeding the standardised type, routine and commissioning tests	

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 BPS or PS without fluids for insulation, switching 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 switching (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 to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
7) number of units in series;
8) minimum clearances in air:
   - to earth;
   - the safety boundaries during a switching operation, for BPSs 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 BPS or PS at the required temperatures of the ambient air;

d) operating mechanism of BPS or PS and associated equipment:

1) type of operating mechanism;
2) rated supply voltage and/or pressure of closing mechanism, pressure limits where different to or expanding data required in c) 4) of 10.3;
3) current required at rated supply voltage to close the BPS or PS;
4) energy consumed to close the BPS or PS, for example measured as a fall in pressure;
5) rated supply voltage of closing and shunt opening release;
6) current required at rated supply voltage for closing and shunt opening release;

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7) number and type of spare auxiliary switches;

8) current required at rated supply voltage by other auxiliaries;

9) setting of high and low pressure interlocking devices;

10) number of releases for opening, if more than one;

11) number of releases for closing, if more than one;

e) overall dimensions and other information:

The manufacturer should give the necessary information as regards the overall dimensions of the BPS or PS and details necessary for the design of the foundation.

General information regarding maintenance of the BPS or PS and its connections should be given.

11 Transport, storage, installation, operating instructions and maintenance

11.1 General

It is essential that the transport, storage and installation of switchgear and controlgear, as well as their operation and maintenance in service, is performed in accordance with instructions given by the manufacturer.

Consequently, the manufacturer shall provide the appropriate version of the instruction manual for the transport, storage, installation, operation and maintenance of switchgear and controlgear. The instructions for the transport and storage should be given at a convenient time before delivery, and the instructions for the installation, operation and maintenance should be given by the time of delivery at the latest. It is preferable that the operation manual be a separate document from the installation and maintenance manual.

It is impossible, here, to cover in detail the complete rules for the installation, operation and maintenance of each one of the different types of apparatus manufactured, but the following information is given relative to the most important points to be considered for the instructions provided by the manufacturer.

11.2 Conditions during transport, storage and installation

A special agreement should be made between manufacturer and user if the service conditions of temperature and humidity defined in the order cannot be guaranteed during transport, storage and installation. Special precautions can be essential for the protection of insulation during transport, storage and installation, and prior to energizing, to prevent moisture absorption due, for instance, to rain, snow or condensation. Vibrations during transport should be considered. Appropriate instructions should be given by the manufacturer.

Special packaging should be proposed by the manufacturer for long term storage of parts for maintenance needs according to customer specifications.

11.3 Installation

11.3.1 General

For each type of switchgear and controlgear the instructions provided by the manufacturer shall include at least the items listed below.

11.3.2 Unpacking and lifting

Each complete equipment shall be provided with adequate lifting facilities and labelled (externally) to show the correct method of lifting. The equipment shall be labelled (externally) to indicate its maximum mass, in kg, when fully equipped. Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in

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the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site).

Required information for unpacking should be given.

11.3.3 Assembly

When the switchgear and controlgear is not fully assembled for transport, all transport units should be clearly marked. Drawings showing assembly of these parts should be provided with the switchgear and controlgear.

11.3.4 Mounting

Instructions for the mounting of switchgear and controlgear, operating device and auxiliary equipment should include sufficient details of locations and foundations to enable site preparation to be completed.

These instructions should also indicate:

– the total mass of the apparatus inclusive of extinguishing or insulating fluids;
– the mass of extinguishing or insulating fluids;
– the mass of each unit to be lifted separately.

11.3.5 Connections

Instructions should include information on:

– connection of conductors, comprising the necessary advice to prevent overheating and unnecessary strain on the switchgear and controlgear and to provide adequate clearance distances;
– connection of auxiliary circuits;
– connection of liquid or gas systems, if any, including size and arrangement of piping;
– connection for earthing;
– auxiliary contacts available to the user.

11.3.6 Information about gas and gas mixtures for controlled and closed pressure systems

For controlled and closed pressure systems filled with gas mixture, the percentage of the different gases and their associated tolerances shall be defined by the manufacturer taking into account handling and uncertainty of measurement. Appropriate gas filling procedures are defined in IEC 62271-4.

During commissioning or maintenance, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling pressure (density) for insulation shall be checked by dew point measurement. Appropriate correction factors shall be used for measurements performed at temperatures other than 20 °C according to the manufacturer's instruction manual.

The maximum allowable humidity content for equipment filled or re-filled with new or used gas should be such that the dew point inside the switchgear compartment is not higher than

– -10 °C for equipment with adsorber material;
– -15 °C for equipment without adsorber material.

during commissioning or after maintenance for a measurement at filling pressure (density) for insulation and at 20 °C.

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NOTE 1 These dew point values during commissioning are expected to give a dew point value lower than -5 °C during service life, for a measurement at 20 °C.

NOTE 2 The measurement of the dew point is specified at a given temperature due to the possible exchange of water between gas and solid materials when the temperature changes, which could change the measured value.

NOTE 3 An example of measurement and determination of the dew point is given in IEEE C37.122.5 [70].

11.3.7 Final installation inspection

Instructions should be provided for inspection and tests which should be made after the switchgear and controlgear has been installed and all connections have been completed.

These instructions should include:

– a schedule of recommended site tests to establish correct operation;
– procedures for carrying out any adjustment that can be necessary to obtain correct operation;
– recommendations for any relevant measurements that should be made and recorded to help with future maintenance decisions;
– a procedure for qualitative gas tightness test at site (sniffing test) on all field assembled connections for closed pressure systems, reference is made to 8.5.3;
– instructions for final inspection and putting into service.

Guidance for electromagnetic compatibility site measurements is given in Annex M (informative).

11.3.8 Basic input data by the user

These data should include:

a) access limitations to the local site;
b) local working conditions and any restrictions that can apply (for example, safety equipment, normal working hours, union requirements for supervisor, manufacturer's and local installation crew, etc.);
c) availability and capacity of lifting and handling equipment;
d) availability, number and experience of local personnel;
e) specific pressure vessel rules and procedures that can apply during installation and commissioning tests;
f) interface requirements for high-voltage cables and transformers;
g) in the case of extensions to existing switchgear and controlgear:
    1) provisions for the extension available within existing primary and secondary equipment;
    2) in-service conditions or operating restrictions that apply;
    3) safety regulations that locally apply.

11.3.9 Basic input data by the manufacturer

These data should include:

a) space necessary for installation and assembly;
b) size and weight of components and testing equipment;
c) site conditions regarding cleanliness and temperature for clean installation and preparation area;
d) number and experience of local personnel required for installation;
e) time and activity schedules for installation and commissioning;
f) electric power, lighting, water and other needs for installation and commissioning;

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g) proposed training of installation and service personnel;

h) in case of extension to existing switchgear and controlgear:

   1) out-of-service requirements of existing components related to the installation schedule;

   2) safety precautions.

i) gas filling procedure (mixed gases) and dew point verification, if necessary.

11.3.101 Commissioning tests

After a BPS or PS 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 BPS or PS. 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 sub-components and the satisfactory nature of both the site work and the functional characteristics dependent upon it.

In addition to the requirements of 11.3.102, a minimum of 50 no-load operations shall be performed on site on the BPS or PS where major sub-assemblies are combined at site without previous routine tests on the complete BPS or PS. 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 BPS or PS.

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

– absence of damage;
– compatibility of separate units;
– correct assembly;
– correct performance of the assembled BPS or PS.

In general, this is achieved when the commissioning tests include, but are not limited to, the programme given in 11.3.102. The results of the tests shall be recorded in a test report.

11.3.102 Commissioning checks and test programme

11.3.102.1 Checks after installation

Subclause 11.3.101 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 in this document.

11.3.102.1.1 General checks

– assembly conforms to manufacturer's drawings and instructions;
– tightness of BPS or PS, 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;

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– record the number on the operations counter(s) at completion of all site testing;

– record the number on the operations counter(s) at first energisation.

11.3.102.1.2 Checks of electrical circuits

– Conformity to the wiring diagram.

– Correct operation of signalling (position, alarms, lockouts, etc.).

– Correct operation of heating and lighting.

11.3.102.1.3 Checks of the insulation and/or switching fluid(s)

Oil	Type, dielectric strength (in accordance with IEC 60296), level
Gas	Filling pressure/density, and quality checks, to confirm the acceptance levels of IEC 60376 and IEC 60480, as applicable. These quality checks are not required on sealed equipment and new gas used from sealed bottles. A dewpoint check and a check of the total impurities shall be carried out to confirm the manufacturer's acceptance levels
Gas mixtures	Quality is to be confirmed prior to energisation
Compressed air	Quality (if applicable) and pressure

11.3.102.1.4 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)

11.3.102.1.5 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 11.3.101.

11.3.102.2 Mechanical tests and measurements

11.3.102.2.1 Measurements of the characteristic insulating and/or switching fluid pressures (where applicable)

11.3.102.2.1.1 General

The measurements in 11.3.102.2.1.2 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.

11.3.102.2.1.2 Measurements to be taken

a) Where applicable, on rising pressure (density):

– the reset value of the closing lockout pressure;

– the reset value of the opening lockout pressure;

– disappearance of the low-pressure alarm.

b) Where applicable, on dropping pressure:

– appearance of a low-pressure alarm;

– operating value of lockout pressure for opening;

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– operating value of lockout pressure for closing.

11.3.102.2.2 Measurements of characteristic operating fluid pressures (if applicable)

11.3.102.2.2.1 General

The following measurements (list to be adapted as necessary) should 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.).

11.3.102.2.2.2 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;
– disappearance of the low-pressure alarm;
– cut-off of the pumping device;
– opening of the safety valve (if applicable).

NOTE The measurements can be combined with the measurements of the recharging time of the operating mechanism (see 11.3.102.2.5.2).

b) On a drop in pressure with the pumping device switched off:

– closing of the safety valve (if applicable);
– starting of the pumping device;
– appearance of the low-pressure alarm;
– 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.

11.3.102.2.3 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 sequences should be evaluated:

– O;
– C;
– OC.

The steady-state pressure after each operation or operating sequence should be noted.

11.3.102.2.4 Verification of the operating sequence

The ability of the BPS or PS to perform its specified 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 11.3.102.2.3.

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.

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The site supply voltage is the on-load voltage available at the BPS or PS from the normal site supply and should be compatible with the rated supply voltage of auxiliary and control circuits.

11.3.102.2.5 Measurement of time quantities

11.3.102.2.5.1 Characteristic time quantities

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 and when possible time spread of the switching units or groups of units;

– opening time and when possible time spread of the switching units or groups of units.

These measurements should be carried out for separate opening and closing operations.

In the case of multiple trip coils, all should be tested and the times recorded for each.

The supply voltage before and during the operations should be recorded. Furthermore, the instant at which the control relay, if any, is energised should also be recorded (relay time plus closing or opening time).

b) Operation of control and auxiliary contacts

The timing of the operation of one of each kind (make and break) of control and auxiliary contacts should be determined in relation to the operation of the main contacts, on closing and on opening of the BPS or PS.

11.3.102.2.5.2 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 should be measured at the site supply voltage.

11.3.102.2.6 Record of mechanical characteristics

As required by 8.101, a record can be made of the mechanical characteristics where the BPS or PS has been assembled 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 characteristics obtained during the reference no-load tests detailed in 7.101.1.1.

11.3.102.2.7 Checks of certain specific operations

11.3.102.2.7.1 Closing at the minimum filling 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 should 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.

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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 closing (short-circuited contact).

11.3.102.2.7.2 Opening at the minimum filling 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 should 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. There should be sufficient safety margin to the minimum functional pressure for closing.

In case of doubt, an alternative test may be performed, starting with a lower pressure than the minimum functional pressure for operation for opening (short-circuited contact). It should then be verified that closing operation is still possible.

11.3.102.2.7.3 Check of anti-pumping device

Measurement should be taken of the time during which the BPS or PS remains closed on a CO operating cycle or open after an OC operating cycle with the trip close circuit energised 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 opening or closing command.

The opening or closing command should be maintained for 1 s to 2 s so that the anti-pumping device can be checked for effective operation.

NOTE A simplified anti-pumping test can also be executed, using the local control. In this case, a closing or opening command is applied and maintained, while a consecutive opening or closing command is applied.

11.3.102.2.7.4 Behaviour on a closing (or opening) command while an opening (or closing) command is already present

It should be verified that the switch meets the technical specifications in the presence of a closing (or opening) command when previously an opening (or closing) command is applied and maintained.

11.3.102.2.7.5 Application of an opening or closing command on both releases simultaneously (if applicable)

It can happen that both releases (normal and emergency) are energised 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.

11.3.102.3 Electrical tests and measurements

11.3.102.3.1 Dielectric tests

Dielectric tests on auxiliary circuits shall be performed to confirm that transportation and storage of the BPS or PS have not damaged these circuits. However, it is recognised 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.

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For dielectric tests on the main circuit of metal-enclosed switchgear and controlgear, IEC 62271-200 and IEC 62271-203 are applicable.

11.3.102.3.2 Measurement of the resistance of the main circuit

Measurement of the resistance of the main circuit is only required if switching units have been assembled on site. The measurement shall be made with a direct current in accordance with 8.4 of IEC TS 62271-5:2024.

11.4 Operating instructions

The operating instructions given by the manufacturer shall contain the following information:

– a general description of the equipment with particular attention to the technical description of its characteristics and operation so that the user has an adequate understanding of the main principles involved;
– a description of the safety features of the equipment and the operation of the interlocks and padlocking facilities;
– as relevant, a description of the action to be taken to manipulate the equipment for operation isolation, earthing, maintenance, and testing;
– as relevant, measures against corrosion should be given.

11.5 Maintenance

In addition, the manufacturer should give information regarding the maintenance of BPS or PSs following

a) switching operations;
b) operations in normal service.

This information should include the number of operations according to items a) and b) after which the BPS or PS is to be overhauled.

Subclauses 11.5.1 to 11.5.5 of IEC TS 62271-5:2024 are applicable. The checks required in 11.3.102.1 apply.

11.5.1 General

The effectiveness of maintenance depends mainly on the way instructions are prepared by the manufacturer and implemented by the user.

11.5.2 Information about fluids and gas to be included in maintenance manual

Where applicable, the following information shall be provided by the manufacturer:

a) type and required quantity and quality of liquid to be used in switchgear and controlgear;
b) type and required quantity and quality of gas to be used in switchgear and controlgear.

11.5.3 Recommendations for the manufacturer

The manufacturer should be responsible for ensuring the continued availability of spare parts required for maintenance for a period of not less than 10 years from the date of final manufacture of the switchgear and controlgear.

The manufacturer should inform the purchasers of a particular type of switchgear and controlgear about corrective actions required by systematic defects and failures detected in service.

The manufacturer's maintenance manual should include the following information listed below.

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a) Extent and frequency of maintenance. For this purpose, the following factors should be considered:
   1) switching operations (current and number);
   2) total number of operations;
   3) time in service (periodic intervals);
   4) environmental conditions;
   5) activity after a seismic event (if applicable);
   6) measurements and diagnostic tests, (if any).

b) Detailed description of the maintenance work:
   1) recommended place for the maintenance work (indoor, outdoor, in factory, on site, etc.);
   2) procedures for inspection, diagnostic tests, examination, overhaul;
   3) reference to drawings;
   4) reference to part numbers;
   5) use of special equipment or tools;
   6) precautions to be observed (for example cleanliness and possible effects of harmful arcing by-products);
   7) lubrication procedures.

c) Comprehensive drawings of the details of the switchgear and controlgear important for maintenance, with clear identification (part number and description) of assemblies, subassemblies and significant parts.

NOTE Expanded detail drawings which indicate the relative position of components in assemblies and subassemblies are a common illustration method.

d) Limits of values, which can be measured during operation or routine maintenance and tolerances which, when exceeded, make corrective action necessary, for example:
   1) pressures, density levels, gas mixtures tolerance;
   2) insulating liquid or gas characteristics;
   3) quantities and quality of liquid or gas (see IEC 60480 and IEC 62271-4 for SF_6);
   4) dew point inside gas-filled switchgear compartment according to 11.3.6;
   5) resistance and/or capacitance (of the main circuit);
   6) operating times;
   7) permissible erosion of parts subject to wear;
   8) torques;
   9) important dimensions.

e) Specifications for auxiliary maintenance materials, including warning of known non-compatibility of materials:
   1) grease;
   2) oil;
   3) fluid;
   4) cleaning and degreasing agents.

f) List of special tools, lifting and access equipment.

g) Tests after the maintenance work.

h) List of the recommended spare parts (description, reference number, quantities) and advice for storage.

i) Estimate of active scheduled maintenance time, carried out in accordance with an established time schedule.

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j) How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

11.5.4 Recommendations for the user

If the user wishes to perform maintenance, the maintenance manual of the manufacturer should be followed.

The user should record the following information:

– the serial number and the type of the switchgear and controlgear;
– the date when the switchgear and controlgear is put in service;
– the results of all measurements and tests including diagnostic tests carried out during the life of the switchgear and controlgear;
– dates and extent of the maintenance work carried out;
– the history of service, periodical records of the operation counters and other indications (for example short-circuit operations);
– references to any failure report.

In case of failures and defects, the user should make a failure report and should inform the manufacturer by stating the special circumstances and measures taken. Depending upon the nature of the failure, an analysis of the failure should be made in collaboration with the manufacturer.

11.5.5 Failure report

The purpose of the failure report is to standardize the recording of the switchgear and controlgear failures with the following objectives:

– to describe the failure using a common terminology;
– to provide data for the user statistics;
– to provide a meaningful feedback to the manufacturer.

The following gives guidance on how to make a failure report.

A failure report should include the points listed below.

a) Identification of the switchgear which failed:
   1) substation name;
   2) identification of the switchgear (manufacturer, type, serial number, ratings);
   3) switchgear technology (mechanical switching device, power electronic DC circuit-breaker, hybrid DC circuit-breaker, vacuum, SF_6, gas mixture, etc.);
   4) location (indoor, outdoor);
   5) enclosure;
   6) drive mechanism, if applicable (hydraulic, spring, motor, manual).
b) History of the switchgear:
   1) date of commissioning of the equipment;
   2) date of failure/defect;
   3) total number of operating cycles, if applicable;
   4) date of last maintenance;
   5) details of any changes made to the equipment since manufacture;
   6) total number of operating cycles since last maintenance;

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7) condition of the switchgear when the failure/defect was discovered (in service, maintenance, etc.).

c) Identification of the subassembly/component responsible for the primary failure/defect:
   1) high-voltage stressed components;
   2) electrical control and auxiliary circuits;
   3) drive mechanism, if applicable;
   4) other components.

d) Stresses presumed to contribute to the failure/defect:
   1) operation mistake or misuse of the equipment;
   2) environmental conditions (temperature, wind, rain, snow, ice, pollution, lightning, etc.).

e) Classification of the failure/defect:
   1) major failure;
   2) minor failure;
   3) defect.

f) Origin and cause of the failure/defect:
   1) origin (mechanical, electrical, tightness if applicable);
   2) cause (design, manufacture, inadequate instructions, incorrect mounting, incorrect maintenance, stresses beyond those specified, etc.);
   3) operation mistake or misuse.

g) Consequences of the failure or defect:
   1) switchgear down-time, which is time interval during which an item is in a down state;
   2) time consumption for repair;
   3) labour cost;
   4) cost of spare parts.

A failure report can include the following information:

– drawings, sketches;
– photographs of defective components;
– single-line station diagram;
– operation and timing sequences;
– records or plots;
– references to maintenance or operating manuals.

11.101 Resistors and capacitors

When checking resistors and capacitors, permitted variations of the values should be given. Users should be aware of the Garton effect that can lead to incorrect values of tanδ, see CIGRE TB 368 [4].

12 Safety

Any known chemical and environmental impact hazards should be identified in the handbook/manual of the BPS or PS.

12.1 General

High-voltage switchgear and controlgear, complying with the applicable IEC standards, can be considered safe when installed in accordance with the relevant installation rules including

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instructions provided by the manufacturers and used and maintained in accordance with the manufacturer's' instructions (see Clause 11).

High-voltage switchgear and controlgear is normally only accessible by instructed persons. Performing operations and maintenance is only allowed to skilled persons. When unrestricted access is available to switchgear and controlgear, additional safety features should be required.

High-voltage switchgear and controlgear in accordance with IEC offers a high level of safety with regard to external effects that might harm personnel, mainly because the high-voltage parts can be surrounded by an enclosure. Nevertheless, high power equipment, can comprise some potential risks, some examples are:

– the enclosures, if any, can be pressurized with gas;
– pressure-relief devices can open due to exceptional conditions, e.g. resulting from an internal arc. In extreme circumstances, the arc can burn through the enclosures. Both result in the sudden release of hot gas;
– sudden events, which are in themselves with low risk to humans, can alarm personnel and lead to accidents (for example, a fall);
– commissioning, maintenance and extension activities can require special attention due to the complexity of the equipment and its internal parts which are mostly not visible.

Experience has shown that human error is a factor that shall be considered (for example, closing an earthing switch on an energized conductor).

12.2 Precautions by manufacturers

The following list provides examples of precautions usually implemented by manufacturers.

– design and test pressurized enclosures, pressure relief devices and relevant switchgear elements to international established standards;
– provide adequate and easy means to check interlocking systems (the most reasonable way to avoid human error);
– explain safe operation of the switchgear and controlgear clearly in instruction manuals. Explain precautions to prevent improper operation and the consequences of improper operation;
– provide the user and/or contractor with appropriate information related to design of the surrounding area, possibly ventilation and gas detection information, to minimize personnel risks in case a failure occurs;
– provide safe procedures for dismantling and disposal.

12.3 Precautions by users

The following list provides examples of precautions that can be taken by users:

– limit access to the installation to people who are trained and authorized;
– keep operators and other personnel instructed regarding risks and safety requirements including local regulations;
– keep switchgear and controlgear maintained and up to date in terms of technical standards, especially interlocking and protection devices;
– use remote control and have the interlocking system working as intended;
– select equipment that minimizes the risk to personnel from improper operation (for example earthing switches with short-circuit making capacity on lines, motor actuators to allow remote operation);
– coordinate the protection system with product properties (for example, do not reclose on internal faults);

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– prepare earthing procedures considering the difficulty of referring to and understanding the complex arrangement and operation of the switchgear and controlgear. Depending on the configuration of the DC system, monopolar or bipolar, and type of switch, one or both of the terminals of the switchgear and controlgear can be connected to one pole or neutral conductor of the system. For reliable protection of personnel and equipment, the protective earthing of the switchgear and controlgear shall be achieved through connecting the earthing point provided by the switchgear and controlgear to the system earth (see 6.3 for earthing point);
– label equipment clearly for easy identification of individual devices and gas compartments.

Especially during maintenance, repair or extension work:

– ensure that maintenance, repair and extension work is carried out only by qualified and trained personnel;
– prepare a safety and protection plan for the work. Indicate who is responsible for planning, implementing and enforcing safety and protection measures;
– check interlocking and protection devices before starting;
– pay special attention to manual operations, especially when the switchgear and controlgear is energized;
– inform personnel who can be near the switchgear and controlgear before operating the equipment (for example, a horn or flashing light);
– mark emergency exits and keep passages clear of obstructions;
– instruct the people involved how to work safely in a switchgear and controlgear environment and what to do in an emergency.

13 Influence of the product on the environment

Documentation shall include the following relevant information about the environmental impact of the switchgear:

a) When fluids are used in switchgear and controlgear, instructions shall be provided in order to allow the user to:
   1) minimize the leakage rate as far as is practicable;
   2) control the handling of the new and used fluids. IEC 62271-4 is referred to gases for insulation and/or switching.
b) Instructions concerning disassembly and end-of-life procedures for the different materials of the equipment and indicate the possibility to recycle.

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Annex A
(informative)

Examples of HVDC side switchgear arrangement for one pole in an HVDC substation

This annex provides examples of HVDC side switchgear arrangement for one pole in an HVDC substation. The upper side of Figure A.1 shows an example for LCC, whereas the bottom side shows that for VSC. The purpose of these examples are to introduce many various types of switching devices which are used in HVDC substations and they do not represent the real configuration. In addition to the switching devices shown in Figure A.1, there is a switching device called paralleling switch used for multiterminal HVDC systems. For the details of the purpose or usage of each switch, references can be made to CIGRE Technical Brochure 683 [72], IEC 60633 and IEC TS 63014-1 [66].

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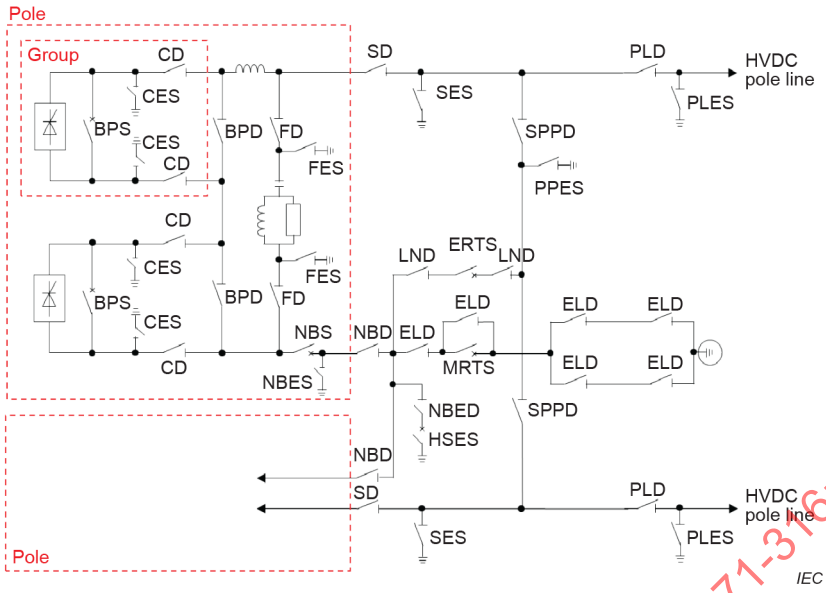
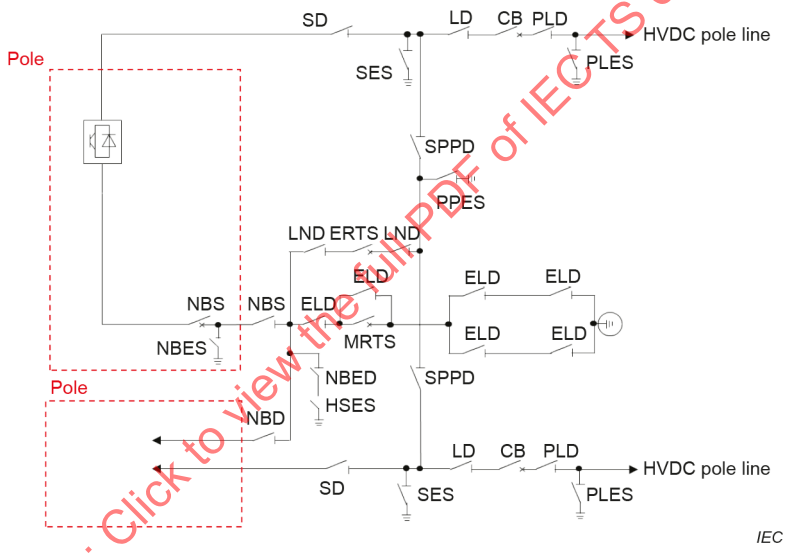


Line Commutated Converter (LCC)



Voltage Sourced Converter (VSC)

Key

CD	Converter Disconnector	NBES	Neutral Bus Earthing Switch
BPD	Bypass Disconnector	FES	Filter Earthing Switch
FD	Filter Disconnector	CES	Converter Earthing Switch
SD	Substation Disconnector	SES	Substation Earthing Switch
LD	Line Disconnector	PPES	Pole Paralleling Earthing Switch
PLD	Pole Line Disconnector	NBS	Neutral Bus Switch
LND	Line to Neutral Disconnector	MRTS	Metallic Return Transfer Switch
NBD	Neutral Bus Disconnector	ERTS	Earth Return Transfer Switch
NBED	Neutral Bus Earthing Disconnector	BPS	Bypass Switch
ELD	Electrode Line Disconnector	HSES	High Speed Earthing Switch
SPPD	Substation Pole Paralleling Disconnector	CB	Circuit Breaker
PLES	Pole Line Earthing Switch		

Figure A.1 – Example of HVDC side switchgear arrangement for one pole in an HVDC substation

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Annex B
(informative)

Exposure to pollution

B.1 General

The quality of ambient air with respect to pollution by dust, smoke, corrosive and/or flammable gases, vapours, or salt is a consideration under normal and special service conditions (refer to Clause 4). This annex defines recommendations for the minimum specific creepage distance across external insulation.

The approach for DC insulator design and selection with respect to pollution is different to that used for AC. In particular no discrete site severity classes are used, but instead a direct transfer from corrected site pollution severity to necessary USCD is employed. Reference is made to IEC 60815-4.

B.2 Minimum requirements for switchgear in normal service condition

In outdoor normal service condition RUSCDDC of 60 mm/kV is often used for non-HTM insulators and 45 mm/kV is often used for HTM insulators. In indoor normal service condition with uncontrolled environment (for example in indoor DC yard) RUSCDDC between 20 mm/kV and 30 mm/kV satisfies the performance. Reference is made to IEC 60071-11:2022.

IEC TS 60815-4:2016 gives information how to calculate USCD and to check the profile parameters.

B.3 Minimum requirements for switchgear in special service condition

In indoor clean and controlled (valve hall) environment with humidity control RUSCDDC of 14 mm/kV is widely used. Reference is made to IEC 60071-11:2022.

For the other cases of special service condition (for example outdoor offshore and costal area installation), IEC TS 60815-4:2016 gives information on how to determine RUSCDDC.

IEC TS 60815-4:2016 gives information on how to calculate USCD and to check the profile parameters.

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Annex C
(informative)

Preferred insulation levels for rated voltages lower than 105 kV

For possible future development of this document, and due to the lack of applications or products, the following preferred insulation levels for rated voltages lower than 105 kV are given as an indication. These values have been derived from pilot projects, products and values from CIGRE Technical Brochure 793 [74].

Table C.1 – Preferred insulation levels for rated voltages lower than 105 kV

Typical System direct voltage $U_{typ,d}$ kV	Rated direct voltage U_{rd} kV (NOTE 1)	Rated direct withstand voltage U_{dd} kV	Rated lightning impulse withstand voltage U_p kV	
		Pole-to-earth, Across open switching device and/or isolating distance (NOTE 2)	Pole-to-earth and across open switching device (NOTE 3)	Across the isolating distance[a]
(1)	(2)	(3)	(4)	(5)
6	6,3	15	40	40(+6,3)
12	12,5	25	75	75(+12,5)
20	21	40	125	125(+21)
30	31,5	55	185	185(+31,5)
50	52,5	90	250	250(+52,5)
70	73,5	125	325	325(+73,5)

NOTE 1 The rated direct voltage U_{rd} takes into account 5 % of ripples and harmonics to the typical system direct voltage, based on that the ripples and harmonics are in the range of 2 % to 5 % of the typical system direct voltage. Reference is made to CIGRE Technical Brochure 684 [73] and the nominal voltage is referred to IEC 60071-11:2022.

NOTE 2 For MVDC systems, the pole-to-earth over-voltage are limited to 1,7 times the rated voltage of the MVDC system, reference is made to CIGRE Technical Brochure 793 [74].

NOTE 3 The values for AC switchgear in IEC 62271-1 are referred to due to lack of sufficient data for DC switchgear.

[a] In column (5), values in brackets are the rated direct voltage applied to the opposite terminal (combined voltage). For multiterminal systems, where the full direct voltage can occur at the opposite terminal, the 100 % rated direct voltage shall be applied. For two-terminal systems, where no higher values can occur at the opposite terminal, the value of 10 % of rated direct voltage is chosen.

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Withstand values given in Table C.1 cover the application of switchgear and controlgear under normal service conditions defined in 4.1 including altitudes from sea level up to 1 000 m. However, for testing purposes to verify a rating or capability, they shall be considered as insulation values at the standardized reference atmosphere temperature (20 °C), pressure (101,3 kPa) and humidity (11 g/m^3) specified in 5.9.2 of IEC 60071-1:2019. For special service conditions, refer to IEC TR 62271-306 [62].

NOTE 1 The normal environmental conditions and the standard reference atmospheric conditions are currently not stated in IEC 60071-11:2022. In terms of these conditions 5.9.1 and 5.9.2 of IEC 60071-1:2019 are applied in this document.

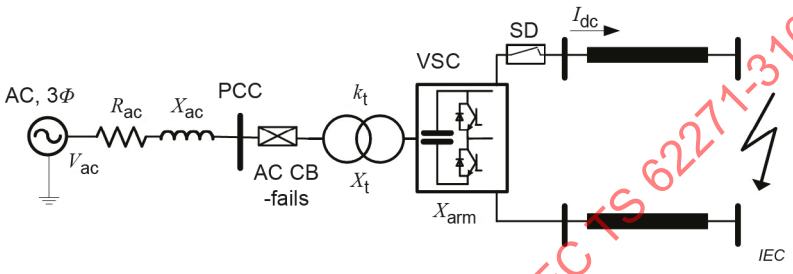
NOTE 2 The insulation levels in Table C.1 are considered being applicable in the temperature range of -40 °C up to 40 °C for DC systems. Reference is made to IEC 60071-1:2019, 5.9.1 for AC systems,

Annex D
(informative)

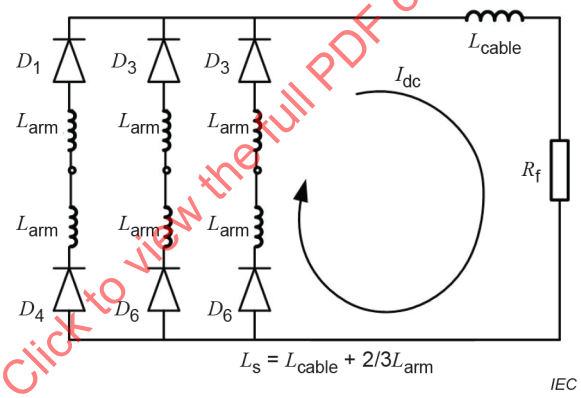
Short-circuit current in HVDC systems

D.1 VSC HVDC

Figure D.1a) shows considered 2-terminal VSC HVDC under DC fault, and Figure D.1b) shows the diode bridge discharge circuit once AC CB opens. It is assumed that the fault is cleared by AC back-up protection. The worst case DC fault current occurs for DC fault at zero cable length.



a) Circuit topology



b) Circuit for determining discharge time constant

Figure D.1 – VSC HVDC under worst-case, pole-pole DC fault

The diode bridge current feed is supplied from AC system with RMS line voltage V_{ac}, through equivalent AC grid impedance of resistance R_{ac} and reactance X_{ac}, (X_{ac} = $2\pi fL_{ac}$) transformer of stepping ratio k_t and reactance X_t, VSC as diode bridge and DC fault path. Neglecting circuit resistance, and assuming the DC voltage under fault is 0,05-0,1 pu, the DC fault current can be approximated as (see [77]):

$$I_f = \frac{6V_{ac}/\left(k_t\sqrt{3}\right)}{\pi\sqrt{\left(R_{ac}\right)^2+\left(X_{ac}+X_t+k_t^2X_{arm}/2\right)^2}} \quad (D.1)$$

The impact of AC system frequency f is reflected in X_{ac}.

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The rated duration of short circuit (t_{kd}) is expressed as:

$$t_{kd} = t_k + \frac{L_s}{R_f} \quad \text{(D.2)}$$

Where t_k is the duration of diode bridge current feed that is the interval of time from the fault until AC CB opens, which is determined by back-up protection and typical value is t_k = 0,5 s. L_s and R_f are the impedance and resistance, respectively in the DC fault current path after AC CB opens.

D.2 LCC HVDC

Figure D.2 shows the considered LCC HVDC under a DC fault. Normally LCC converter responds rapidly to DC fault using one of redundant LCC converter controllers (see Table 9 of [76]). The LCC converter responds to nearby DC fault in the station by blocking and bypassing. This results in rapid LCC converter DC voltage reduction and application of negative DC voltage that leads to DC fault current extinction in 10 ms to 20 ms. A thyristor failure does not affect LCC converter operation because, they fail in short circuit and there is a number of redundant thyristors in each valve.

In Figure 2b) the LCC converter responds to nearby DC fault in the station by blocking and bypassing. This is self-protection LCC mechanism for extreme DC currents.

The rated duration of short circuit (t_{kd}) is expressed as:

$$t_{kd} = \frac{L_s}{R_f} \quad \text{(D.3)}$$

Where L_s and R_f are the impedance and resistance, respectively, in the DC fault current path after LCC bypass, which resembles the circuit in Figure D.1b).

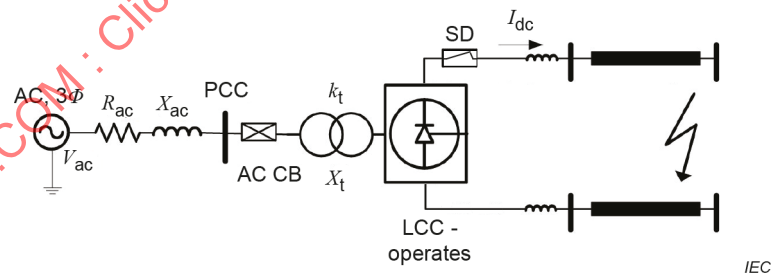

Figure D.2 – LCC HVDC under worst-case, pole-pole DC fault

D.3 Special case of LCC HVDC DC faults – LCC as diode bridge

Figure D.3 shows the special case DC fault with LCC HVDC that can give much higher DC fault current. This case is based on the following assumptions:

– DC fault occurs on the valve-side of DC smoothing inductor, like for example inadvertent operation of bypass switch.

– The LCC converter is forced to operate as a diode bridge, to reduce semiconductor voltage stresses. This is self-protection LCC operating mode for extreme DC currents.

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The diode bridge current feed is determined as:

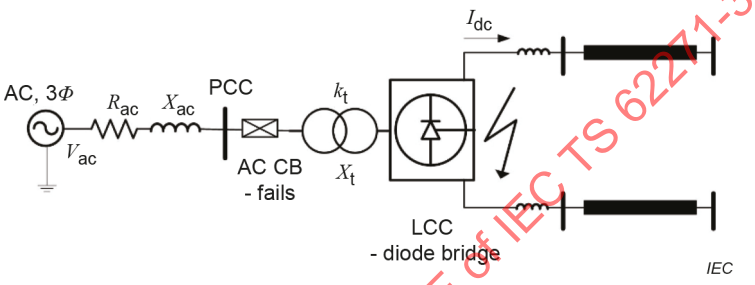
$$I_f = \frac{6V_{ac}/\left(k_t\sqrt{3}\right)}{\pi\sqrt{\left(R_{ac}\right)^2+\left(X_{ac}+X_t\right)^2}} \quad \text{(D.4)}$$

The preferred value for the rated peak withstand current is $10I_{rd}$.

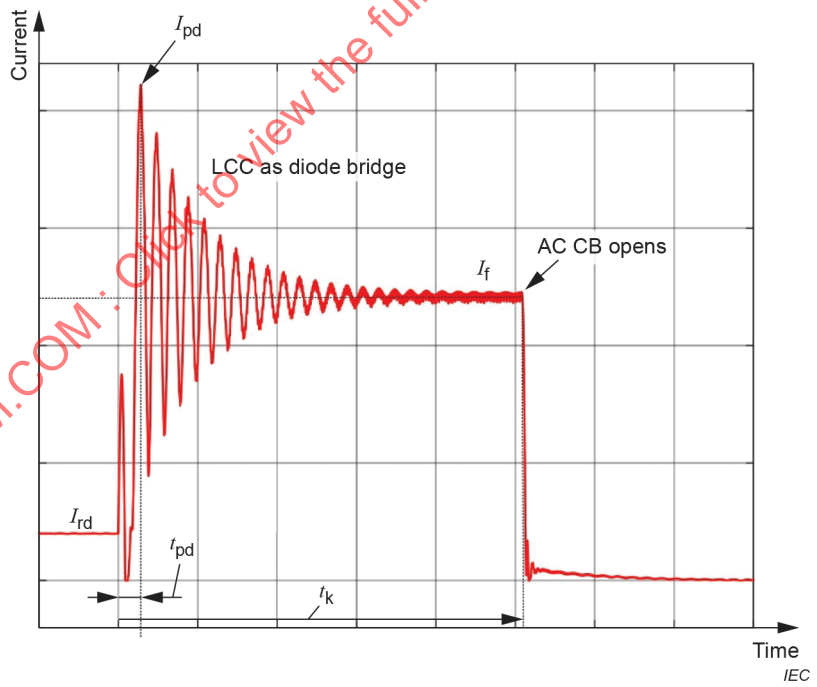
The preferred value for rated duration of short circuit is 0,5 s.

The time to peak short circuit current is 0,01 s.

An alternative value higher than above may be chosen.



a) Circuit diagram



b) Typical DC fault current I_{dc} response

Figure D.3 – Special case LCC HVDC under worst-case, pole-pole DC fault

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D.4 HVDC systems with DC circuit-breakers

Figure D.4 shows the considered DC system with Line Disconnector (LD) under short-time DC fault current. The Station Disconnector (SD) shall be considered under the circuit in Figure D.1. It is assumed that the fault is cleared by back-up protection (DC CB on adjacent DC lines and AC CBs). The typical value for operating time of AC CB is t_k = 0,05 s in this case. Figure D.5 shows the assumed simplified DC CB model (see [77]).

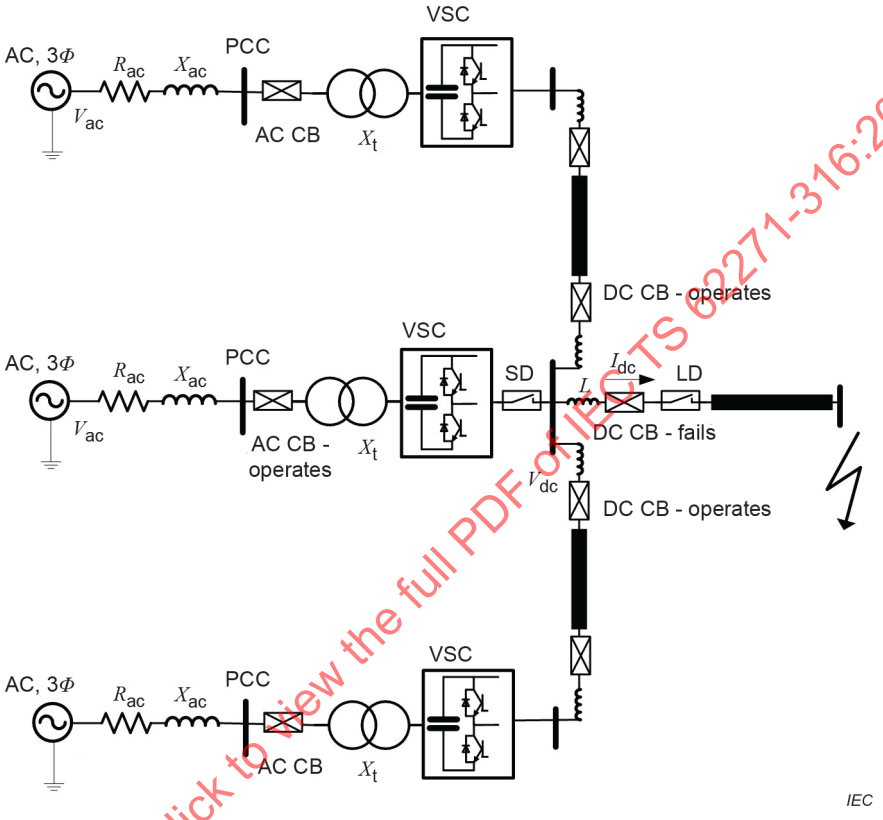

Figure D.4 – HVDC system with DC circuit-breaker under worst-case, pole-pole DC fault

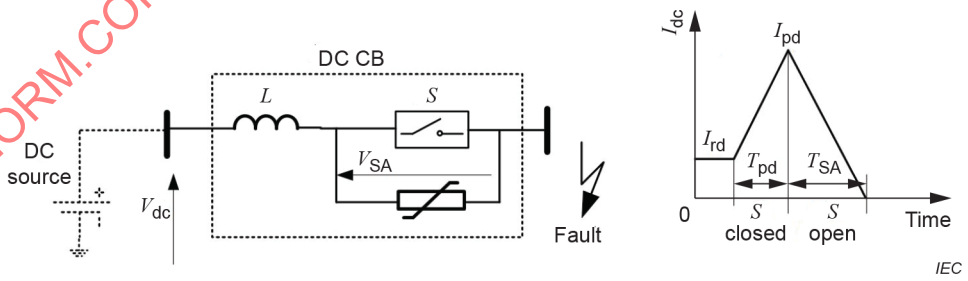

Figure D.5 – DC circuit-breaker simple model

The slope of DC line current rise will be the sum of currents slopes on each DC line:

$$S_L = \left(S_{p1} + S_{p2} + S_{p3}\right) \quad \text{(D.5)}$$

Where S_{p1}, S_{p2} and S_{p3} are slopes of current rise on each of the 3 DC lines.

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Assuming that I_{rd} = 0, and V_{dc} = constant, the fault path resistance is zero, and the total impedance in the fault path is L, the positive slope is defined, using the above DC CB model, the base value for positive slope (S_p) is V_{dc}/L: The slope S_{p2} will be the largest as only one inductor (L) is placed in the current path. Because of voltage drop during the current rise interval, and considering back-up protection time, typical value for slope of the local current is

$$0{,}1\frac{V_{DC}}{L} < S_{p2} < 0{,}5\frac{V_{DC}}{L} \tag{D.6}$$

Whereas the slope on remaining DC lines will be lower:

$$0{,}05\frac{V_{DC}}{L} < S_{p1} < 0{,}3\frac{V_{DC}}{L} \tag{D.7}$$

The rated duration of short circuit (t_{kd}) is expressed as:

$$t_{kd} = \frac{L + L_s}{R_f} \tag{D.8}$$

Where L+L_s and R_f are the impedance and resistance, respectively, in the fault current path, after AC circuit-breaker opens, and L_s is defined as in Figure D.1b).

D.5 Calculation of the rated short-time withstand direct current

The value of the rated short-time withstand direct current (I_{kd}) is obtained by the following formula.

$$I_{kd} = \sqrt{E_f / t_{kd}} \tag{D.9}$$

Where E_f is Joule integral value as calculated in D.6. This means that I_{kd} is the equivalent RMS value of the short-circuit current in Figure 2, as shown in Figure D.6.

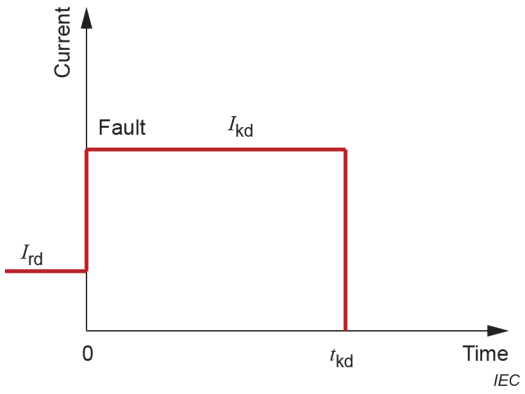

Figure D.6 – Equivalent fault current for calculation of rated short time withstand direct current

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D.6 Calculation of Joule integral value (E_j)

Joule integral value is obtained by calculation as $E_j = \int I^2 dt$ based on relevant waveform indicated in Figure 2a), 2b), 2c). Based on the simplification of the waveforms in Figure 2, the following values for Joule integral are recommended:

– For the circuit in Figure 2a), $E_j = I_f^2 t_k + I_f^2 \frac{t_{kd} - t_k}{3}$

where the preferred value of duration of the diode bridge current feed (t_k) is 0,5 s;

– For the circuit in Figure 2b), $E_j = I_{pd}^2 \frac{t_{kd}}{3}$,

where the preferred value of the duration of time to peak short-circuit current (t_{pd}) is 0,07 s;

– For the circuit in Figure 2c), $E_j = I_f^2 t_k + I_{pd}^2 \frac{t_{kd}}{3}$

– For the LCC special case circuit, $E_j = I_f^2 t_k$

where the duration of time to peak short-circuit current (t_{pd}) ranges typically from 0,002 s to 0,01 s, depending on the operating time of DC CB and protection (or back-up protection) time. For the purpose of calculation of the necessary thermal withstand capability of the switchgear or controlgear, it should be 0,01 s, considering time to back-up protection.

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Annex E
(informative)

References for auxiliary and control circuit components

Table E.1 is provided as a quick reference to many of the component standards. The latest editions should be used.

Table E.1 – List of reference documents for auxiliary and control circuit components

Device		IEC standard
Cables and wiring	Insulation of PVC wiring	IEC 60227 (all parts) [19]
	Size and area of conductors	IEC 60228 [20]
	Insulation of rubber cable	IEC 60245 (all parts) [21]
	Identification	IEC 60445 [28]
Terminals	Terminal blocks for round wire	IEC 60947-7-1 [51]
	Protective terminal blocks for round wire	IEC 60947-7-2 [52]
	Identification	IEC 60445 [28]
Relays	All-or-nothing relays	IEC 61810 (all parts) [54]
	Voltage ratings and operating range of all-or-nothing relays	IEC 61810-1 [55]
	Performance of relay contacts	IEC 61810-2 [56]
Contactors and motor starters	Electromechanical contactors for closing and opening electrical circuit	IEC 60947-4-1 [48]
	Electromechanical contactors combined with relay for short-circuit protection	IEC 60947-2 [46]
	Motor starters (AC)	IEC 60947-4-1 [48]
	AC semiconductor motor controllers	IEC 60947-4-2 [49]
	Motor protective overload relays	IEC 60947-4-1 [48]
Low-voltage switches	Low-voltage switches for motor circuits and distribution circuits	IEC 60947-3 [47]
	Manual control switches and push-buttons	IEC 60947-5-1 [50]
	Pilot switches: pressure, temperature switches etc.	IEC 60947-5-1 [50]
	Household humidity sensing controls	IEC 60730-2-13 [43]
	Household switches	IEC 60669-1 [32]
	Household thermostats	IEC 60730-2-9 [42]
	Lever (toggle) switch	IEC 61020-1 [53]
	Graphical symbols for manual switches	IEC 60417 [27]
	Colours of lights for manual switches	IEC 60073 [14]
Low-voltage circuit-breakers and low-voltage circuit-breakers with residual current protection	Requirements	IEC 60947-2 [46]
Low-voltage fuses	General requirements	IEC 60269-1 [22]
	Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K	IEC 60269-2 [23]

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Device		IEC standard
Low-voltage disconnectors	Requirements	IEC 60947-3 [47]
Motors	Requirements	IEC 60034-1 [6]
Meters	Analogue meters	IEC 60051-1 [7]
	Ammeters and voltmeters	IEC 60051-2 [8]
	Frequency meters	IEC 60051-4 [9]
	Phase-angle and power-factor meters	IEC 60051-5 [10]
Lamp used as an indicator	Requirements	IEC 60947-5-1 [50]
	Graphical symbols	IEC 60417 [27]
	Colour lights	IEC 60073 [14]
Plugs, socket-outlets, and couplers	Requirements for plugs, sockets-outlet, industrial cable couplers, appliance couplers	IEC 60309-1 [24]
	Dimensional and interchangeability	IEC 60309-2 [25]
	Household plugs, socket-outlets and couplers	IEC TR 60083 [16]
	Other couplers and plugs	IEC 60130 (all parts) [18]
Printed circuit-boards	Requirements	IEC 62326-1 [63]
Resistors	Potentiometers	IEC 60393-1 [26]
	Resistors 1 W to 1 000 W	IEC 60115-4 [17]
Illumination	Illumination fluorescents	IEC 60081 [15]
	Illumination for LED	IEC 62612 [65]
	Tungsten filament lamps	IEC 60064 [12]
NOTE For electronic components used in auxiliary and control equipment additional information can be found in IEC TR 62063 [60].		

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Annex F
(informative)

List of symbols

Description	Symbol	Subclause
Absolute leakage rate	F	3.6.6.4
Absolute leakage rate	F_{liq}	3.6.7.1
Alarm pressure (or density) for insulation and/or switching	p_{ae} (ρ_{ae})	3.6.5.3
Alarm pressure (or density) for operation	p_{am} (ρ_{am})	3.6.5.4
Diode bridge current feed	I_f	5.5.3
Duration of polarity reversal tests	t_1, t_2	7.2.7.6
Filling pressure	p_r	7.7.2
Filling pressure (or density) for insulation and/or switching	p_{re} (ρ_{re})	3.6.5.1
Filling pressure (or density) for operation	p_{rm} (ρ_{rm})	3.6.5.2
Highest voltage for equipment	U_m	3.7.3
Joule integral value	E_j	D.6
Main circuit resistance measured before continuous current test	R_u	8.4
Mass of switchgear and controlgear (including any fluid)	M	6.11.2
Replenishing pressure	p_m	7.7.2
Minimum functional pressure (or density) for insulation and/or switching	p_{me} (ρ_{me})	3.6.5.5
Minimum functional pressure (or density) for operation	p_{mm} (ρ_{mm})	3.6.5.6
Number of replenishments per day	N	3.6.6.8
Number of replenishments per day	N_{liq}	3.6.7.3
Permissible leakage rate	F_p	3.6.6.5
Permissible leakage rate	$F_{p(liq)}$	3.6.7.2
Positive slope	S_p	5.5.1
Pressure drop	Δp	3.6.6.9
Pressure drop	Δp_{liq}	3.6.7.4
Rated continuous current	I_{rd}	5.4
Rated direct withstand voltage	U_{dd}	5.3
Rated duration of short-circuit	t_{kd}	5.5.4
Rated lightning impulse withstand voltage	U_p	5.3
Rated peak withstand current	I_{pd}	5.5.3
Rated short-time withstand direct current	I_{kd}	5.5.2
Rated supply voltage	U_a	5.6.2
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_a	5.6
Rated switching impulse withstand voltage	U_s	5.3
Rated direct voltage	U_{rd}	5.2
Relative leakage rate	F_{rel}	3.6.6.6

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Description	Symbol	Subclause
Time between replenishments	t_r	3.6.6.7
Time to peak short-circuit current	t_{pd}	5.5.3
Type and mass of fluid (liquid or gas) for insulation	M_f	6.11.2
Typical system direct voltage	$U_{typ,d}$	5.2.1

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Annex G
(normative)

Method for the weatherproofing test for outdoor switchgear and controlgear

The switchgear and controlgear to be tested shall be fully equipped and complete with all covers, screens, bushings, etc., and placed in the area to be subjected to with artificial precipitation. For switchgear and controlgear comprising several functional units a minimum of two units shall be used to test the joints between them.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the surfaces under test. The various parts of the switchgear and controlgear may be tested separately, provided that a uniform spray is simultaneously applied also to both of the following:

a) the top surfaces from nozzles located at a suitable height;

b) the floor outside the equipment for a distance of 1 m in front of the parts under test with the equipment located at the minimum height above the floor level specified by the manufacturer.

Where the width of the equipment exceeds 3 m, the spray may be applied to 3 m wide sections in turn. Pressurized enclosures do not need to be submitted to artificial precipitation.

Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 3 l/min at a pressure of 460 kPa ± 46 kPa and a spray angle of 60° to 80°. The centre lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal as it is directed towards the surfaces being tested. It is convenient to arrange the nozzles on a vertical stand-pipe and to space them about 2 m apart (refer to test arrangement in Figure G.1).

The pressure in the feed pipe of the nozzles shall be 460 kPa ± 46 kPa under flow conditions. The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for duration of 5 min. The spray nozzles shall be at a distance between 2,5 m and 3 m from the nearest vertical surface under test.

NOTE When a nozzle in accordance with Figure G.2 is used, the quantity of water is considered to be in accordance with this document when the pressure is 460 kPa ±10 %.

After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met:

a) no water shall be visible on the insulation of the main and auxiliary circuits;

b) no water shall be visible on any internal electrical components and drive mechanisms of the equipment;

c) no significant accumulation of water shall be retained by the structure or other non-insulating parts (to minimize corrosion).

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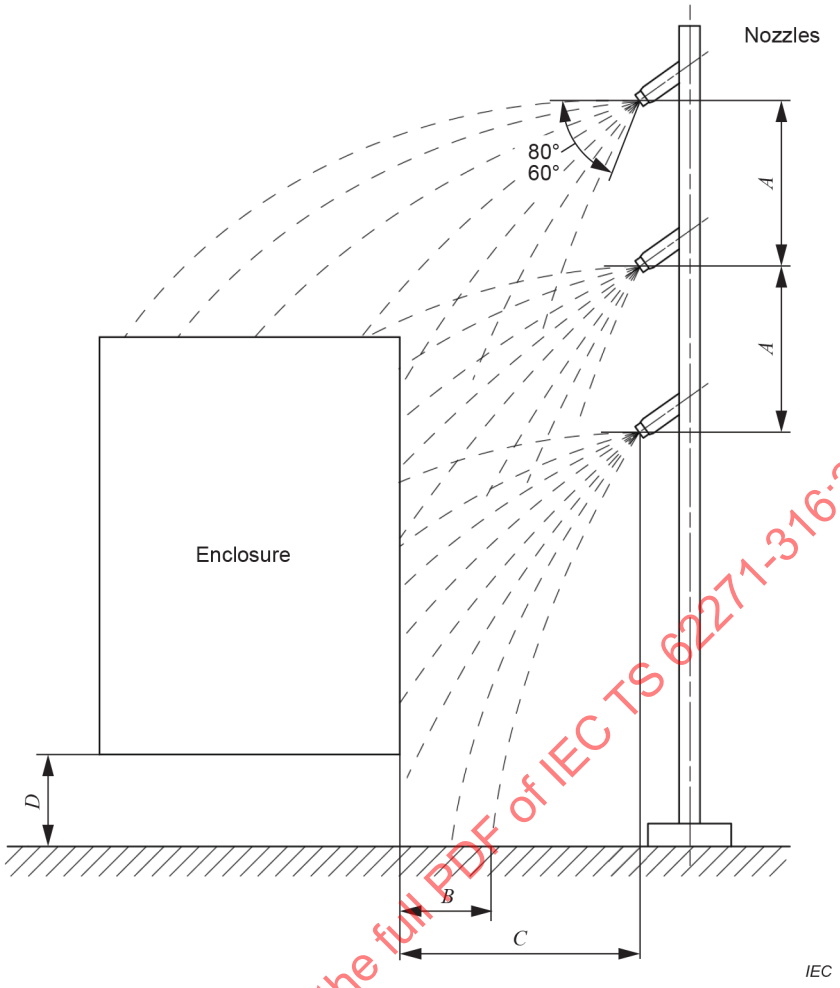

A	About 2 m
B	1 m
C	2,5 m to 3 m
D	Minimum height above floor

Figure G.1 – Arrangement for weatherproofing test

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Dimensions in millimetres

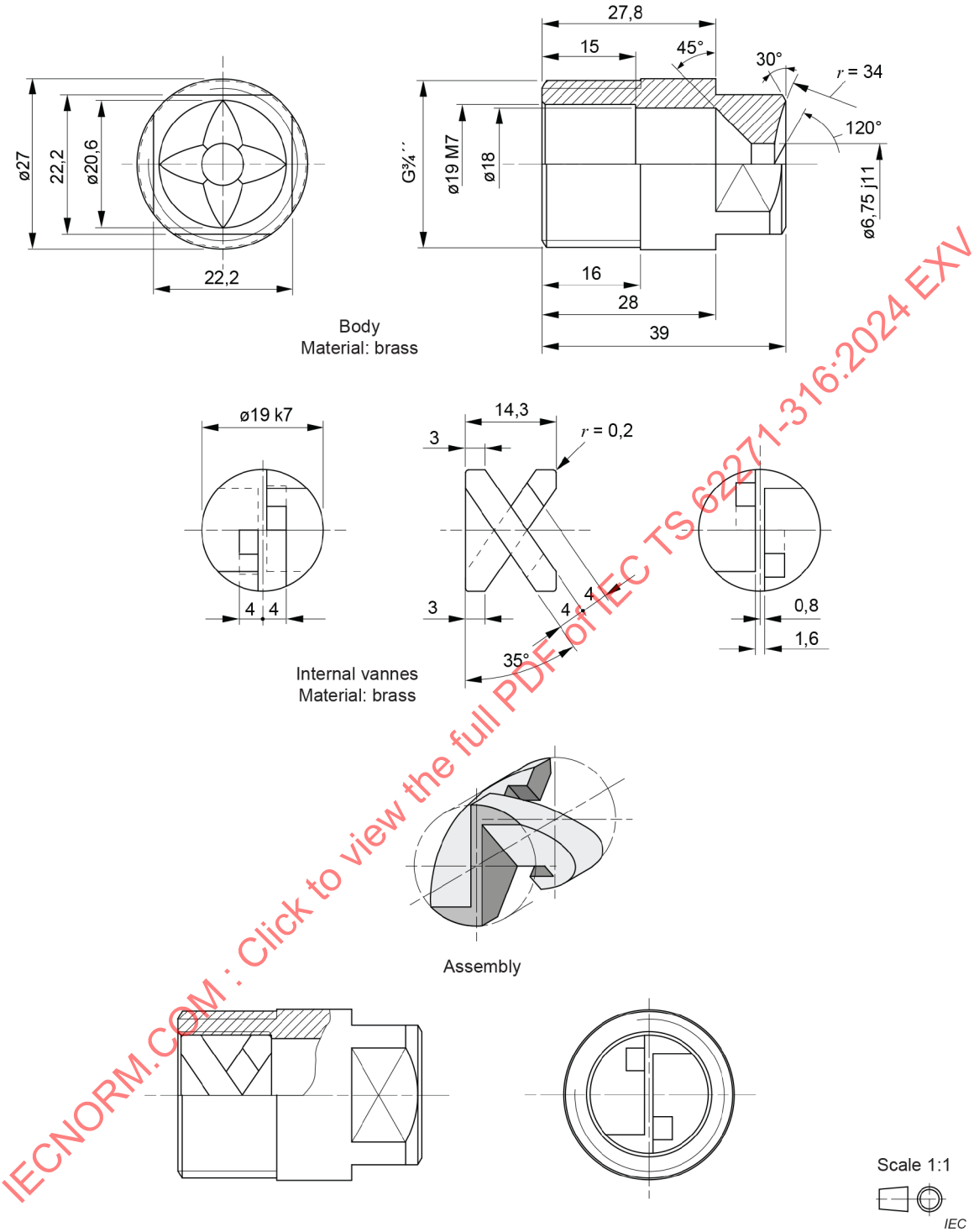

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Figure G.2 – Nozzle for weatherproofing test

Annex H
(normative)

Tolerances on test quantities during tests

During type tests, the following types of tolerances can 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.

A tolerance is defined as the range of the test value specified in the standard within which the measured test value shall lie for a test to be valid. In certain cases, the test may remain valid even if the measured value falls outside the range: this is the case when it results in a more severe test condition.

Any deviation between 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 application of tolerances on test quantities during type tests are as follows:

a) testing stations shall aim wherever possible for the test value specified;
b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses exceeding those tolerances are permitted only with the consent of the manufacturer;
c) where, for any test quantity, no tolerance is given within this document, or the standard to be applied, the type test shall be not less severe than specified. The upper stress limits are subject to the consent of the manufacturer.

Table H.1 – Tolerances on test quantities for type test

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.2 up to 7.2.11	Dielectric tests				
7.2.7.2 and 7.2.11	Direct voltage tests	Test voltage	Rated direct withstand voltage	±1 %	IEC 60060-1
7.2.7.3	Switching impulse voltage tests	Peak value	Rated switching impulse withstand voltage	±3 %	IEC 60060-1
		Front time	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
7.2.7.4	Lightning impulse voltage tests	Peak value	Rated lightning impulse withstand voltage	±3 %	IEC 60060-1
		Front time	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	

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Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.2.7.5	Superimposed impulse voltage tests	Test voltage (direct voltage)	Rated direct voltage	±1 %	IEC 60060-1
		Test voltage (Lightning impulse voltage)	Rated lightning impulse withstand voltage	Referred to lightning impulse voltage tests	
		Test voltage (Switching impulse voltage)	Rated switching impulse withstand voltage	Referred to switching impulse voltage tests	
7.2.7.6	Polarity reversal tests	Test voltage		±1 %	
7.2.11	AC power-frequency voltage test	Test voltage (RMS value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1
		Frequency	–	45 Hz to 65 Hz	
		Wave shape	Peak value / RMS value = $\sqrt{2}$	±5 %	
7.3.4	Measurement of the resistance of circuits	DC test current, I_{DC}	–	50 A < I_{DC} ≤ rated continuous current , or −20 %, +0 % of I_r ≤ 50 A	
7.4	Continuous current tests	Ambient air velocity	–	≤ 0,5 m/s	
		Test current	Rated continuous current	−0 %, +2 % These limits shall be kept only for the last two hours of testing period	
		Ambient air temperature T_a	--	10 °C < T_a ≤ 40 °C	
7.5	Short-time withstand current and peak withstand current tests	Peak current	Rated peak withstand current	−0 %, +5 %	
		Value of Joule integral $\int I^2 dt$	Value of Joule integral $\int I^2 dt$ Derived from the prospective current waveform	−0 %, +10 %	
		Short-circuit current duration	Rated short-circuit duration	Maximum 5 s	
7.8.1.1	Radio interference voltage tests	Test voltage		±1 %	
		Tune frequency of measurement circuit		Within +10 % of 0,5 MHz or between 0,5 MHz to 2 MHz	
7.8.2.3	Oscillatory wave immunity test	Damped oscillatory wave tests	Test frequency 100 kHz, 1 MHz	±30 %	IEC 61000-4-18
7.9.3.3	Auxiliary contact rated short-time withstand current	Test current amplitude		−0 %, +5 %	
		Test current duration		−0 %, +10 %	

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Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.9.3.4	Auxiliary contact breaking capability	Test voltage amplitude		−0 %,+10 %	
		Test current amplitude		−0 %, +5 %	
		Circuit time constant		−0 %, +20 %	
7.9.4.2	Cold tests	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-1: 2007
7.9.4.3	Dry heat test	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-2: 2007
7.9.4.4	Cyclic humidity test	Minimum temperature of cycle		±3 K	IEC 60068-2-30: 2005
		Maximum temperature of cycle		±2 K	
7.9.4.5	Vibration response and seismic tests				IEC 60255-21-1: 1988
7.9.5	Power-frequency voltage test	Test voltage (RMS value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1
		Frequency	–	45 Hz to 65 Hz	
		Waveshape	Peak value / RMS value = √2	±5 %	
7.10.1.3	Radiation instrument	Accuracy measurement of radiation		±25 %	
	Energy response	Accuracy measurement of energy		±15 %	

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Annex I
(informative)

Extension of validity of type tests

I.1 General

An individual type test does not need to be repeated in some situations e.g.:

– for a change of construction detail, if the manufacturer can establish that this change does not influence the result of that individual type test;

– for a change in the installation instructions, provided that the test conditions are not invalidated by the new instructions (e.g. see I.2);

– for covering other values of ratings for the same switchgear and controlgear, if these new ratings are covered by the tests already performed (e.g. see I.3 or when lower performances are requested).

Particular examples where extension of a type test may be used to validate design changes or other similar equipment, without repeating type tests, are given in the following subclauses. It should be noted that supporting evidence should be provided to validate such extensions of type tests.

I.2 Dielectric tests

For non-enclosed conductors, the dielectric tests performed cover other dispositions having equal or higher clearances to surroundings (e.g. height above ground) and between conductors, if the insulating materials and shapes of conductors and insulators are the same.

I.3 Short-time withstand current and peak withstand current tests

A test performed in worst condition for instance with a rated short-time withstand direct current (I_{kd}), rated peak withstand current (I_{pd}) and rated duration of short-circuit (t_{kd}) covers equal or less values independently from which of the three waveforms, indicated in 5.5.1, has been used.

I.4 Electromagnetic immunity test on auxiliary and control circuits

Subassemblies may be positioned in different places within the auxiliary and control circuits, without invalidating the type test of the complete system, provided that the overall wiring length and the number of individual wires connecting the subassembly to the auxiliary and control circuits is not greater than in the tested system.

Interchangeable subassemblies may be replaced by similar subassemblies, without invalidating the original type test, provided that:

– rules for design and installation given in IEC 61000-6-5 are followed;

– type tests have been performed on the most complete subassembly applicable to the type of switchgear and controlgear;

– manufacturer's design rules are the same as for the type-tested subassembly.

I.5 Environmental tests on auxiliary and control circuits

Environmental tests on auxiliary and control circuits do not need to be repeated if performance requirements are validated during environmental tests on a whole switchgear and controlgear.

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Parts, or pieces of equipment, of auxiliary and control circuits validated in a given arrangement are validated also when used in a different arrangement of auxiliary and control circuits belonging to the same range of switchgear and controlgear equipment.

Tests performed with a given supply voltage for auxiliary and control circuit cover similar auxiliary and control circuits designed for lower supply voltages.

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Annex J
(normative)

Identification of test objects

J.1 General

For identification of a test object, the following topics shall be covered.

J.2 Data

– Manufacturer's name;
– Type designation, ratings and serial number of apparatus;
– Outline description of apparatus (including interlocking system, busbar system, earthing system, and the arc extinguishing process);
– Make, type, serial numbers, ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances, relays, fuse links, insulators);
– Rated characteristics of fuse links and protective devices;
– Whether the apparatus is intended for operation in the vertical and horizontal plane.

J.3 Drawings

Table J.1 Drawing list and contents

Drawings to be submitted	Drawing content (as applicable)
Single-line diagram of main circuit	Type designation of principal components
General layout For an assembly it can be necessary to provide drawings of the complete assembly and of each switching device.	Overall dimensions Supporting structure and mounting points Enclosure(s) Pressure-relief devices Conducting parts of the main circuit Earthing conductors and earthing connections Electrical clearances: – to earth; – between open contacts Location of earthed metallic screens, shutters or partitions in relation to live parts Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulant in filled boxes Cable termination details

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Drawings to be submitted	Drawing content (as applicable)
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Identity of springs Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and drive mechanisms)	Arrangement and identity of main components of the kinematic chains to: – main contacts; – auxiliary switches; – pilot switches; – position indication. Latching device Assembly of drive mechanism Interlocking devices Identity of springs Control and auxiliary devices
Electrical diagram of auxiliary and control circuits (if applicable)	Type designation of all components

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Annex K
(informative)

Test circuit for superimposed impulse voltage tests

K.1 General

The superposition of an impulse wave on a direct voltage is obtained by using a blocking capacitor or a sphere gap and a current limiting resistor. The results according to both procedures are considered equivalent (see CIGRE Technical Brochure 842 [75]).

K.2 Test circuit using blocking capacitor

The choice of the blocking elements for the direct voltage has an influence on the protection effect and the waveform. Using blocking capacitors, the blocking capacitor and the test object form a capacitive voltage divider as shown in Figure K.1. Therefore, the rated direct voltage U_{rd} and the impulse voltage generator output can be added to receive approximately the amplitude of the superimposed voltage.

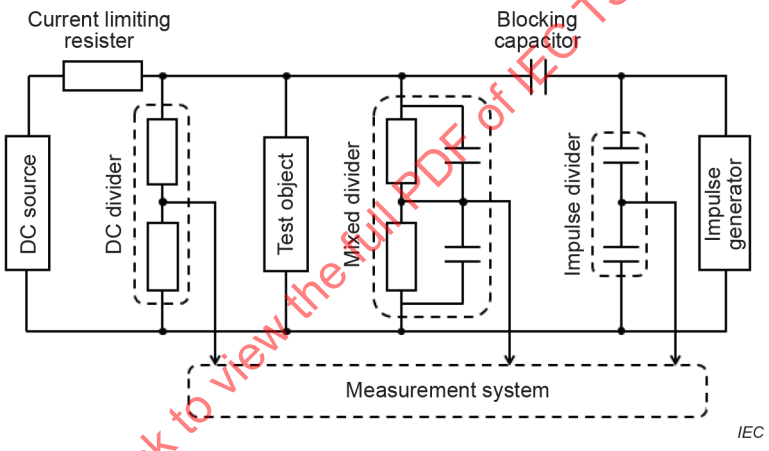

Figure K.1 – Test circuit for superimposed impulse tests using blocking capacitor

K.3 Test circuit using sphere gap

By ignition of the sphere gap (see Figure K.2), the test object is directly connected to the impulse voltage generator. Therefore, the amplitude of the composite voltage is equal to the impulse generator output voltage in this case. On the other hand, the impulse voltage waveshape can be different from the standard LI or SI waveshape. In any case, attention shall be paid to the design of the test circuits, and particularly the coupling elements.

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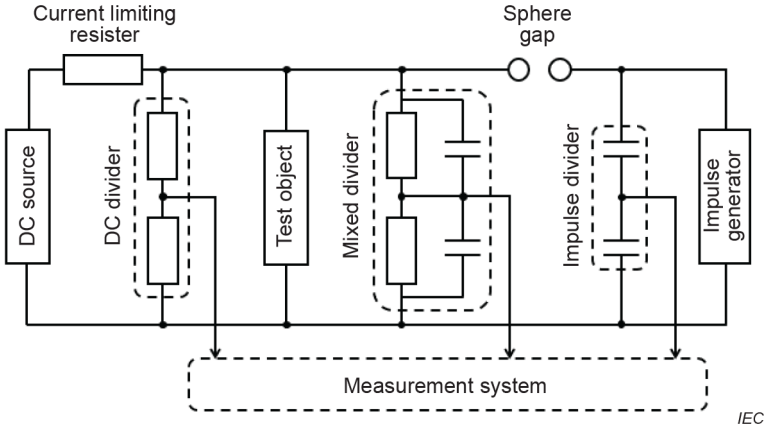

Figure K.2 – Test circuit for superimposed impulse tests using sphere gap

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Annex L
(informative)

Information and technical requirements to be given with enquiries, tenders and orders

L.1 General

This annex provides a list of useful technical information items in a tabular form to be considered for possible exchange between user and supplier during contracting stage.

When in the table "supplier information" is mentioned, this means that only the supplier should deliver this information.

Attention should be paid to the fact that such table should be complemented with information and characteristics relevant for the type of switchgear and controlgear considered; see product standards.

L.2 Normal and special service conditions (refer to Clause 4)

		User requirements	Supplier proposals
Service condition	Indoor or outdoor		
Ambient air temperature: Minimum Maximum	 °C °C		
Solar radiation	W/m^2		
Altitude	m		
RUSCD for pollution	mm/kV		
Excessive dust or salt			
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in auxiliary and control circuits	kV		

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L.3 Ratings (refer to Clause 5)

		User requirements	Supplier proposals
Rated direct voltage for equipment (U_{rd})	kV		
Rated insulation levels pole to earth Rated direct withstand voltage (U_{dd}) Rated switching impulse withstand voltage (U_s) Rated lightning impulse withstand voltage (U_p)	 kV kV kV		
Rated continuous current (I_{rd})	A		
Rated short-time withstand direct current (I_{kd})	kA		
Rated peak withstand current (I_{pd})	kA		
Rated duration of short-circuit (t_{kd})	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 or 60	

L.4 Design and construction (refer to Clause 6)

To be complemented with information provided by the relevant product standards.

		User requirements	Supplier proposals
Number of units in series, or, in parallel			
Mass of the heaviest transport unit			
Mounting provisions			
Type of gas-pressure or liquid-pressure system			
Overall dimensions of the installation			
Description by name and category of the various compartments			
Rated filling level and minimum functional level			
Low- and high-pressure interlocking and monitoring devices			
Interlocking devices			
Degrees of protection			
Arrangement of the external connections			
Accessible sides			
Volume of liquid or mass of gas or liquid for the different compartments			
Facilities for transport and mounting			
Instructions for operation and maintenance			
Specification of gas or liquid condition			

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L.5 System information

		User information
Nominal voltage of system	kV	
Highest voltage of system	kV	

L.6 Documentation for enquiries and tenders

	User requirements	Supplier proposals
Scope of supply (training, technical and layout studies and requirements for co-operation with other parties)		
Single-line diagram		
General arrangement drawings of substation layout		
Provisions for transport and mounting to be given by the user		
Foundation loading	Supplier information	
Gas schematic diagrams	Supplier information	
List of type test reports	Supplier information	
List of recommended spare parts	Supplier information	

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Annex M
(informative)

Electromagnetic compatibility on site

EMC site measurements are not type tests but can be performed in special situations:

– where it is deemed applicable to verify that actual stresses are covered by the EMC severity class of the auxiliary and control circuits;
– in order to evaluate the electromagnetic environment;
– in order to apply proper mitigation methods, if applicable;
– to record the electromagnetically induced voltages in auxiliary and control circuits, due to switching operations both in the main circuit and in the auxiliary and control circuits. It is not considered useful to test all auxiliary and control circuits in a substation under consideration. A typical configuration should be chosen.

Measurement of the induced voltages should be made at representative ports in the interface between the auxiliary and control circuits and the surrounding network, for example, at the input terminals of control cubicles, without disconnection of the system. Instrumentation for recording induced voltages should be connected as outlined in IEC TR 60816 [44].

Switching operations should be carried out at normal operating voltage, both in the main circuit and in the auxiliary and control circuits. Induced voltages will vary statistically and thus a representative number of both making and breaking operations should be chosen, with random operating instants.

The switching operations in the main circuit shall be made under no-load conditions. The tests will thus include the switching of parts of the substation but no switching of load currents and no fault currents.

The making operations in the main circuit should be performed with trapped charge on the load side corresponding to normal operating voltage. This condition can be difficult to obtain at testing, and, as an alternative, the test procedure can be as follows:

– discharge the load side before the making operation, to assure that the trapped charge is zero;
– multiply recorded voltage values at the making operation by 2, in order to simulate the case with trapped charge on the load side.

The switching device in the primary system shall preferably be operated at rated pressure and auxiliary voltage.

NOTE 1 The most severe cases, with regard to induced voltages, normally occur when only a small part of a substation is switched.

NOTE 2 The most severe electromagnetic disturbances are expected to occur at disconnector switching, especially for GIS installations.

The recorded or calculated peak value of induced common-mode voltage, due to switching in the main circuit, should not exceed 1,6 kV for interfaces of the auxiliary and control circuits.

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Annex N
(informative)

Standardization activities of HVDC

There are over 200 HVDC projects installed worldwide, and a number of projects is in planning stage. The applications of HVDC have been increasing in recent years, driven by the need to integrate remote renewable sources, to strengthen network, and to facilitate controllable power interchange between countries and regions. There is growing demand to reduce equipment cost, and size/weight, especially in the offshore HVDC terminals. The first HVDC grid was installed in 2021, and it is projected that demands for multiterminal HVDC and HVDC grids will increase.

HVDC applications today and in future are seen in many different cases in the network. The need of controllable power flow is increasing due to the requirements of the integration of renewable and fluctuating power generation. The goals of today to reach CO_2 neutral electric power generation within the next decades will require more controllable power flow in the network. HVDC will offer practical solutions. Space requirements for the HVDC converter station including the substation are not easy to fulfil on land and have high cost impact for converter stations to connect offshore wind farms.

DC power transmission systems use today voltage sourced converter technology (VSC) and line commutated converter technology (LCC) depending on their application in the network. VSC technology becoming the mainstream for applications in the network while LCC technology is used for very high voltages (up to 1 100 kV) and very high currents (up to 6 000 A). Along with this, plans for multiple terminals are in progress.

DC switching devices (AIS and GIS) and DC assemblies (GIS) are now under standardization works in SC 17A and SC 17C. This work in TC 17 will provide common specifications for devices and assemblies of high-voltage application.

In addition to standardization for HV switchgear of TC 17 IEC documents of DC equipment and systems are being promoted by other TCs.

The need for standardization of HV DC switchgear was discussed at the plenary meeting of the switchgear technical committee TC 17 and ad-hoc group Ahg 37 was established to investigate the standardization requirements and a report was published in 2018.

At the 2018 Korea Busan plenary meeting, it was decided by TC 17, SC 17A and SC 17C to start standardization work of DC common requirements in TC 17, DC switchgear devices in SC 17A and DC switchgear assemblies in SC 17C.

Based on this, in TC 17 a questionnaire was distributed (17/1052/Q) and the NP proposal was approved by P-member voting in May 2019. Then the dedicated WG was established in TC 17 to prepare common specifications for DC switchgear.

Regarding the DC standard voltages, TC 8 provides the horizontal standard requirements for DC networks, TC 99 defines the requirements for DC substations and TC 115 for DC transmission systems. This Technical Specification provides rated and test voltage values for insulation coordination as recommendations from the view of air and gas insulated switchgear technology.

HVDC switchgear equipment today is designed following project specific requirements. In future with more HVDC projects the requirement for standardized requirements will be more important to gain from cost reductions coming with standard switchgear devices and assemblies. In addition to cost reduction with standardization of equipment reliability, performance, and delivery time will improve. Standardization will bring benefits to the market, manufacturers, and testing laboratories.

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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 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.

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 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 BPS or PS 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 standard 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.

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

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 7.2.11	Direct voltage tests	Test voltage	Rated direct withstand voltage	±1 %	IEC TS 62271-5, IEC 60060-1
7.2.7.3	Switching impulse voltage tests	Peak value	Rated switching impulse withstand voltage	±3 %	
		Front time	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
7.2.7.4	Lightning impulse voltage tests	Peak value	Rated lightning impulse withstand voltage	±3 %	
		Time to peak	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	
7.2.7.6	Polarity reversal tests	Test voltage		±1 %	
7.8 and 7.8.1.1	Radio interference voltage tests	Test voltage		±1 %	
		Tune frequency of measurement circuit		Within ±10 % of 0,5 MHz or between 0,5 MHz and 2 MHz	
8.4	Measurement of the resistance circuits	DC test current I_{DC}		50 A ≤ I_{DC} ≤ rated continuous current or $^{0}_{-20}$ of I_r ≤ 50 A	IEC TS 62271-5
7.4	Continuous current test	Ambient air velocity		≤ 0,5 m/s	IEC TS 62271-5
		Test current	Rated continuous current	$^{+2}_{0}$ % These limits shall be kept only for the last two hours of the testing period	
		Ambient air temperature T	--	+10 °C < T ≤ 40 °C	

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Subclause	Designation of the test	Test quantity	Specified test value	Test tolerances/ limits of test values	Reference to
7.5	Short-time withstand current and peak withstand current tests	Peak current	Rated peak withstand current	$^{+5}_{0}$ %	IEC TS 62271-5
		Short-circuit current duration	Rated short-circuit duration	Maximum 5 s	
		Value of Joule integral $\int I^2 dt$	Value of Joule integral $\int I^2 dt$ derived from the prospective current waveform	$^{+10}_{0}$ %	
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 the service conditions of BPS or PS (see IEC TS 62271-5:2024)	±3 K	
7.101.4	Humidity test	Minimum temperature of a cycle	25 °C	±3 K	
		Maximum temperature of a cycle	40 °C	±2 K	

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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 Clause B.2 shall be made of all switching operations and no-load operations.

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 BPS or PS during the test and of the condition of the BPS or PS after the test, in so far as an examination is made. The statement shall include the following particulars:

a) condition of BPS or PS, giving details of any replacements or adjustments made and condition of contacts, arc control devices, oil (including any quantity lost), statement of any damage to arc shields, enclosures, insulators and bushings;
b) description of performance during the test, 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

IEC TS 62271-5:2024, 7.1.3 and IEC TS 62271-5:2024, Annex A are applicable with the following additions:

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 BPS or PS, including its operating devices and auxiliary equipment

The values of rated characteristics specified in Clause 5.

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B.2.4 Test conditions (for each series of tests)

a) diagram of test circuit including connection(s) to earth;
b) details of connection of the BPS or PS to the test circuit (for example orientation);
c) pressure for switching;
d) pressure of fluid for operation.

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Annex C
(informative)

Voltages associated with BPSs in different configurations

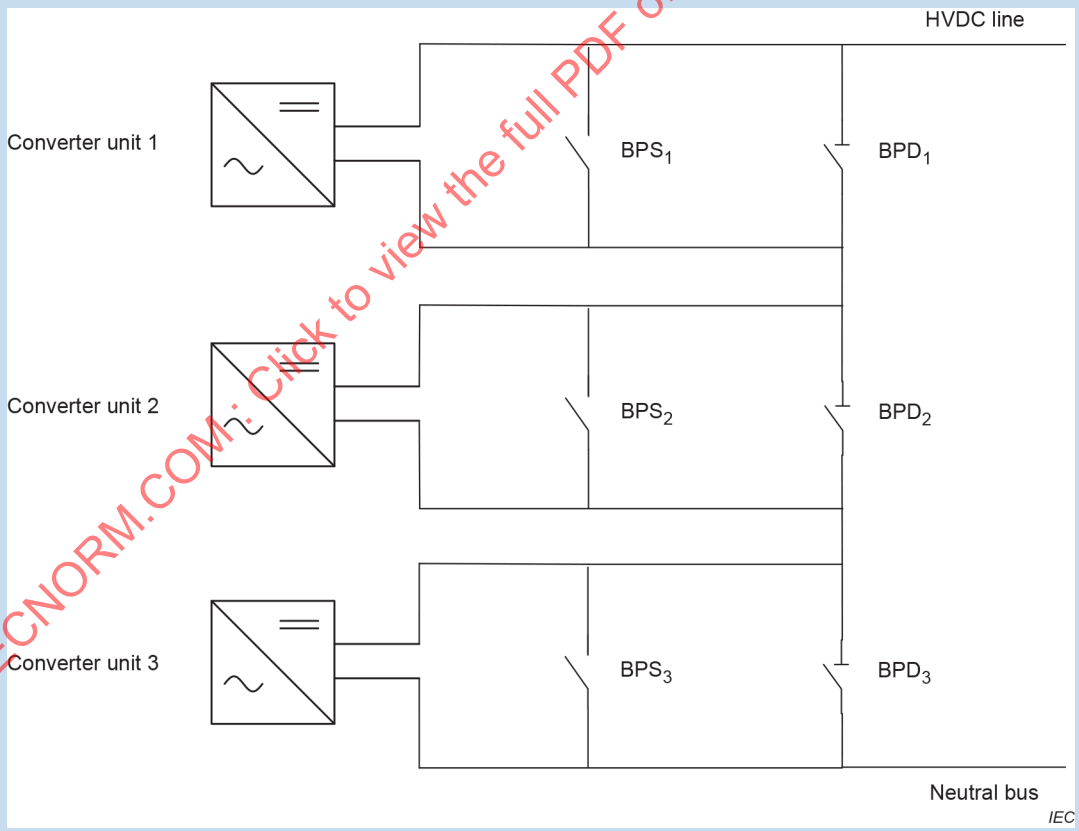
C.1 General

An HVDC transmission system can consist of one or more converter units per pole. If required, these converter units can be bypassed by BPSs. Depending on the voltage per converter unit and number of switching units in series per BPS, the configuration of the BPS may change. A few examples are given to illustrate this. As can be seen, the configuration of the BPS has an impact on the rated direct voltage across the open contacts and to earth.

C.2 Case 1: BPS consisting of a single switching unit

C.2.1 General

Figure C.1 shows a case of a 525 kV HVDC transmission system that consists of 3 series connected converter units. The voltage per converter unit is 175 kV. The BPSs each consist of a single switching unit on top of a post insulator. As the BPS consists of a single switching unit, there is no need for grading elements across the open BPS as the voltage sharing is determined by the converter units and their protective devices.



Key

BPS By-pass switch

BPD By-pass disconnector

Figure C.1 – HVDC system with 3 series connected converter units per pole

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In normal operation all three BPSs are in the open position. That means that the contact gap of each BPS sees a voltage difference of 175 kV.

The three BPSs can be connected in several ways, see Figure C.2.

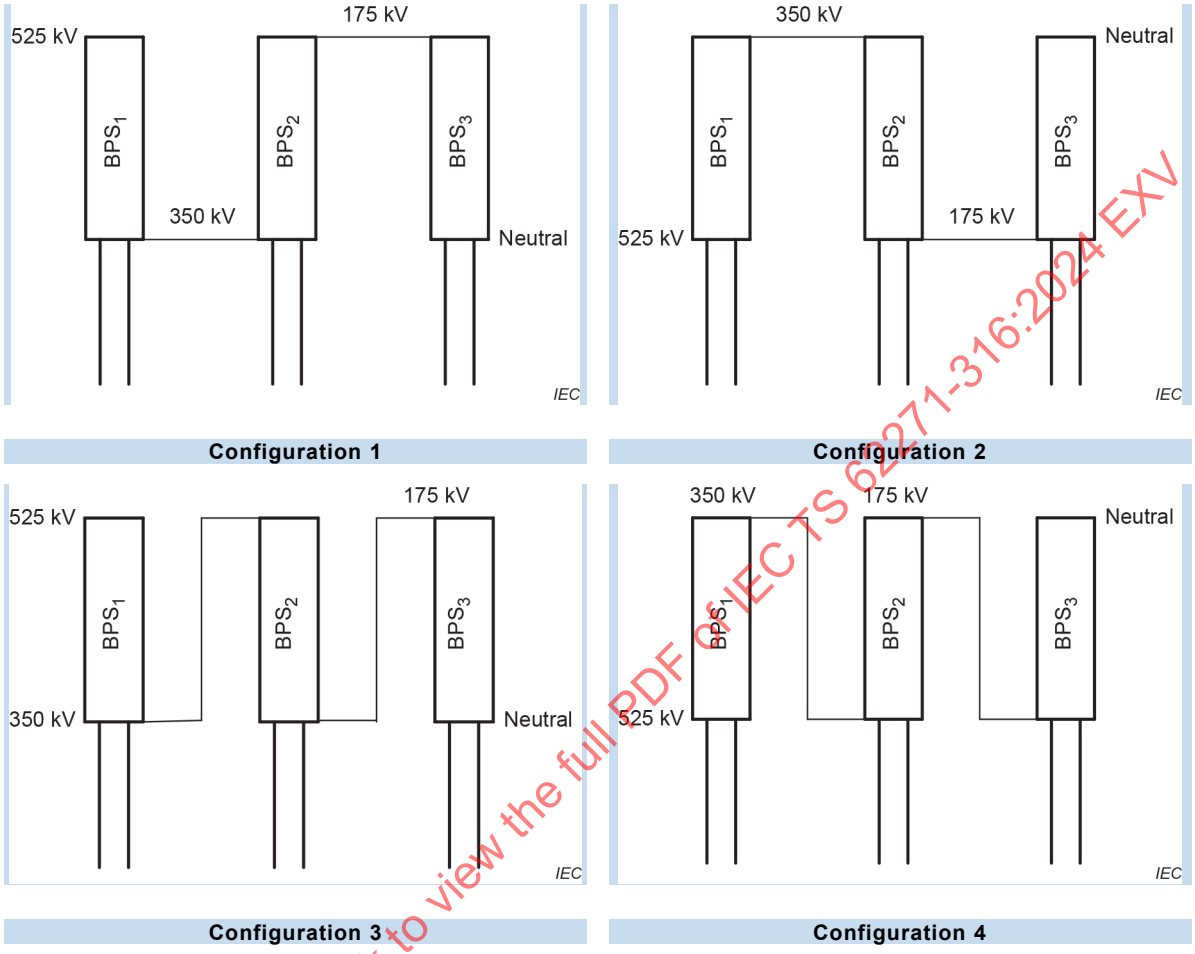

Figure C.2 – Different ways to connect a BPS to the grid

C.2.2 Configuration 1

In configuration 1 the top terminal of BPS_1 is connected to the HVDC line. In that case the voltage of 525 kV is across the insulator of the switching unit of BPS_1 and the post insulator. The voltage across the post insulator of BPS_1 and BPS_2 is 350 kV. The voltage across the post insulator of BPS_3 is the voltage of the neutral.

C.2.3 Configuration 2

In configuration 2 the bottom terminal of BPS_1 is connected to the HVDC line. In that case the voltage across the post insulator of BPS_1 is 525 kV. The voltage across the post insulator of BPS_2 and BPS_3 is 175 kV.

C.2.4 Configuration 3

In configuration 3 the top terminal of BPS_1 is connected to the HVDC line. In that case the voltage of 350 kV is across the post insulator of BPS_1. The voltage across the post insulator of BPS_2 is 175 kV. The voltage across the post insulator of BPS_3 is the voltage of the neutral.

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C.2.5 Configuration 4

In configuration 4 the bottom terminal of BPS_1 is connected to the HVDC line. In that case the voltage across the post insulator of BPS_1 is 525 kV. The voltage across the post insulator of BPS_2 is 350 kV and that of BPS_3 175 kV.

C.2.6 Summary of the voltages across the post insulator for the different configurations

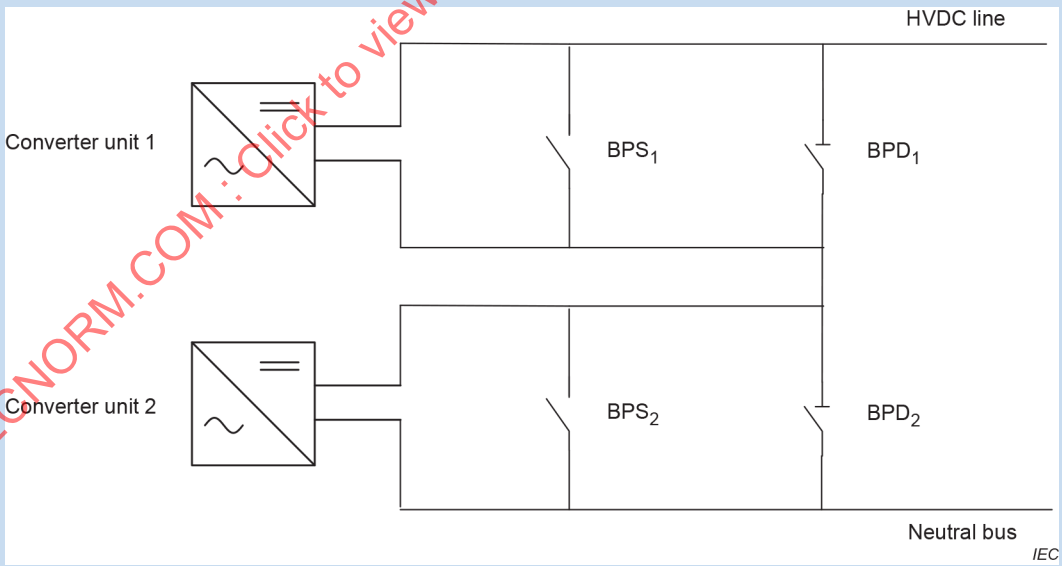
Table C.1 provides a summary of the different voltages across the post insulators of the BPSs for the different configurations.

Table C.1 – Voltage across the post insulator

Configuration	BPS_1 kV	BPS_2 kV	BPS_3 kV
1	350	350	Neutral
2	525	175	175
3	350	175	Neutral
4	525	350	175

C.3 Case 2: BPS consisting of two series connected switching units

Figure C.3 shows a case of an 800 kV HVDC transmission system that consists of 2 series connected converter units. The voltage per converter unit is 400 kV. Both BPSs consist of two series connected switching units on top of a post insulator. The BPS may be fitted with grading elements across the open BPS.



Key

BPS By-pass switch

BPD By-pass disconnector

Figure C.3 – HVDC system with 2 series connected converter units per pole

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The design of BPS_1 and BPS_2 is such that the arrangement of the terminals is symmetrical with respect to earth.

In normal operation BPS_1 and BPS_2 are in the open position. One terminal of BPS_1 is connected to the HVDC line (i.e. 800 kV) on the side and the other terminal to the midpoint voltage (400 kV). One terminal of BPS_2 is connected to the midpoint voltage and the other to the neutral bus.

With both BPSs in the open position, the voltage across the individual post insulators depends on the configuration of the BPS. For example, the voltage of the HVDC line is across one switching unit of BPS_1 and the post insulator (i.e. from terminal to earth). When voltage grading elements are used, the voltage across the post insulator of BPS_1 is 600 kV and the voltage across the post insulator of BPS_2 is 200 kV. Without voltage grading elements the voltage across the post insulators is undefined.

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Annex D
(normative)

Use of mechanical characteristics and related requirements

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

The mechanical characteristics shall be used to confirm that the different test objects used during the mechanical, making and commutation tests behave mechanically in a similar way. All test objects used for mechanical, making and commutation 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 (Figure D.1) shall be used for determining the limits of the allowable deviations over or under this reference curve. From this reference curve, two envelope curves shall be drawn from the instant of contact separation to the end of the contact travel for the opening operation and from the beginning of the contact travel to the instant of contact touch for the closing operation. The distance of the two envelopes from the original course shall be ±5 % of the total stroke as shown in Figure D.2. In case of switching devices 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 switching devices, these methods may be unsuitable, as for example for vacuum switching devices. In such cases the manufacturer shall define an appropriate method to verify the proper operation of the switching device.

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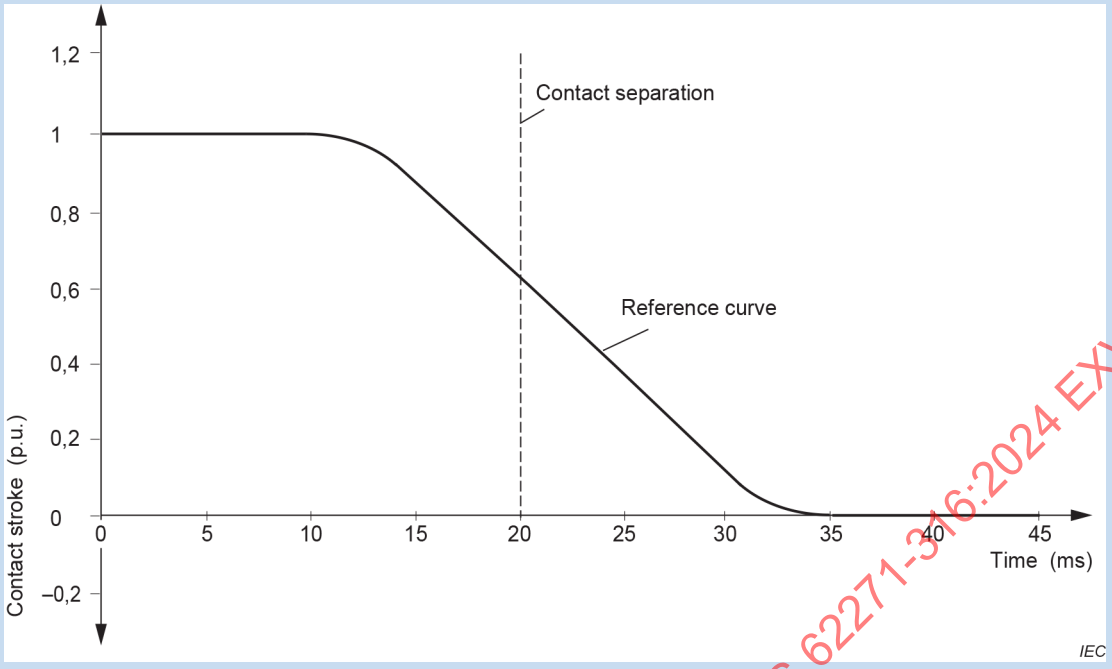

Figure D.1 – Example of reference mechanical characteristics (idealised curve)

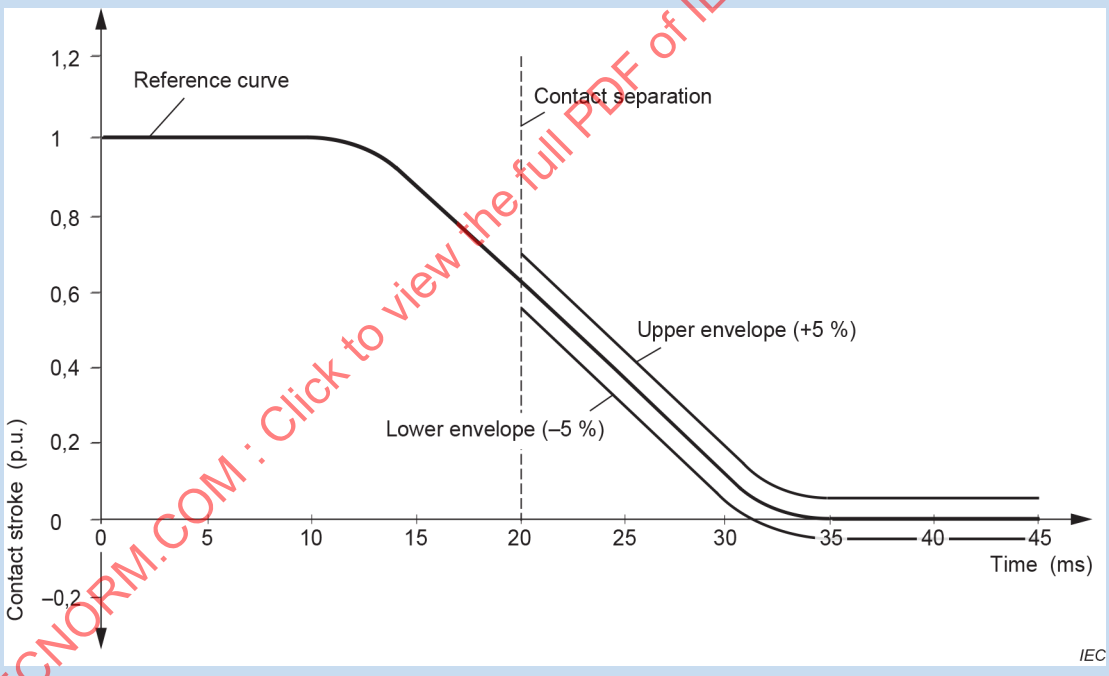

Figure D.2 – Reference mechanical characteristics of Figure D.1 with the envelopes centred over the reference curve (+5 %, –5 %)

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

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The series of Figure D.1, Figure D.2, Figure D.3 and Figure D.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.

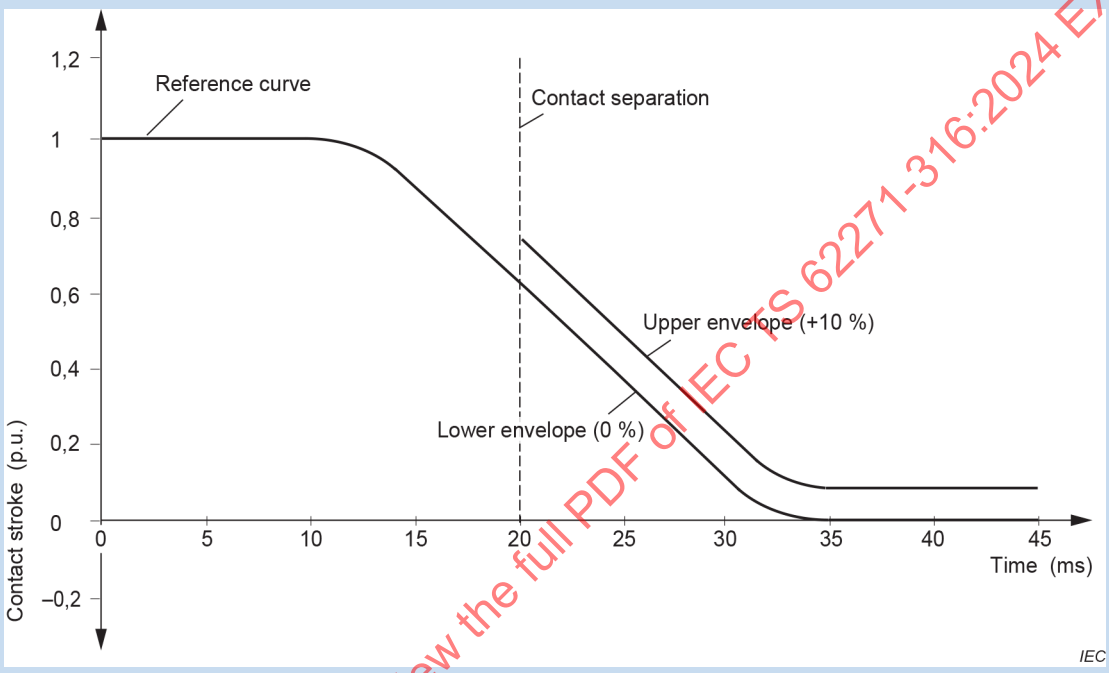

Figure D.3 – Reference mechanical characteristics of Figure D.1 with the envelope fully displaced upward from the reference curve (+10 %, –0 %)

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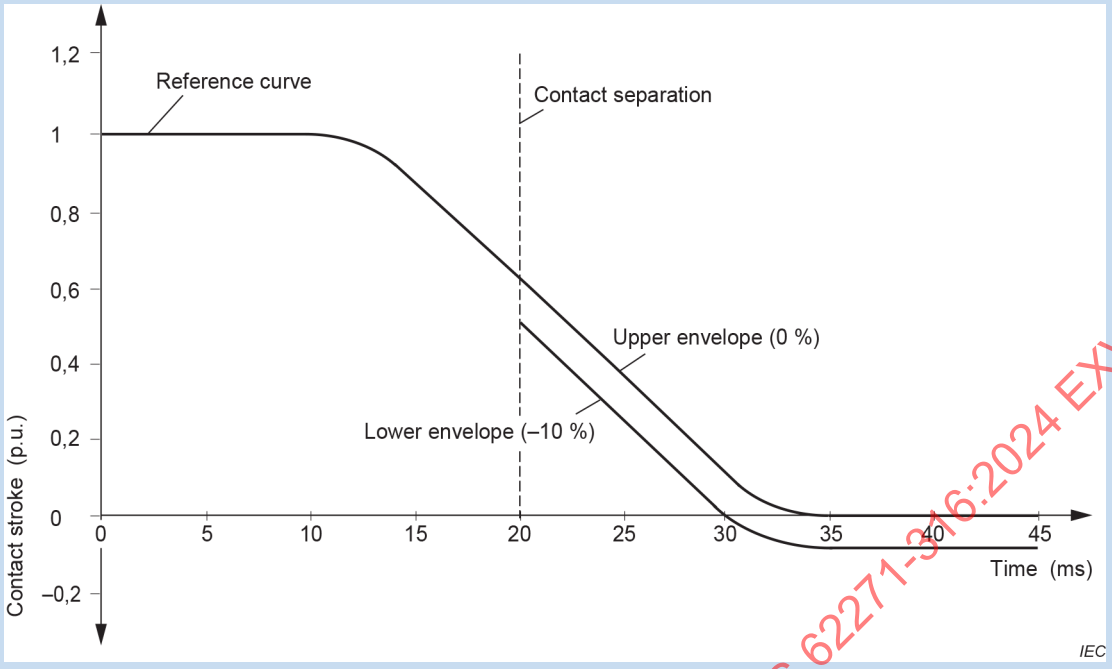

Figure D.4 – Reference mechanical characteristics of Figure D.1 with the envelope fully displaced downward from the reference curve (+0 %, –10 %)

The travel characteristics of all production units shall lie within the 10 % total allowable tolerance around the reference travel characteristic. The reference travel characteristic may lie at any point within the defined tolerance band but the parameters of the 10 % tolerance band, once defined, shall remain unchanged. Figure D.3 and Figure D.4 show the two extremes of the allowable cases which are –0 %, +10 % and –10 %, +0 % respectively.

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[29] IEC 60447, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

[30] IEC 60617, *Graphical symbols for diagrams* (available at *http://std.iec.ch/iec60617*)

[31] IEC 60664-1, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

[32] IEC 60669-1, *Switches for household and similar fixed-electrical installations – Part 1: General requirements*

[33] IEC 60695-1 (all parts), *Fire hazard testing – Part 1: Guidance for assessing the fire hazard of electrotechnical products*

[34] IEC 60695-7 (all parts), *Fire hazard testing – Part 7:Toxicity of fire effluent*

[35] IEC 60721-1, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*

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[37] IEC 60721-2-2, *Classification of environmental conditions – Part 2-2: Environmental conditions appearing in nature – Precipitation and wind*

[38] IEC 60721-2-4, *Classification of environmental conditions – Part 2-4: Environmental conditions appearing in nature – Solar radiation and temperature*

[39] IEC 60721-3 (all parts), *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities*

[40] IEC 60721-3-3, *Classification of environmental conditions – Part 3-3: Classification of groups of environmental parameters and their severities – Stationary use at weatherprotected locations*

[41] IEC 60721-3-4, *Classification of environmental conditions – Part 3-4: Classification of groups of environmental parameters and their severities – Stationary use at non-weatherprotected locations*

[42] IEC 60730-2-9, *Automatic electrical controls – Part 2-9: Particular requirements for temperature sensing control*

[43] IEC 60730-2-13, *Automatic electrical controls for household and similar use – Part 2-13: Particular requirements for humidity sensing controls*

[44] IEC TR 60816:1984, *Guide on methods of measurement of short duration transients on low-voltage power and signal lines*

[45] IEC TR 60943:1998, *Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*
IEC TR 60943:1998/AMD1:2008

[46] IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

[47] IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

[48] IEC 60947-4-1, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

[49] IEC 60947-4-2, *Low-voltage switchgear and controlgear – Part 4-2: Contactors and motor-starters – Semiconductor motor controllers, starters and soft-starters*

[50] IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

[51] IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

[52] IEC 60947-7-2, *Low-voltage switchgear and controlgear – Part 7-2: Ancillary equipment – Protective conductor terminal blocks for copper conductors*

[53] IEC 61020-1, *Electromechanical switches for use in electrical and electronic equipment – Part 1: Generic specification*

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[54] IEC 61810 (all parts), *Electromechanical elementary relays*

[55] IEC 61810-1, *Electromechanical elementary relays – Part 1: General and safety requirements*

[56] IEC 61810-2, *Electromechanical elementary relays – Part 2: Reliability*

[57] IEC 61850 (all parts), *Communication networks and systems for power utility automation*

[58] IEC 61936-1:2021, *Power installations exceeding 1 kV AC and 1,5 kV DC – Part 1: AC*

[59] IEC 61936-2:2015, *Power installations exceeding 1 kV a.c. and 1,5 kV DC – Part 2: DC*

[60] IEC TR 62063, *High-voltage switchgear and controlgear – The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear*

[61] IEC 62271-3:2015, *High-voltage switchgear and controlgear – Part 3: Digital interfaces based on IEC 61850*

[62] IEC TR 62271-306:2012, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

[63] IEC 62326-1, *Printed boards – Part 1: Generic specification*

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[66] IEC TS 63014-1:2018, *High voltage direct current (HVDC) power transmission – System requirements for DC-side equipment – Part 1: Using line-commutated converters*

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[69] IEEE C37.81, *IEEE Guide for seismic qualification of class 1E Metal-Enclosed Power Switchgear Assemblies*

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[71] CIGRE Technical Brochure 430, *SF_6 Tightness Guide*

[72] CIGRE Technical Brochure 683, *Technical requirements and specifications of state-of-the-art HVDC switching equipment*

[73] CIGRE Technical Brochure 684, *Recommended voltages for HVDC grids*

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[77] D Jovcic *"High Voltage Direct Current Transmission: Converters Systems and DC Grids", 2nd edition Wiley, 2019*

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IEC TR 62271-306:2012/AMD1:2019

[3] CIGRE Technical Brochure 163:2000, *Guide for SF_6 gas mixtures*

[4] CIGRE Technical Brochure 368:2009, *Operating environment of voltage grading capacitors applied to high voltage circuit-breakers*

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IEC TS 62271-316

Edition 1.0 2024-11

TECHNICAL SPECIFICATION

High-voltage switchgear and controlgear – Part 316: Direct current by-pass switches and paralleling switches

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 316: Direct current by-pass switches and paralleling switches

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IEC TS 62271-316 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
17A/1407/DTS	17A/1414/RVDTS

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

The language used for the development of this Technical Specification is English.

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This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document shall be read in conjunction with IEC TS 62271-5:2024, to which it refers, and which is applicable unless otherwise specified in this document. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC TS 62271-5. Modifications to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

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

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

- reconfirmed,
- withdrawn, or
- revised.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 316: Direct current by-pass switches and paralleling switches

1 Scope

This part of IEC 62271, which is a Technical Specification, is applicable to direct current (DC) by-pass switches (BPS) and paralleling switches (PS) designed for indoor or outdoor installation and for operation on HVDC transmission systems having direct voltages of 100 kV and above.

Switches other than mechanical switching devices used for the same applications specified here are not covered by this document.

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, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*, (available at www.electropedia.org)

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*, (available at www.electropedia.org)

IEC 60050-442, *International Electrotechnical Vocabulary (IEV) – Part 442: Electrical accessories*, (available at www.electropedia.org)

IEC 60050-461, *International Electrotechnical Vocabulary (IEV) – Part 461: Electric cables*, (available at www.electropedia.org)

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Part 601: Generation, transmission and distribution of electricity – General*, (available at www.electropedia.org)

IEC 60050-614, *International Electrotechnical Vocabulary – Part 614: Generation, transmission and distribution of electricity – Operation*, (available at www.electropedia.org)

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-11:2022, *Insulation coordination – Part 11: Definitions, principles and rules for HVDC system*

IEC 60071-12:2022, *Insulation coordination – Part 12: Application guidelines for LCC HVDC converter stations*

IEC 60296, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

IEC 60376, *Specification of technical grade sulphur hexafluoride (SF_6) and complementary gases to be used in its mixtures for use in electrical equipment*

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IEC 60480, *Specifications for the re-use of sulphur hexafluoride (SF_6) and its mixtures in electrical equipment*

IEC 60633:2019, *High-voltage direct current (HVDC) transmission – Vocabulary*

IEC TS 62271-5:2024, *High-voltage switchgear and controlgear – Part 5: Common specifications for direct current switchgear*

IEC 62271-102:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*
IEC 62271-102:2018/AMD1:2022

IEC TS 62271-315:2024, *High-voltage switchgear and controlgear – Part 315: Direct current (DC) transfer switches*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-151, IEC 60050-441, IEC 60050-442, IEC 60050-461, IEC 60050-601, IEC 60050-614, IEC TS 62271-5 and IEC 60633, some of which are recalled hereunder, and the following apply.

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

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

NOTE Terms and definitions are classified in accordance with IEC 60050-441. Reference from other parts than IEC 60050-441 are classified so as to be aligned with the classification used in IEC 60050-441.

3.1 General terms and definitions

3.1.101
switchgear and controlgear
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 60050-441:1984, 441-11-01]

3.1.102
indoor switchgear and controlgear
switchgear and controlgear designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost

[SOURCE: IEC 60050-441:1984, 441-11-04]

3.1.103
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 60050-441:1984, 441-11-05]

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3.1.104
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device

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

[SOURCE: IEC 60050-441:1984, 441-11-13, modified – "or fuses" removed in note 1 to entry]

3.1.105
temperature rise
difference between the temperature of the part under consideration and the ambient air temperature

3.1.106
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, etc.

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

3.1.107
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]

3.2 Assemblies of switchgear and controlgear

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, for example, air, SF_6, oil.

[SOURCE: IEC 60050-441:1984, 441-14-02]

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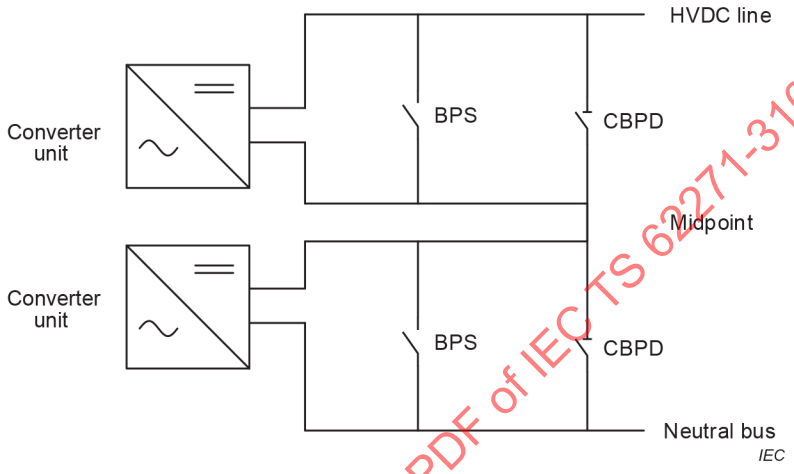
3.4.103
by-pass switch
BPS
high-speed DC switch connected across each converter unit in HVDC schemes using more than one independent converter unit per pole, designed to close rapidly to bypass a converter unit that is being taken out of service and commutate the current back into a converter unit that is being taken back in service

Note 1 to entry: A BPS may also be used for prolonged shunting of the converter unit(s).

Note 2 to entry: Figure 1 illustrates the position of the BPS.

Note 3 to entry: BPS are most commonly used in LCC HVDC schemes.



Key

BPS By-pass switch

BPD By-pass disconnector

NOTE Figure 1 shows an example of the location of the BPS for one polarity only.

Figure 1 – Example of the location of BPSs in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.30, modified – The wording "converter valve group" and "group" replaced with "converter unit" in the definition; Notes 1 and 2 to entry changed; Note 3 to entry and Figure 1 added.]

3.4.104
paralleling switch
PS
mechanical switching device intended for rapid configuration of a HVDC system

Note 1 to entry: A PS can either be a converter paralleling switch or a line paralleling switch.

3.4.105
converter paralleling switch
CPS
high-speed DC switch connected in series with each converter at the high-voltage DC terminal in HVDC schemes where two or more converters are connected in parallel onto a common pole conductor, designed to allow additional converter(s) to be connected in parallel or disconnected without affecting the load current in the other converter

Note 1 to entry: Figure 2 illustrates the position of the CPS.

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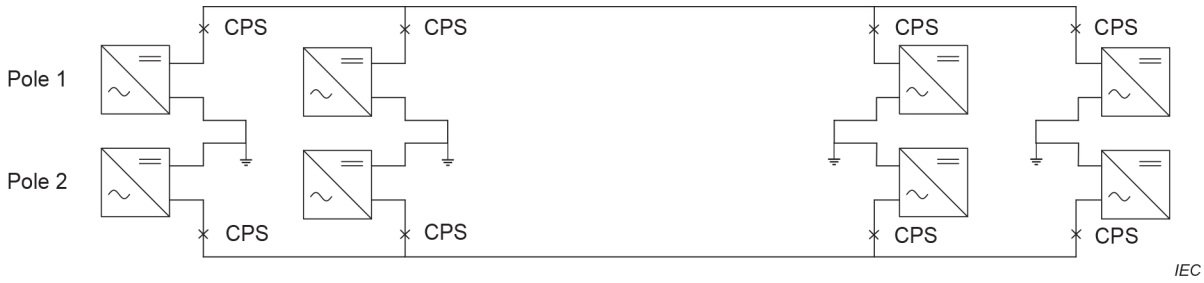


Key

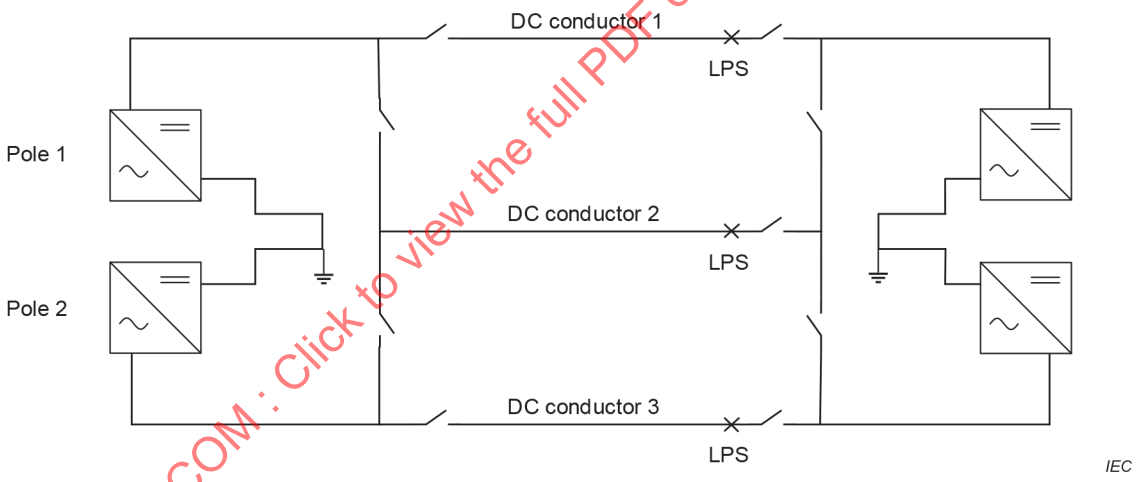
CPS Converter paralleling switch

Figure 2 – Example of the location of a CPS in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.28, modified – Note 1 to entry changed and Figure 2 added.]

3.4.106
line paralleling switch
LPS
DC commutation switch placed in series with one or more high-voltage pole conductors, allowing two or more lines to be connected in parallel or to revert to single-line operation while conducting load current

Note 1 to entry: Figure 3 illustrates the position of the LPS.



Key

LPS Line paralleling switch

Figure 3 – Example of the location of a LPS in an HVDC transmission system

[SOURCE: IEC 60633:2019, 9.29, modified – Note 1 to entry changed and Figure 3 added.]

3.5 Parts of switchgear and controlgear

3.5.101
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 60050-441:1984, 441-15-02]

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3.5.102
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 60050-441:1984, 441-15-07]

3.5.103
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 60050-441:1984, 441-15-08]

3.5.104
"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 60050-441:1984, 441-15-12]

3.5.105
"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 60050-441:1984, 441-15-13]

3.5.106
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 60050-441:1984, 441-15-17]

3.5.107
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 60050-441:1984, 441-15-18]

3.5.108
terminal
conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

Note 1 to entry: The term "terminal" is also used for a connection point in circuit theory.

[SOURCE: IEC 60050-151:2001, 151-12-12]

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3.5.109
enclosure
<of an assembly> part of an assembly providing a specified degree of protection 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

[SOURCE: IEC 60050-441:1984, 441-13-01]

3.5.110
operating mechanism
part of the BPS or PS that actuates the main contacts

3.6 Operational characteristics of switchgear and controlgear

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 BPS or PS, this may be a closing operation or an opening operation.

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

[SOURCE: IEC 60050-441:1984, 441-16-01, modified – "Circuit-breaker" in Note 1 to entry changed to "BPS or PS".]

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 60050-441:1984, 441-16-02]

3.6.103
operating sequence
<of a mechanical switching device> succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:1984, 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 60050-441:1984, 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 60050-441:1984, 441-16-09]

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3.6.106
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 60050-441:1984, 441-16-14]

3.6.107
stored energy operation
operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

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

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

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

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

[SOURCE: IEC 60050-441:1984, 441-16-15]

3.6.108
closed position
<of a mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-22]

3.6.109
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]

3.6.110
shunt release
release energised 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 60050-441:1984, 441-16-41]

3.6.111
anti-pumping device
device which

a) prevents reclosing after a close-open operation as long as the device initiating closing is maintained in the position for closing

b) prevents re-opening after an open-close operation as long as the device initiating opening is maintained in the position for opening

[SOURCE: IEC 60050-441:1984, 441-16-48, modified – item b) added.]

3.6.112
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 60050-441:1984, 441-16-49]

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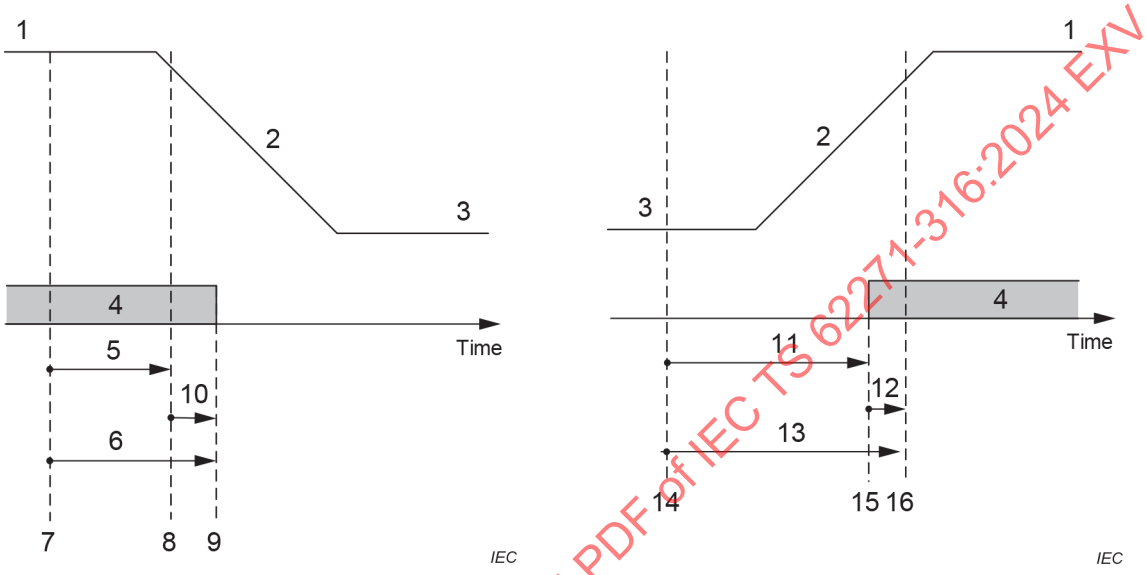
3.6.113
switching
making and/or breaking operation of a mechanical switching device

3.7 Characteristic quantities

Figure 4, Figure 5 and Figure 6 illustrate some definitions of this subclause.

Time quantities, see definitions 3.7.106 through 3.7.113, are expressed in milliseconds.



Opening operation **Closing operation**

Key

1	Closed position	9	Instant of arc extinction
2	Contact travel	10	Arcing time,
3	Open position	11	Make-time, 3.7.110
4	Current flow	12	Pre-arcing time, 3.7.111
5	Opening time, 3.7.106	13	Closing time, 3.7.109
6	Commutation time, 3.7.108	14	Initiation of closing operation
7	Initiation of opening operation	15	Instant of start of current flow
8	Instant of separation of arcing contacts	16	Instant of contact touch

Figure 4 – BPS and PS – Opening and closing operations

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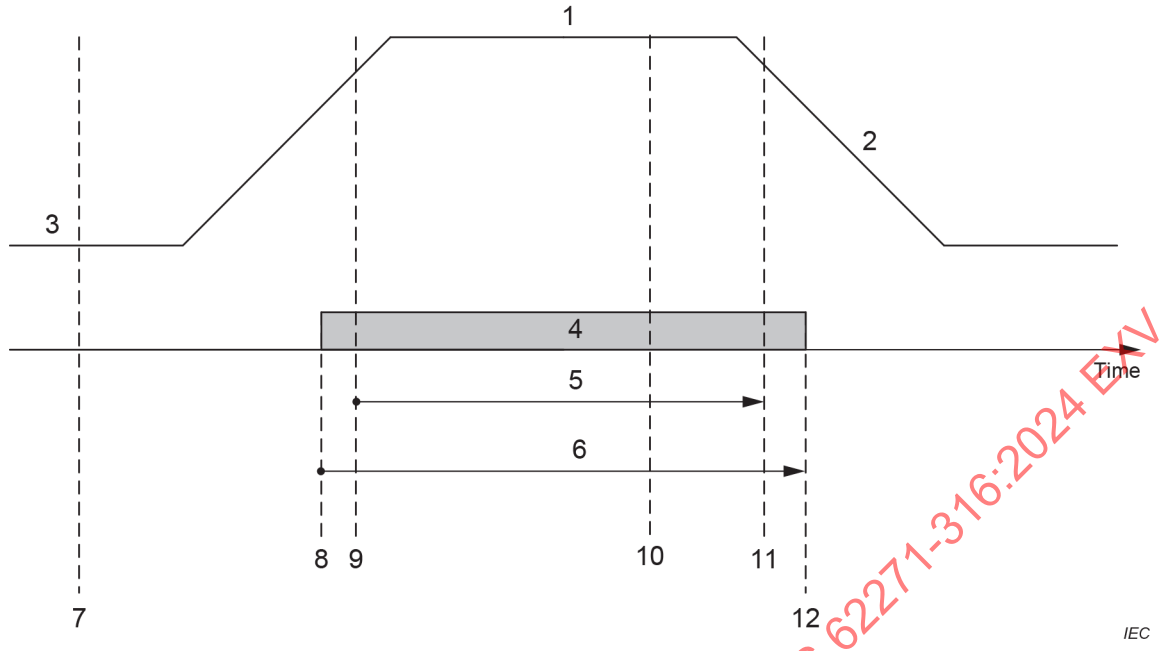

Key

1	Closed position	7	Initiation of closing operation
2	Contact travel	8	Instant of start of current flow
3	Open position	9	Instant of contact touch
4	Current flow	10	Initiation of opening operation
5	Close-open time, 3.7.112	11	Instant of separation of arcing contacts
6	Make-commutation time	12	Instant of arc extinction

Figure 5 – BPS and PS – Close-open cycle

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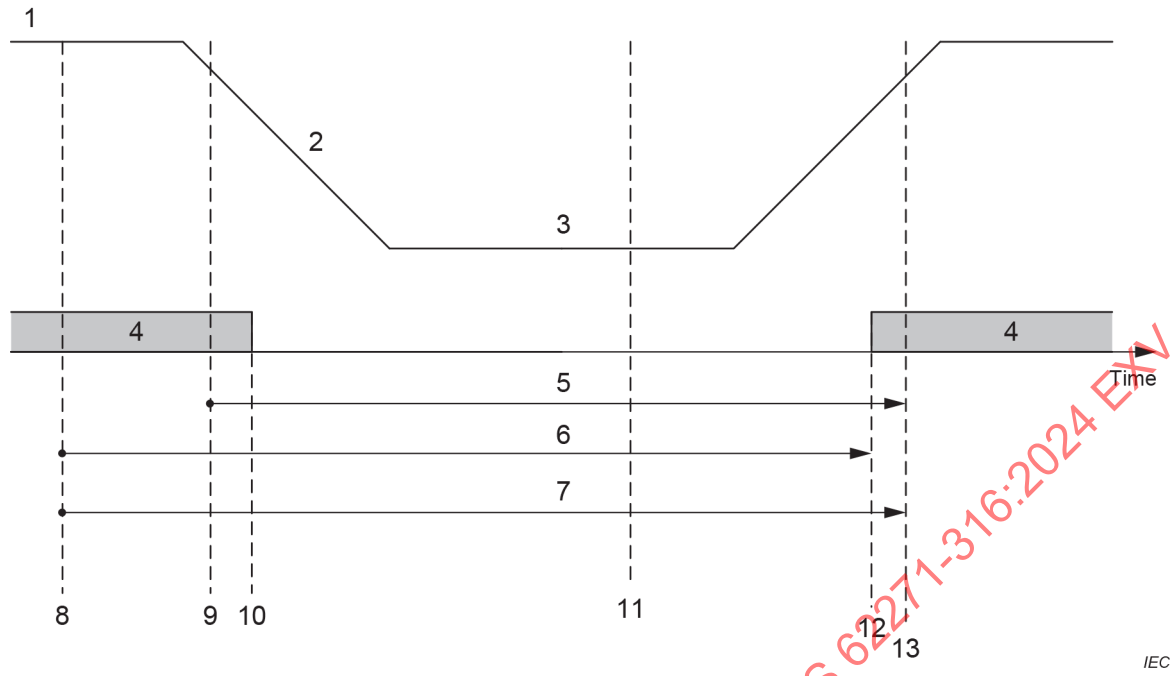

Key

1	Closed position	8	Initiation of opening release
2	Contact travel	9	Separation of arcing contacts
3	Open position	10	Arc extinction
4	Current flow	11	Initiation of closing circuit
5	Open-close time, 3.7.113	12	Instant of start of current flow
6	Re-make time	13	Contact touch
7	Reclosing time		

Figure 6 – BPS and PS – Open-close cycle

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

[SOURCE: IEC 60050-441:2000, 441-18-35, modified – Note 1 to entry deleted.]

3.7.102
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 60050-441:1984, 441-17-17]

3.7.103
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 60050-441:1984, 441-17-18]

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3.7.104
applied voltage
<for a switching device> voltage which exists across the terminals of a switching device just before the making of the current

[SOURCE: IEC 60050-441:1984, 441-17-24, modified – "of a pole" deleted from the definition.]

3.7.105
clearance
distance between two conductive parts along a string stretched the shortest way between these conductive parts

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.7.106
opening time
<of a mechanical switching device> interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated

Note 1 to entry: The instant of initiation of the opening operation, i.e. the application of the opening command (for example energising the release, etc.) is given in the relevant specifications.

[SOURCE: IEC 60050-441:1984, 441-17-36, modified – "in all poles" deleted from the definition.]

3.7.107
arcing time
interval of time between the instant of the initiation of the arc and the instant of final arc extinction

[SOURCE: IEC 60050-441:1984, 441-17-37, modified – The domain "of a pole or a fuse" deleted, and "in a pole or a fuse" and "in that pole or that fuse" deleted from the definition.]

3.7.108
commutation time
interval of time between the beginning of the opening time of a mechanical switching device and the end of the arcing time

3.7.109
closing time
interval of time between the initiation of the closing operation and the instant when the contacts touch

[SOURCE: IEC 60050-441:1984, 441-17-41, modified – "in all poles" deleted from the definition.]

3.7.110
make-time
interval of time between the initiation of the closing operation and the instant when the current begins to flow in the main circuit

[SOURCE: IEC 60050-441:1984, 441-17-40]

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3.7.111
pre-arcing time
interval of time between the initiation of current flow during a closing operation and the instant when the contacts touch

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

3.7.112
close-open time
interval of time between the instant when the contacts touch during a closing operation and the instant when the arcing contacts have separated during the subsequent opening operation

[SOURCE: IEC 60050-441:2000, 441-17-42, modified – "in the first pole" and "in all poles" deleted from the definition.]

3.7.113
open-close time
interval of time between the instant when the arcing contacts have separated and the instant when the contacts touch during a reclosing operation

Note 1 to entry: Unless otherwise stated, it is assumed that the closing release incorporated in the BPS or PS is energised at the instant when the contacts have separated during opening. This represents the minimum open-close time.

3.7.114
continuous current
current that the main circuit is capable of carrying continuously under specified conditions of use and behaviour

3.7.115
temporary current
current that the main circuit is capable of carrying temporarily under specified conditions of use and behaviour

3.7.116
insulation level
set of withstand voltages specified which characterise the dielectric strength of the insulation

[SOURCE: IEC 60050-614:2016:2016, 614-03-23]

3.7.117
direct withstand voltage
value of direct voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

3.7.118
impulse withstand voltage
highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18]

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3.7.119
commutation
transfer of current between any two paths with both paths carrying current simultaneously during this process

Note 1 to entry: Commutation may occur between any two converter arms, including the connected AC phases, between a converter arm and a by-pass arm, or between any two paths in the circuit.

[SOURCE: IEC 60633:2019, 5.6]

3.7.120
initiation of (opening or closing) operation
instant of receipt of command for operation at the control circuit

3.8 Index of definitions

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T

Temperature rise	3.1.105
Temporary current	3.7.115
Terminal	3.5.108

4 Normal and special service conditions

Clause 4 of IEC TS 62271-5:2024 is applicable.

5 Ratings

5.1 General

Subclause 5.1 of IEC TS 62271-5:2024 is replaced by the following.

Ratings define the common specifications of the switchgear and controlgear that are necessary for adequate selection and use in a particular network. Other important characteristics of the switchgear and controlgear are defined in Clause 9, some of which are included on the nameplate but are not ratings. Still other characteristics refer to installation, operation and maintenance; they are not considered as ratings since they are related to the technology used for switchgear and controlgear. Examples include normal filling level or filling / alarm pressure (density) of fluids and tightness for liquids, gas and vacuum systems.

5.1.101 By-pass switches (BPSs)

The characteristics used to determine rated values of a BPS and its operating mechanism and auxiliary equipment are the following:

a) direct voltage across the open BPS (BPS open). This voltage depends on the number of converter units in series;

   direct voltage from terminal to earth (BPS open). This voltage depends on the configuration of the BPS and its connection to the HVDC system. Examples of possible configurations are given in Annex C;

b) insulation level (U_{dd}, U_s, U_p). The considerations provided under a) also apply to the insulation level;

c) continuous current (I_{rd}) or its temporary current (I_t);

d) short-time withstand direct current (I_{kd});

e) peak withstand current (I_{pd});

f) duration of short-circuit (t_{kd});

g) supply voltage of auxiliary and control circuits (U_a);

h) supply frequency of auxiliary and control circuits.

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5.1.102 Parallelling switches (PSs)

The characteristics used to determine rated values of a PS and its operating mechanism and auxiliary equipment are the following:

a) direct voltage (U_{rd});

b) insulation level (U_{dd}, U_s, U_p);

c) continuous current (I_{rd});

d) short-time withstand direct current (I_{kd});

e) peak withstand current (I_{pd});

f) duration of short-circuit (t_{kd});

g) supply voltage of auxiliary and control circuits (U_a);

h) supply frequency of auxiliary and control circuits;

i) commutation current (for LPS only, see 3.4.106).

5.2 Rated direct voltage (U_{rd})

Subclause 5.2 of IEC TS 62271-5:2024 is applicable with the following addition.

5.2.1 General

Subclause 5.2.1 of IEC TS 62271-5:2024 is applicable with the following addition.

As BPSs are installed in parallel with a converter unit, the rated voltage of a BPS is different across open switch and to earth. Therefore, different rated voltages are defined for BPSs to earth in open position and across the open BPS.

PSs usually have same rated voltages across open switching device and to earth in both (open and closed) positions.

In some applications PSs not intended for rapid configuration of the HVDC system are connected in series with a disconnector that always operates and with a short time delay after the PS, to reduce the duration of voltage stress across the open PS. For such applications, a lower value of the rated direct voltage across the open PS can be chosen, whereby dielectric capabilities and creepage distance across open switching device are reduced.

Such applications are subject to agreement between user and manufacturer (see also Clause 9).

5.2.101 Rated direct voltage to earth (U_{rde})

Subclause 5.2.2 of IEC TS 62271-5:2024 is applicable with the following addition.

For PS this rating is applicable for both open and closed position.

For BPSs this rating is applicable for the open position only and may be specified for one or both terminals. If the arrangement of the terminals is not symmetrical with respect to the frame, the rating is applicable for the terminal which is designed for the highest direct voltage to earth. The manufacturer must in this case specify which terminal the rating is assigned to.

5.2.102 Rated direct voltage across open switching device (U_{rdo})

Subclause 5.2.2 of IEC TS 62271-5:2024 is applicable.

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