IEC TS 62271-315

Edition 1.0 2025-03
EXTENDED VERSION

TECHNICAL SPECIFICATION

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This full version of IEC TS 62271-315:2025 includes the content of the references made to IEC TS 62271-5:2024

High-voltage switchgear and controlgear –
Part 315: Direct current (DC) transfer switches

IEC TS 62271-315:2025-03 EXV(en)

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 315: Direct current (DC) transfer switches

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IEC TS 62271-315 EXV includes the content of IEC TS 62271-315:2025, and the references made to IEC TS 62271-5:2024.

The specific content of IEC TS 62271-315:2025 is displayed on a blue background.

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IEC TS 62271-315 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/1412/DTS	17A/1417/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 is to be read in conjunction with IEC TS 62271-5:2024, to which it refers and which is applicable unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC TS 62271-5. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

A list of all parts of IEC 62271 series, 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- withdrawn, or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 315: Direct current (DC) transfer switches

1 Scope

This part of IEC 62271 is applicable to direct current (DC) transfer switches designed for indoor or outdoor installation and for operation on HVDC transmission systems having direct voltages of 100 kV and above.

DC transfer switches normally include metallic return transfer switches (MRTS), earth return transfer switches (ERTS), neutral bus switches (NBS) and neutral bus earthing switches (NBES).

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

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

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

IEC 60060-1:2010, *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*

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 co-ordination – Part 11: Definitions, principles and rules for HVDC system*

IEC 60076-6, *Power transformers– Part 6: Reactors*

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

IEC 60099-9, *Surge arresters – Part 9: Metal-oxide surge arresters without gaps for HVDC converter stations*

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 60270:2000, *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, *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 60871-1, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General*

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

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 61000-4-18:2019, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

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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 and controlgear*

IEC 62271-100:2021, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

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

IEC 62271-207, *High-voltage switchgear and controlgear – Part 207: Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV*

IEC TS 63014-1, *High-voltage direct current (HVDC) power transmission – System requirements for DC-side equipment Part 1: Using line-commutated converters*

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*

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*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in in IEC 60633, IEC TS 63014-1 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. References 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]

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]

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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".]

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]

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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.

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

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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.

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

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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.

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

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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.

3.2 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

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.

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[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
active DC transfer switch
DC transfer switch with charging device in oscillating branch, installed in parallel to the commutation switch

3.4.102
blank DC transfer switch
DC transfer switch with a sole commutation switch only, without any additional external branches or components

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Note 1 to entry: Some commutation switches use internal components to increase voltage drop across the switching units during transfer operation.

3.4.103
passive DC transfer switch
DC transfer switch without charging device in oscillating branch, installed in parallel to the commutation switch

3.4.104
earth return transfer switch
ERTS
DC transfer switch used to transfer direct current from a metallic return path to an earth return path

Note 1 to entry: "DC transfer switch" is used instead of "DC commutation switch" to refer to whole switch, including oscillating branch and energy dissipation branch.

Note 2 to entry: Although the term "earth return transfer breaker" (ERTB) has been widely used in the industry for many years, it is misleading since such switches have no ability to interrupt fault current.

[SOURCE: IEC 60633:2019, 9.23, modified – The terms "earth return transfer breaker" and "ERTB" have been removed, "DC commutation switch" has been replaced by "DC transfer switch", DC current is replaced by direct current, Note 1 to entry and reference to Figure 7 have been deleted.]

3.4.105
metallic return transfer switch
MRTS
DC transfer switch used to transfer direct current from an earth return path to a metallic return path

Note 1 to entry: "DC transfer switch" is used instead of "DC commutation switch" to refer to whole switch, including oscillating branch and energy dissipation branch.

Note 2 to entry: Although the term "metal return transfer breaker" (MRTB) has been widely used in the industry for many years, it is misleading since such switches have no ability to interrupt fault current.

[SOURCE: IEC 60633:2019, 9.22, modified – The terms "metallic return transfer breaker" and "MRTB" have been removed, "DC commutation switch" has been replaced by "DC transfer switch", DC current is replaced by direct current, Note 1 to entry is moved to Note 2, and reference to Figure 7 has been deleted.]

3.4.106
neutral bus switch
NBS
DC transfer switch connected in series with the neutral bus on a bipolar HVDC scheme, designed to commutate current out of the pole conductor or neutral bus and into the electrode line or dedicated metallic return conductor or earth e.g. in response to a fault in a converter or neutral bus

Note 1 to entry: "DC transfer switch" is used instead of "DC commutation switch" to refer to whole switch, including oscillating branch and energy dissipation branch.

[SOURCE: IEC 60633:2019, 9.26, modified, "DC commutation switch" has been replaced by "DC transfer switch" and Note 1 has been replaced by a new Note 1.]

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3.4.107
neutral bus earthing switch
NBES
DC transfer switch connected from the neutral bus to the station earth mat on a bipolar HVDC scheme, designed to provide a temporary earth connection, e.g. in the event of an open circuit fault on the electrode line until the imbalance of current between the two poles can be reduced to a safe minimum level or the electrode line connection can be restored

Note 1 to entry: Although the term "Neutral Bus Grounding Switch" (NBGS) has been widely used in the industry for many years.

Note 2 to entry: In some applications, NBES and high-speed earthing switch (HSES) are used in series.

[SOURCE: IEC 60633:2019, 9.27, modified – The terms "neutral bus grounding switch" and "NBGS" have been removed, "DC commutation switch" has been replaced by "DC transfer switch", Note 1 and Note 2 have been replaced by new notes.]

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]

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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”.]

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]

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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]

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.]

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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]

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.

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[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]

3.5.101
commutation switch
mechanical switching device used in the main current path of DC transfer switches

Note 1 to entry: A single pole of an AC circuit-breaker or its modification was often used as commutation switch in DC transfer switch.

Note 2 to entry: Some commutation switches use internal components to increase voltage drop across the switching units during transfer operation.

3.5.102
oscillating branch
circuit in parallel with the commutation switch in DC transfer switches, consisting of

– capacitors and reactors, in case of passive DC transfer switches;
– capacitors including a charging device and a making switch, in case of active DC transfer switches.

Note 1 to entry: The oscillating branch forces a current oscillation between itself and the commutation switch branch in order to produce current zeros in the last one.

Note 2 to entry: Depending on the stray inductance of the arrangement reactors are not necessarily needed to be installed.

Note 3 to entry: Passive DC transfer switches having a making device in series with the oscillating branch are also known.

3.5.103
current zero device
oscillating circuit in case of passive DC transfer switch or current impulse generator in case of active DC transfer switch

3.5.104
energy dissipation branch
impedance circuit in parallel with the commutation switch of DC transfer switches which dissipates the energy stored in the energy storage components (e.g. reactors, stray inductance, stray capacitance, etc.) in DC system after successful commutation of current from commutation switch branch to oscillating branch

Note 1 to entry: In real transfer switch, metal oxide surge arrester commonly is used as energy dissipation device.

3.5.105
charging device
device used in active DC transfer switches to charge capacitors in current zero device

3.5.106
making switch
mechanical switch in series with oscillating branch or current injection branch, designed for fast closing

Note 1 to entry: A making switch is used to close the oscillation branch to excite oscillation during current transfer operation.

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3.5.107
platform
support for the oscillating branch and the energy dissipation branch

Note 1 to entry: Two versions are known:

– insulated platform with certain insulation level to earth;
– earthed platform.

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.

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

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

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[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 $\mathrm{Pa} \times \mathrm{m}^3 \times \mathrm{s}^{-1}$.

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

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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

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

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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]

3.7 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

3.7.101
initiation of (opening or closing) operation
instant of receipt of command for operation at the control circuit

[SOURCE: IEC 62271-100:2021, 3.7.153]

3.7.102
opening time
<of 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

[SOURCE: IEC 60050-441:1984, 441-17-36, modified – “in all poles” and the Note to entry have been deleted.]

3.7.103
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 words* “(of a pole or a fuse)” has been removed from the term and from the definition itself.]

3.7.104
commutation time
interval of time between the beginning of the opening time of the commutation switch and the end of the arcing time

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3.7.105
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 – The words “in all poles” have been removed at the end of the definition.]

3.7.106
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 cycle

3.7.107
arcing withstand capability
maximum duration of commutation switches capable of withstanding an arc with specified current in case of an unsuccessful commutation

Note 1 to entry: This time shall include the open-close time of commutation switch and the time delay of control and protection system.

3.7.108
continuous current
direct current flowing through DC transfer switches with the DC transmission system operating

3.7.109
transfer current
direct current which the DC transfer switch is able to transfer in an adjacent return path

3.7.110
commutation voltage
transient voltage across the terminals of a DC transfer switch during the current commutation process, describing the time development of the voltage

Note 1 to entry: The commutation voltage depends mainly on the characteristics of the DC transfer switch and is characterised by two effects. Until arc extinguishing in the commutation switch the commutation voltage is equal to its arcing voltage, after arc extinguishing the commutation voltage is equal to the charging voltage of current zero device and will be limited in peak by the energy dissipation device.

Note 2 to entry: The value of commutation voltage at the end of commutation process depends on the HVDC transmission system and is equal to the voltage drop across the current path to which the current was transferred.

3.8 Index of definitions

A

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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;

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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.

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. $k_{\mathrm{alt}} = e^{m(H-1000/8150)}$, 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.

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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.

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].

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5 Ratings

5.1 General

The common ratings of switchgear and controlgear assigned by the manufacturer, including their operating devices and auxiliary equipment, shall be selected from the following (as applicable):

a) rated direct voltage (U_{rd});

b) rated insulation level (U_{dd}, U_s and U_p where applicable);

c) rated continuous current (I_{rd});

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

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

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

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

h) rated supply frequency of auxiliary and control circuits;

i) rated pressure of compressed gas supply for controlled pressure systems.

j) rated direct voltage of transfer switch (U_{rts});

k) rated transfer current (I_t);

l) rated commutation voltage (U_c);

m) rated dissipated energy during transfer operation (E_{rd});

n) rated operating sequence;

o) rated open-close time.

NOTE Other ratings can be necessary and will be specified in the relevant IEC product standards.

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 3, e.g., minimum functional pressure for insulation, 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.

5.2 Rated direct voltage (U_{rd})

Subclause 5.2 of IEC TS 62271-5:2024 is not applicable and is replaced by 5.101: Rated direct voltage of transfer switch (U_{rts}).

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

Subclause 5.3 of IEC TS 62271-5:2024 is not applicable.

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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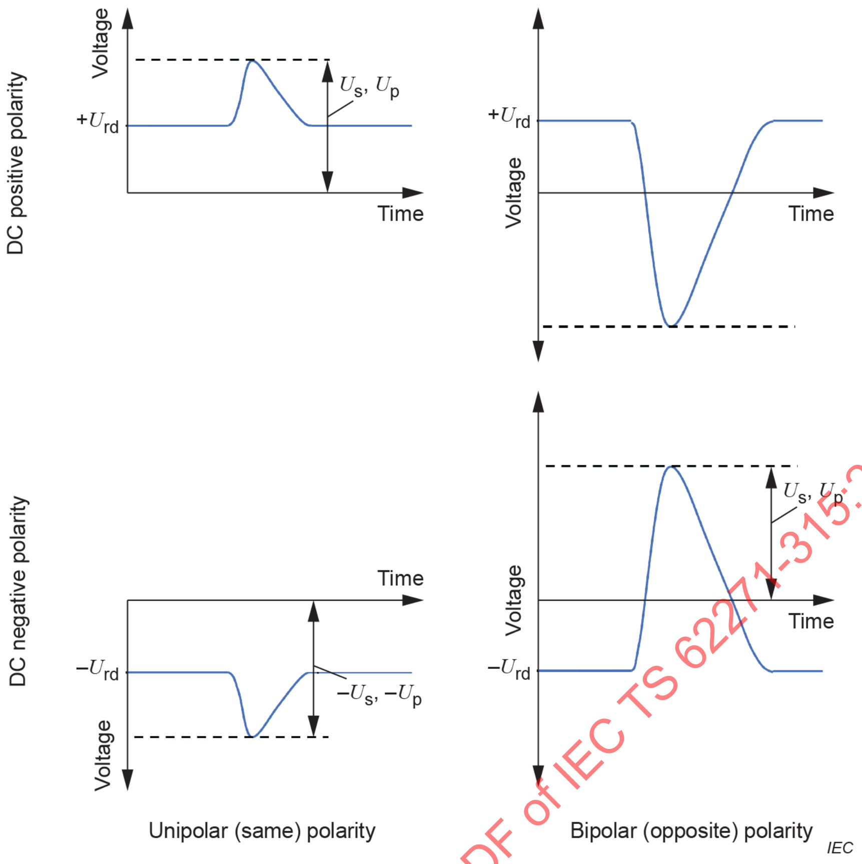

Figure 1 – Schematic representation of superimposed impulse voltage tests

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The insulation levels for transfer switches shall be selected from the values given in Table 1.

Withstand values given in Table 1 cover the application of transfer switches under normal service conditions defined in 4.1 of IEC TS 62271-5:2024 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 60071-11:2022. For special service conditions, refer to IEC TR 62271-306 [1][2].

NOTE According to IEC 60071-11:2022 the insulation levels in Table 1 cover the temperature range of −40 °C up to 40 °C.

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

2 Numbers in square brackets refer to the Bibliography.

Table 1 – Rated insulation levels for transfer switches

Rated direct voltage of transfer switch U_{rts} kV	Rated direct withstand voltage U_{dd} kV	Rated lightning impulse withstand voltage U_p kV
	Terminal-to-earth and across open transfer switch	Terminal-to-earth and across open transfer switch
(1)	(2)	(3)
5	7,5	60
10	15	95
25	37,5	200
50	75	325
75	112,5	450
100	150	550
150	225	650
200	300	750

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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.

5.5 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;

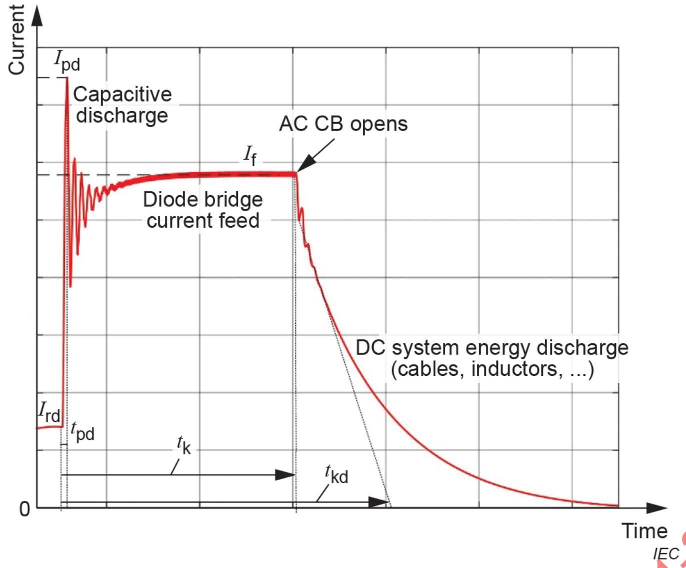
– The current waveform in Figure 2b) corresponds to a typical LCC (Line Commutated Converter), in a 2-terminal LCC HVDC; A special case of LCC under DC fault, that generally gives higher current stress, is discussed in Annex D (informative); This waveform also applies to 2-terminal, full-bridge MMC HVDC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

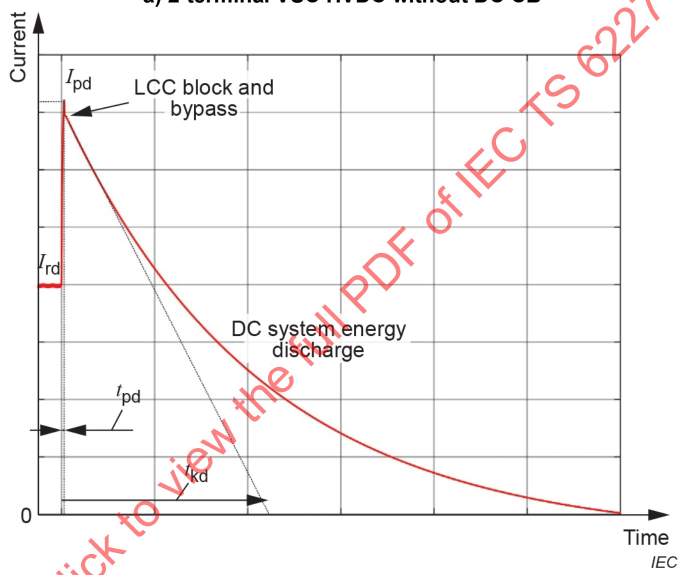
Annex D (informative) gives further information on the circuit topologies, assumptions, and calculations.

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.

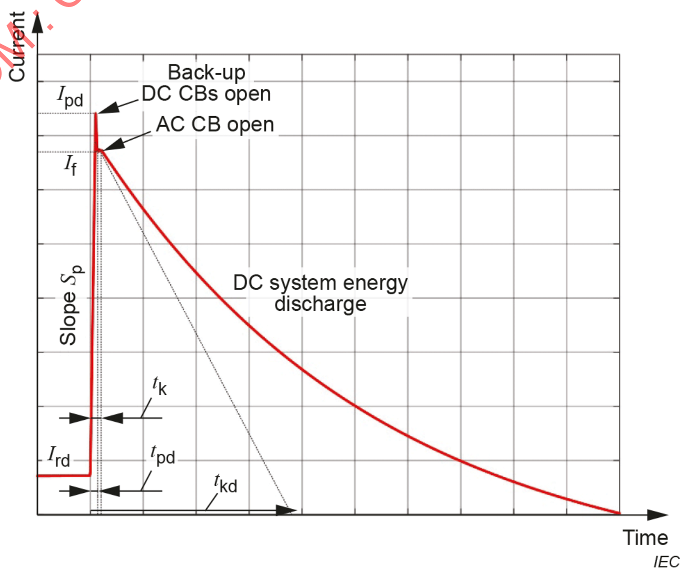
NOTE The definition of typical waveform for DC short-circuit currents is in the scope of IEC TC 73 (Short-circuit currents) activities. The definitions in 5.5 are provisionally provided by IEC TC 17 (High-voltage switchgear and controlgear) for the purpose of this document, and will be updated when definitions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



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

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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.

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 direct voltage of transfer switch (U_{rts})

The rated direct voltage of transfer switch (U_{rts}) is the highest direct voltage terminal-to-earth that includes harmonics for which the transfer switch is designed in respect of its insulation as well as other characteristics, to operate as specified for indefinite period of time (lifetime).

NOTE 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.

The rated direct voltages of transfer switch are 5 kV – 10 kV – 25 kV – 50 kV – 75 kV – 100 kV – 150 kV – 200 kV.

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5.102 Rated transfer current (I_t)

The values of rated transfer current should be selected from the R10 series, specified in IEC 60059 [2].

NOTE 1 The R10 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 For certain projects or special applications other values than from R10 series could be chosen by agreement between manufacturer and user.

5.103 Rated commutation voltage (U_c)

The rated commutation voltage is the highest voltage which the transfer switch shall be capable of withstanding after commutating the current into the oscillating branch or after extinguishing the arc inside of the commutation switch.

NOTE 1 The rated commutation voltage of a transfer switch will be defined by its energy dissipation branch.

NOTE 2 Specific ratings can generally not be assigned because they are specific parameters to each project. The commutation voltage for each transfer switch in a specific project will be defined by system studies.

As an estimation the rated commutation voltage could be calculated from the rated voltage of transfer switch (U_{rts}) multiplied with a factor of 1,2.

NOTE 3 The rated commutation voltage is the determining factor for successful current commutation. Lower or higher factors than 1,2 between U_c and the U_{rts} at location of installation could arise for specific applications. In existing projects, this factor is mostly between 0,6 and 2,5. Further information can be found in Clause 9.

5.104 Rated dissipated energy during transfer operation (E_{rd})

The rated dissipated energy during transfer operation is the highest amount of energy which the energy dissipation device inside the DC transfer switch can manage in a single operating sequence without sustained deterioration. The value will be stated by the manufacturer of DC transfer switch according to the requirements at location of installation, usually based on system studies.

NOTE 1 The rated dissipated energy during transfer operation of a DC transfer switch normally regards to the energy dissipation device or the current limitation branch.

NOTE 2 The rated dissipated energy during transfer operation should be higher than the maximum energy which the transmission system could supply during current transfer operation at location of installation of DC transfer switch.

NOTE 3 Depending on the margin between the rated dissipated energy during transfer operation and the maximum energy which the transmission system could supply during current transfer operation at location of installation of DC transfer switch, specific cooling time between two transfer operations has to be considered. Further information should be supplied by the manufacturer.

5.105 Rated operating sequence

The rated operating sequence of direct current transfer switches are as follows:

a) O – t – C: for ERTS, MRTS and NBES

b) C – 0,1 s – O – t – C: for NBS

NOTE 1 sequence b) gives a typical operating sequence when NBS is used to connect converter neutral to an already energized current return path in a bipolar or DC grid system.

NOTE 2 The final closing operation in each operation sequence is to protect the commutation switch itself in case of unsuccessful transfer operation.

with:

t is more than the rated open-close time and less than T_{aw} (see 6.102.7).

where

– O represents an opening operation;

– C represents a closing operation.

5.106 Rated open-close time

This value shall be provided by manufacturer.

NOTE All ratings except subclause 5.104 are applicable for commutation switches also.

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

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with the "protective earth" symbol, as indicated by symbol IEC 60417-5019:2006-08. 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.

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6.4 Auxiliary and control equipment and circuits

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;
- 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.

- 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 can be the use of series control contacts arranged so that when the transfer switch is closed, the close release control contact ("b" contact or break contact) is open and the open release control contact ("a" contact or make contact) is closed, and when the transfer switch 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 transfer switch at rest, open or closed. The signal shall be sustained;
- connections shall withstand the stresses imposed by the transfer switch, 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, making and commutating and/or insulating and operating media, and be able to switch the loads which are stated by the transfer switch manufacturer;
- special items of auxiliary equipment such as liquid indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of making and commutating and/or insulating and operating media;
- where anti-pumping devices are part of the transfer switch control scheme, they shall act on each control circuit, if more than one is installed.

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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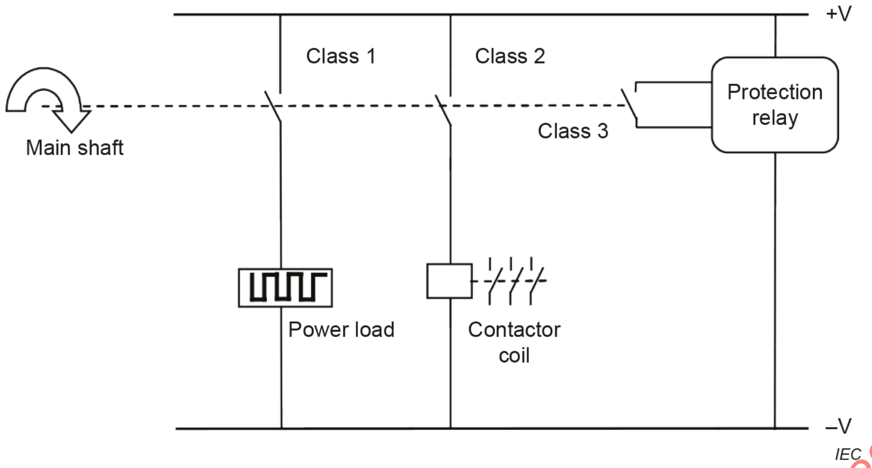

Figure 3 – Examples of classes of contacts

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 transfer switch arranged for dependent power operating with external energy supply shall also be capable of closing immediately following the opening according to its rated operating sequence.

6.6 Stored energy operation

A transfer switch arranged for stored energy operating shall also be capable of closing immediately following the opening according to its rated operating sequence.

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 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).

d) 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.

e) 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)

The mechanism shall not reach the energy release point of a close operation if the switching device is in the closed state or of an open operation if it is open.

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NOTE 1 This requirement is to prevent the inadvertent, and potentially damaging, discharge of stored energy against an already closed or already open switching device.

It shall not be possible to progressively store energy by incomplete operations against an interlock, if supplied. During the operation, any movement of the contacts prior to release of the energy shall not reduce any electrically stressed gap to below that which will withstand rated insulation levels.

For a switching device with short-circuit making capacity but no short-circuit current breaking capacity, a time delay shall be introduced between the closing and opening operation. This time delay shall be not less than the rated duration of the short-circuit (refer to 5.5.4).

NOTE 2 The intention of the provision is to let the switching device "ride out" the short-circuit in the closed position until a back-up device safely clears the fault.

6.8 Manually operated actuators

Subclause 6.8 of IEC TS 62271-5:2024 is not applicable.

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.

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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).

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.

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 for all assemblies of the DC transfer switch should be in accordance with their relevant standards. The nameplate of the DC transfer switch, commutation switch and making switch shall be provided at least as the following (see Table 2):

Table 2 – Nameplate information

Item		Symbol	Unit	(**)			Condition: Marking only required if
				Transfer switch	Commutation switch	Making switch	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Name of manufacturer			X	X	X	
2	Type designation and serial number			X	X	X	
3	Rated direct voltage of transfer switch	U_{rts}	kV	X	X	X	
4	Rated direct withstand voltage	U_{dd}	kV	X	X	X	
5	Rated lightning impulse withstand voltage	U_{p}	kV	X	X	X	
6	Rated continuous current	I_{rd}	A	X	X		
7	Rated short-time withstand direct current	I_{kd}	kA	X	X		
8	Rated peak withstand current	I_{pd}	kA	X	X		
9	Rated duration of short-circuit	t_{kd}	s	X	X		
10	Rated transfer current	I_{t}	A	X			
11	Rated commutation voltage	U_{c}	kV	X	X		
12	Rated dissipated energy during transfer operation	E_{rd}	MJ	X			

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13	Filling pressure for insulation(*)	p_e	MPa	X	X	X	
14	Filling pressure for operation(*)	p_m	MPa	X	X	X	
15	Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_a	V	X	X	X	
16	Rated operating sequence			X	X	X	
17	Rated open-close time		ms	X	X		
18	Closing time		ms	X	X	X	
19	Type and mass of fluid (liquid or gas) for insulation	M_f	kg	X	X	X	
20	Mass of switchgear and controlgear (including any fluid)	M	kg	Y	Y	Y	more than 300 kg
21	Year of manufacture			X	X	X	
22	Minimum and maximum ambient air temperature		°C	Y	Y	Y	If 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 (8).

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 appear.

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.

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”.

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

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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.

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.

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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 Seismic requirement for operation

DC transfer switch shall be able to withstand the specified seismic stress and meet the requirements in IEC 62271-207.

6.102 Commutation switch

Subclauses 6.1 to 6.101 of this specification are applicable with the following additions:

6.102.1 General requirement for operation

A commutation switch, including its operating devices, shall be capable of completing its rated operating sequence 5.105 in accordance with the relevant provisions of 6.5 to 6.10 and 6.102.2 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.

Commutation switches provided with heaters shall be designed to permit an opening operation at the minimum ambient air temperature when the heaters are not operational for a minimum time of 2 h.

6.102.2 Pressure limits of fluids for operation.

The manufacturer shall state the maximum and minimum pressures of the fluid for operation at which the commutation switch is capable of performing according to its ratings and at which the appropriate low- and high-pressure interlocking devices shall be set (see 6.10).

The manufacturer can specify pressure limits at which the commutation switch is capable of each of the following performances:

– a “C” operation;

– an “OC” operating cycle;

The commutation switch shall be provided with energy storage of sufficient capacity for satisfactory performance of the appropriate operations at the corresponding minimum pressures stated.

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6.102.3 Vent outlets

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

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

6.102.4 Time quantities

Subclause 6.105 of IEC 62271-100:2021 is applicable with the following modifications:

Values may be assigned to the following time quantities:

– opening time;
– closing time;
– open-close time.

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 pressure for controlled pressure systems (see 5.8);
– filling levels for insulation and/or operation (see 6.22);
– an ambient air temperature of 20°C±5°C.

6.102.5 Static mechanical loads

6.102.5.1 General

Commutation switches shall be designed to withstand static forces such as those from connected conductors, wind, etc. and dynamic forces (for example caused by short-current and operation of the commutation switch).

These forces can occur simultaneously.

6.102.5.2 Static mechanical loads

This capability is demonstrated by calculation.

When calculating the stresses resulting from ice and wind, the ice coating and wind pressure shall be in accordance with 4.1.3 of IEC TS 62271-5:2024.

Commutation switches may be equipped with suitable terminal. The capability of its mechanical load should be not less than:

– horizontal longitudinal: 2 000 N;
– horizontal transversal: 1 500 N;
– vertical: 1 500 N.

6.102.5.3 Dynamic loads

This capability is demonstrated by calculation.

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NOTE A calculation method of the effects of short-circuit current on rigid and flexible conductors is given in IEC 60865-1:2011

6.102.6 Classification

The classification of DC transfer switch normally regards to the commutation switch.

The commutation switch (and the making switch, if applicable) can be classified according to the performance of mechanical endurance as Table 3.

Table 3 – Classification of commutation switches and making switches

Class	Number of operating cycles	Mechanical endurance
M0	1 000	Normal
M1	2 000	Extended

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6.102.7 Arcing withstand capability

In the case of DC transfer switches with oscillation branches, the commutation switch shall withstand arc of transfer current for time (T_{aw}) without causing obvious damage (for example, explosion of porcelain insulator).

Here:

$$T_{aw} \geq T_b + T_2 + T_c$$

T_b is contact separating time, which is the time interval from the instant that arc contact separates to the instant that moving contact reaches its final open position;

T_2 is the time delay of control and protection system during which it determines commutation succeed or not, if not, send a signal to commutation switch to close. It depends on the judgment strategy. In the case of a CT is installed inside of the DC transfer switch, direct in series with the commutation switch, 20 ms is preferred. In the case of the commutation switch branch without a CT, T_2 can be up to 40 ms and shall be discussed between manufacture and user;

T_c is closing time.

NOTE After a reclosing operation with arcing (in case of failed commutation operation), the current commutation capability can be impaired due to the internal pollution. In such cases, early maintenance becomes necessary. This issue can be agreed between manufacture and user.

6.103 Insulated platform

The insulated platform shall be able to support all the devices installed on it and without mechanical damage under specified conditions.

The insulated platform also should fulfil the dielectric requirement.

Each metallic support of insulated platform shall have a point through where it can be earthed reliably.

6.104 Commutation capacitor

The capacitor used in oscillating branch shall meet the requirements of IEC 60871-1, and it shall withstand the rated commutation voltage (U_c).

6.105 Energy dissipation device

The energy dissipation device used in the energy absorption branch shall meet the requirements of IEC 60099-9. Some measures shall be taken to ensure that the current sharing between parallel columns of energy dissipation device within manufacture’s specification.

6.106 Reactor

The reactor used in the oscillating branch shall meet the requirements in IEC 60076-6.

6.107 Making switch (if applicable)

Subclause 6.102 is applicable except 6.102.7.

6.108 Charging device (if applicable)

To ensure successful current transfer operation, the charging device has to keep the commutation capacitor always charged excepted the short period of re-charging time after a transfer operation.

The re-charging time shall be as short as possible, should be agreed by manufacturer and user and has to be mentioned in the relevant documents.

NOTE If there is no requirement to perform two transfer operations within a few min, this re-charging time could be considered as neglectable.

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).

Type tests shall be performed on a complete assembled DC transfer switch, except when it is otherwise noted in the relevant subclause.

For test situations which are aligned to one specific component of the DC transfer switch, or the test result is only affected by this component, the specified test may be performed only on this component.

NOTE 1 For example, the mechanical test can be performed on a commutation switch only.

If specific product standards are available for components of DC transfer switches, like reactors, capacitors, energy dissipation devices and so on, these components shall be tested according to their relevant product standards as far as applicable.

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In this specific application of DC transfer switches, not all requirements specified in IEC 60871-1 for capacitors, IEC 60076-6 for reactors and IEC 60099-9 for arrester apply.

NOTE 2 For example, there is no continuous current in the oscillating branch, thus the temperature rise test on reactor and thermal stability test for capacitors are not necessary.

Generally, tests on components of DC transfer switches should be carried out in accordance with their relevant product standards unless a specified test specification or condition is defined in this specification. For such cases, the condition given in this specification should be considered.

Each component of DC transfer switches, like reactors, capacitors, energy dissipation devices and so on, shall pass the tests specified in Annex A.

The type tests for transfer switches are listed in Table 4 and can be performed on a new or refurbished transfer switch.

Table 4 – Type tests

Type test	Condition	Subclauses
Dielectric tests	[a]	7.2
Resistance measurement	[a]	7.3
Continuous current test	[a]	7.4
Short-time withstand current and peak withstand current tests	[a]	7.5
Additional tests on auxiliary and control circuits	[a]	7.9
Mechanical operation test at ambient temperature (class M0)	[a]	7.101.2
Direct current commutation test	[a]	7.103
Direct arc withstand tests	[a]	7.104
Verification of the protection	Assigned IP and IK class [b]	7.6
Tightness test	Controlled, sealed or closed pressure systems [b]	7.7
EMC tests	Electronic equipment or components are included in the secondary system [b]	7.8
X-ray radiation test	Vacuum interrupters [b]	7.10
Extended mechanical operation test at ambient temperature	Class M1 specified [b]	7.101.2
Low and high temperature tests	If ambient air temperature is different from −5 °C and/or +40 °C [b]	7.101.3
Humidity test	Insulation subject to voltage stress and condensation [b]	7.101.4
Test to prove operation under severe ice conditions	Outdoor transfer switches '(or all mechanical switching devices) with moving external parts [b]	7.101.5
Seismic tests	[b]	7.102

[a] Mandatory type tests required for all transfer switches regardless of rated voltage, design or intended use.

[b] Other type tests, shown in the lower part of the table, are required for all transfer switches where the associated rating or requirement is specified, for example X-ray radiation test is required only for vacuum interrupters.

If a pole of a type tested AC circuit-breaker is used as commutation switch, the existing test documentation could be used as far as applicable.

Tolerances on test quantities are given in Annex C and Table C.1.

Information regarding the extension of validity of type tests is given in Annex E.

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

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).

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 D.

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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.

Test on a complete DC transfer switch can be omitted if any component of the DC transfer switch was tested in accordance with Annex A and the air clearance between the components and between each component to earth comply with the requirements of Annex B of IEC 60071-11:2022.

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.

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.

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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.

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

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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.

7.2.6 Application of the test voltage and test conditions

- Only the general case, sub-clause 7.2.6.2 of IEC TS 62271-5:2024, is applicable for DC transfer switches
- Subclause 7.2.6.3 of IEC TS 62271-5:2024 is not applicable.

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

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.

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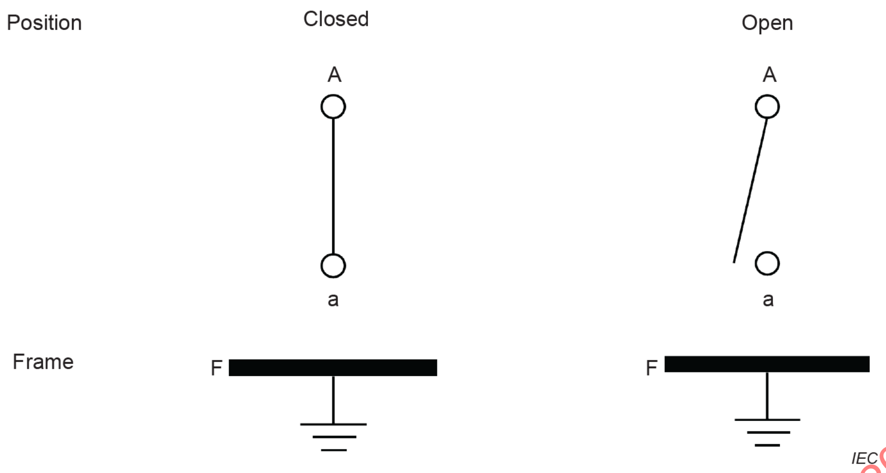

Figure 4 – Diagram of connections of a switching device

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.			

7.2.6.3 Special cases

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 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.

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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 tests shall be performed with the test voltage equal to the rated withstand voltages selected from Table 1.

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.

For DC transfer switches comprising a non-switchable oscillating branch (commutation switches using a non-switchable oscillating branch in parallel) direct withstand voltage test will be performed with the transfer switch in the closed position, with voltage applied between the switch terminals and earth only.

NOTE If an oscillating branch is fixed connected in parallel to the commutation switch, the complete DC transfer switch has to be disconnected from neutral system after commutation switch is opened. Otherwise, the energy dissipation device could be overloaded by repeatedly discharging the capacitor inside the oscillating branch, which will be charged by the neutral system.

To demonstrate the direct voltage withstand capability across such transfer switches, the direct voltage test across open transfer switch can be limited in time (e.g. to 1 min) by agreement between manufacturer and user.

To demonstrate the direct voltage withstand capability across the commutation switch of such transfer switches, the direct voltage test across open transfer switch can be performed on the commutation switch only (similar to test on a blank DC transfer switch) by agreement between manufacturer and user.

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7.2.7.3 Switching impulse voltage tests

Subclause 7.2.7.3 of IEC TS 62271-5:2024 is not applicable.

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.

For DC transfer switches comprising a non-switchable oscillating branch (commutation switches using a non-switchable oscillating branch in parallel) lightning impulse voltage tests will be performed with the transfer switch in the closed position, with voltage applied between the switch terminals and earth only.

During lightning impulse voltage test across DC transfer switch, the test voltage will usually be limited by the internal energy dissipation device Therefore, lightning impulse voltage test across DC transfer switch with reduced test voltage could be performed by agreement between manufacturer and user.

To demonstrate the full lightning impulse voltage withstand capability across DC transfer switch, the lightning impulse voltage test across open transfer switch can be performed with disconnected energy dissipation device by agreement between manufacturer and user.

To demonstrate the lightning impulse voltage withstand capability across the commutation switch of such transfer switches, the lightning impulse voltage test across open transfer switch can be performed on the commutation switch only (similar to test on a DC blank transfer switch) by agreement between manufacturer and user.

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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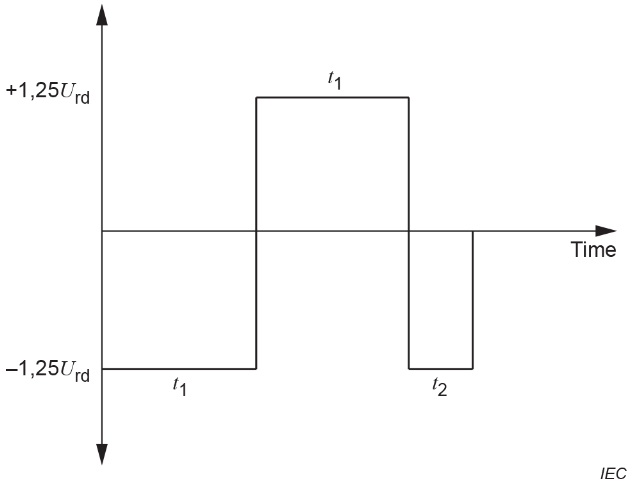

Figure 5 – Test sequence for polarity reversal tests

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.

Partial discharge tests are normally not required on transfer switches. However, in the case of a transfer switch using components for which a relevant IEC standard exists, including partial discharge measurements (for example, bushings, see IEC/IEEE 65700-19-03:2014 [3]), evidence shall be produced by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant IEC standard.

7.2.10 Dielectric tests on auxiliary and control circuits

The dielectric test on auxiliary and control circuits are covered under 7.9.5.

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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 $\sqrt{2}$.

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.

Any component of a DC transfer switch shall be tested in accordance with its relevant product standard. As an alternative, for the commutation switch and making switch (if any), a direct voltage test in dry conditions according to subclause 7.2.7.2 can be applied.

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.

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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.

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.

This test is only applicable for the commutation switch and any accessory that is connected between both terminals of transfer switch and direct in series with the commutation switch.

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.

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7.4 Continuous current tests

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.

This test is only applicable for the commutation switch and any accessory that is connected between both terminals of transfer switch, including these terminals and its supports, and direct in series with the commutation switch.

NOTE Accessory means any component connected between the terminals of the commutation switch and the outer terminals of the transfer switch, e.g.: shielding, clamps, wires…

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 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.

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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.

For convenience of testing, alternating current may be used alternatively without any correction.

A test with alternating current of arbitrarily frequency without any correction is more severe than a test with direct current and should only apply upon approval of manufacturer.

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.

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.

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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;
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).

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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.

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

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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
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)
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

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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
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”.

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.

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Point 15 For further details regarding temperature limits for hot surfaces to be touched, refer to IEC Guide 117 [67].

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.

This test is only applicable for the commutation switch and any accessory which is connected between both terminals of transfer switch, including these terminals and its supports, and direct in series with the commutation switch.

NOTE Accessory means any component connected between the terminals of the commutation switch and the outer terminals of the transfer switch, for example: shielding, clamps, wires.

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.

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 insulating fluid.

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 manufacture. 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

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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:

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;

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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.

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,

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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;
- 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.

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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 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.

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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 $F_{\text{p(liq)}}$.

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;
– 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)

Subclause 7.8.1.1 is not applicable.

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.

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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.			

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.

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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).

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.

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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.

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.

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.

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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

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.

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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.

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.

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.

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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.

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:

$$R(1\ \text{m}) = R(d) \times d^2 \qquad (3)$$

where $R(d)$ is the radiation level measured, at the distance d (in m) from the external surface of the vacuum interrupter.

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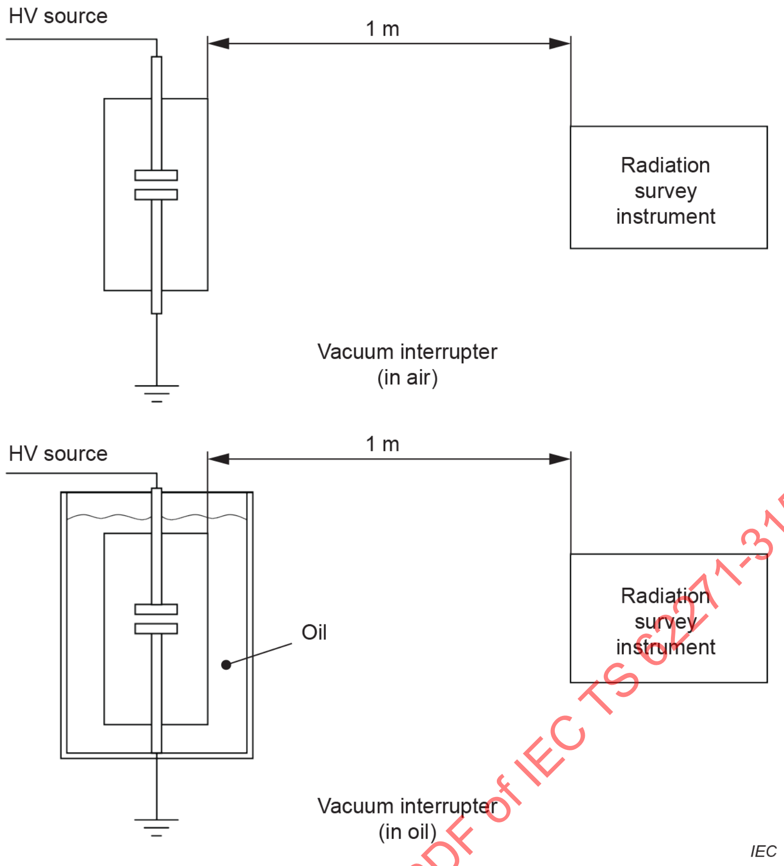

Figure 7 – Test location of radiation survey instrument

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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

The mechanical characteristic shall be only established for the commutation switch and all other mechanical switching devices inside the DC transfer switch.

At the beginning of the type tests, the mechanical characteristics of the DC transfer switch shall be established individually on all mechanical switching devices. IEC TR 62271-306 [1] gives examples on how to measure the mechanical characteristics. The mechanical characteristics will serve as the reference for the purpose of characterizing the mechanical behaviour of the DC transfer switch. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical and commutation type tests behave mechanically in a similar way. The reference mechanical characteristics are also used to confirm that production units behave mechanically in a similar way compared to the test samples used during type tests.

Following 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, for convenience of testing, at the minimum functional pressure for insulation.

7.101.1.2 Component tests

When testing of a complete mechanical switching device is not practicable, component tests may be accepted as type tests as far as applicable. 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 mechanical switching device (example given: part of a pole, 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 mechanical switching device is tested. Component tests shall cover all different types of components of the complete mechanical switching device, 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 mechanical switching devices.

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 commutation switch shall be verified.

7.101.1.3 Characteristics and settings of the mechanical switching device 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;

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c) time spread between units of one pole;
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, 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 mechanical switching device during and after the tests

During and after the tests, the mechanical switching device shall be in such a condition that it is capable of operating normally, carrying its rated continuous current and withstanding the voltage values according to its rated insulation level.

In general, these requirements are fulfilled if

– during the tests, the mechanical switching device 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 (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 mechanical switching device in the open position shall be in essentially the same condition as before the tests. Visual inspection of the mechanical switching device after the tests is usually sufficient for verification of the insulating properties. In the case of mechanical switching device with sealed-for-life interrupters, a voltage test as a condition check in accordance with 7.2.11 replaces this visual inspection;
– for sealed-for-life interrupters, 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 types of mechanical switching devices, the resistance condition check of the test object is satisfactory if the resistance determined in 7.3.4 is not greater than 20 % and that the visual inspection of the contact system does confirm that the contact system complies with the requirements stated above in this subclause. If the resistance increase exceeds 20 % then also a visual inspection shall be performed to see if the contact system is complying the requirements stated above in this subclause.

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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 7.9.5 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 tests at ambient air temperature

7.101.2.1 General

The mechanical operation test shall be performed on the commutation switch and all other mechanical switching devices inside the DC transfer switch only 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.

In cases where a making switch is used in series with the oscillation branch in parallel to the commutation switch the mechanical operation test shall be performed on the making switch also.

In accordance with 7.101.2.3 the mechanical operation test shall consist of:

– 1 000 operating cycles for DC transfer switches of endurance class M0;
– 2 000 operating cycles for DC transfer switches of endurance class M1.

Mechanical switching device 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 C.

7.101.2.2 Condition of the mechanical switching device before the test

The mechanical switching device for test shall be 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.

A multicolumn mechanical switching device actuated by a single operating device and/or with all columns mounted on a common frame shall be tested as a complete unit.

Tests shall be conducted at the filling pressure for insulation.

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

– reference mechanical travel characteristics;
– power and strength of closing and opening mechanism;

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– rigidity of structure.

7.101.2.3 Operating sequence

The commutation switch shall be tested in accordance with Table 5 if it is intended to be used in DC transfer switches with mechanical endurance class M0.

For commutation switches intended to be used in DC transfer switches with mechanical endurance class M1 the numbers given in Table 5 shall be doubled.

In cases where a making switch is used in series with the oscillation branch in parallel to the commutation switch, this switch normally will operate single close and single open operation.

The making switch shall be tested in accordance with Table 6 if it is intended to be used in DC transfer switches with mechanical endurance class M0.

For making switches intended to be used in DC transfer switches with mechanical endurance class M1 the numbers given in Table 6 shall be doubled.

Table 5 – Number of operating sequences for commutation switches

Operating sequence	Supply voltage	Operating pressure	ERTS, MRTS, NBES	NBS
$O - t_a - C - t_a$	Minimum	Minimum functional	250	250
	Rated	Filling pressure	250	250
	Maximum	Filling pressure	250	250
$O - t - C - t_a$	Rated	Filling pressure	250	-
$C - 0{,}1\ s - O - t - C - t_a - O - t_a$	Rated	Filling pressure	-	125

O = opening;

C = closing;

t is less than or equal to the rated open-close time (5.106);

t_a = time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the commutation switch (this time can be different according to the type of operation).

NOTE 1 The sequences and numbers given for NBS will also cover the requirements for commutation switches which are intended to operate in ERTS, MRTS or NBES as agreed by manufacturer and user.

NOTE 2 Operating sequence shall be in line with application, see subclause 5.105.

Table 2 – Number of operating sequences for making switches

Operating sequence	Supply voltage	Operating pressure	
$O - t_a - C - t_a$	Minimum	Minimum functional	250
	Rated	Filling pressure	500
	Maximum	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 making switch (this time can be different according to the type of operation).

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.

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7.101.2.4 Acceptance criteria for the mechanical operation tests

a) Before and after the total test program, the following operations shall be performed:

- five open-close 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 open-close operating cycles at the minimum supply voltage of closing and opening devices and of auxiliary and control circuits and/or the minimum functional pressure for operation;
- five open-close 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 operation tests shall be within the tolerances given by the manufacturer.

b) After the total test program, the condition of the mechanical switching devices shall be in accordance with 7.101.1.4.

The DC transfer switch is considered to pass the mechanical operation tests if the mechanical switching devices fulfil the criteria detailed above.

7.101.3 Low and high temperature tests

7.101.3.1 General requirements

The low and high temperature test should be performed on a fully assembled DC transfer switch as far as possible.

If a test on a fully assembled DC transfer switch is not possible for dimensional reasons in testing station, tests on single component of DC transfer switch should be performed as agreed between manufacturer and client.

Low and high temperature test shall be performed always on the commutation switch and all other mechanical switching devices inside the DC transfer switch.

In cases where a making switch is used in series with the oscillation branch in parallel to the commutation switch, the low and high temperature test shall also be performed on this switch. Other as described in the following test procedure below a making switch shall operate with single close or open operations only.

Other components like capacitors, reactors, resistors, or energy dissipation devices shall be tested in accordance with their relevant standards.

It is permitted to store this component in a climatic test cell during the low and high temperature test to demonstrate its performance as agreed by manufacturer and client.

In cases when the component is tested individually, the DC transfer switch is deemed having passed the test if all components pass these tests individually.

The two tests need not be performed in succession, and the order in which they are made is arbitrary. If the minimum ambient air temperature of indoor and outdoor DC transfer switches

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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 transfer switch operation are to be at the test air temperature unless the transfer switch design requires a heat source for these supplies.

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

The transfer switch has passed the test if the conditions stated in 7.101.1.4 and 7.101.1.5 are fulfilled. Furthermore, the conditions in 7.101.3.3 and 7.101.3.4 shall be fulfilled and the leakage rates recorded shall not exceed the limits given in Table 11 of IEC TS 62271-5:2024. In the test report the testing conditions and the condition of the transfer switch 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 transfer switch design may be fitted with several variants of auxiliary equipment (shunt releases and motors) 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 7.101.1.1.

The conditions during and after the tests are given in 7.101.1.4.

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 transfer switch and at a distance of 1 m from the transfer switch.

The maximum temperature deviation over the height of the transfer switch shall not exceed 5 K.

7.101.3.3 Low-temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 1.

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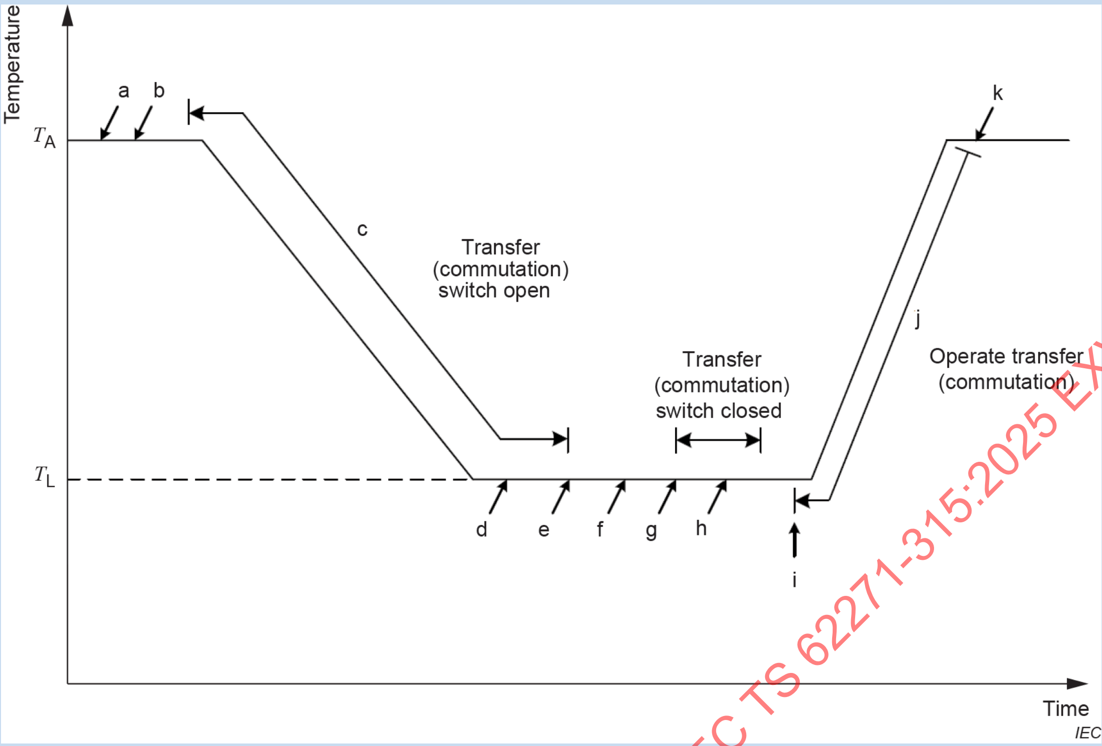

NOTE Letters a through k identify application points of tests specified in 7.101.3.3.

Figure 1 – Test sequence for low temperature test

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

a) The test transfer switch shall be prepared and adjusted in accordance with the manufacturer's instructions;

b) Characteristics and settings of the transfer switch 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 transfer switch in the open 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 transfer switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_L;

d) During the 24 h period with the transfer switch in the open position at temperature T_L, a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the transfer switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 11 of IEC TS 62271-5:2024;

e) After 24 h at temperature T_L, the transfer switch shall be 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 transfer switch and its alarms and lock-out systems shall be verified by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x. During this interval, occurrence of 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 within the manufacturer's specified tolerances.

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

g) The transfer switch shall be left in the closed position for 24 h;

h) During the 24 h period with the transfer switch in the closed position at temperature T_L, a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the transfer switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 11 of IEC TS 62271-5:2024;

i) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the transfer switch at temperature T_L. At least a 3 min interval shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded. 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 made by performing O – t_a – C –t_a operating sequences (t_a is defined in Table 5);

j) After completing the 50 opening and 50 closing operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour;

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

k) After the transfer switch has stabilized thermally at ambient air temperature T_A, a recheck shall be made of the transfer switch 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 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).

7.101.3.4 High-temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 2.

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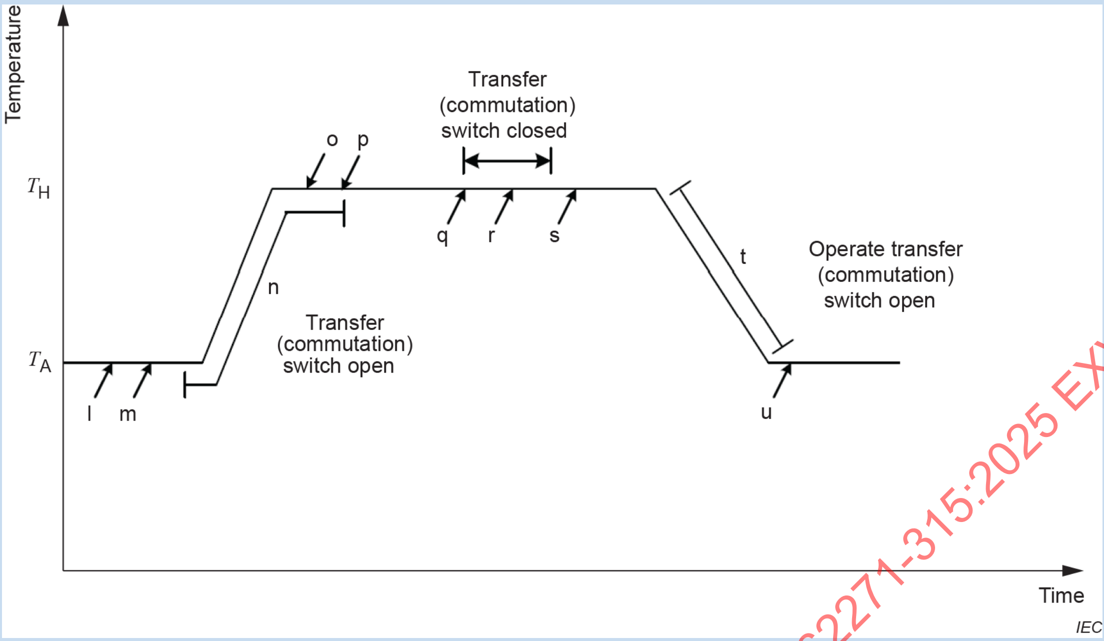

NOTE Letters l through u identify application points of tests specified in 7.101.3.4.

Figure 2 – 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.

a) The test transfer switch shall be prepared and adjusted in accordance with the manufacturer's instructions;

b) Characteristics and settings of the transfer switch 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 transfer switch in the open 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 transfer switch shall be kept in the open position for 24 h after the ambient air temperature stabilizes at T_H;

d) During the 24 h period with the transfer switch in the open position at the temperature T_H, a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the transfer switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 11 of IEC TS 62271-5:2024;

e) After 24 h at the temperature T_H, the transfer switch shall be 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 transfer switch shall be closed and left closed for 24 h at the temperature T_H;

g) During the 24 h period with the transfer switch in the closed position at the temperature T_H, a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the transfer switch is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 11 of IEC TS 62271-5:2024;

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h) At the end of the 24 h period, 50 opening and 50 closing operations shall be made at rated values of supply voltage and operating pressure with the transfer switch at the temperature T_H. An interval of at least 3 min shall be allowed for each cycle or sequence. The first opening and closing operation shall be recorded. 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 operation cycles shall be performed. The additional operations shall be made by performing O – t_a – C –t_a operating sequences (t_a is defined in Table 5);

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

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

j) After the transfer switch has stabilized thermally at ambient air temperature T_A, a recheck shall be made of the transfer switch 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 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).

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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 DC transfer switches. The test shall be performed on DC transfer switches or its component, 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 DC transfer switches. It 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 components of transfer switch or of active current injection circuit, 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 below:

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 (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 3) in which the low air temperature is applied.

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 may be necessary to start the fog generation later within the low air temperature period.

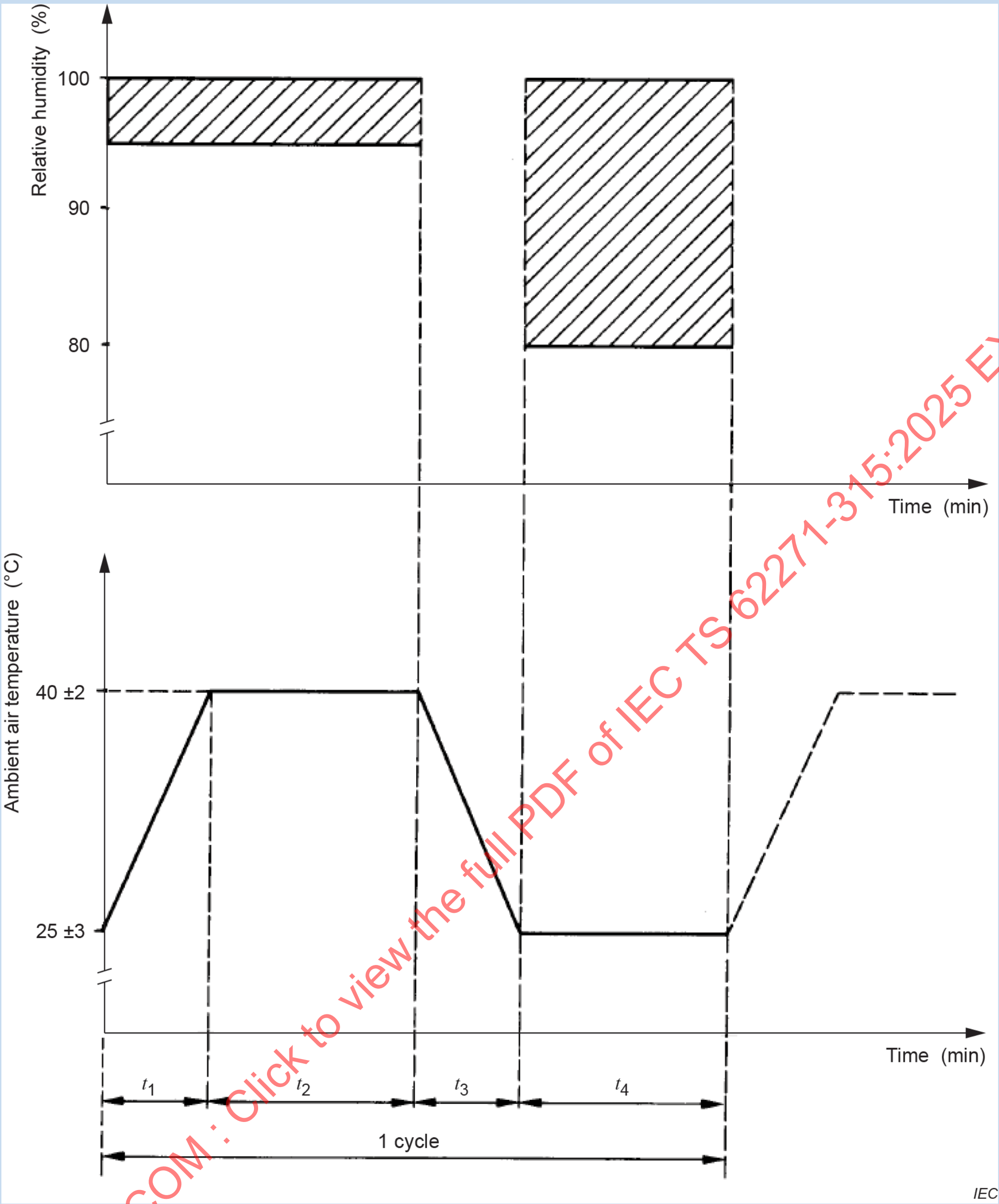

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Figure 3 – Humidity test

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 atomized; the rise from 25 °C to 40 °C may be obtained with the provision of heat coming from the steam or atomized 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 transfer switches, usually having time constants smaller than 10 min, the duration of the time intervals given in Figure 3 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 atomization of 0,2 l to 0,4 l of water (with the resistivity characteristics given below) per hour and per cubic meter of test chamber volume. The diameter of the droplets shall be less than 10 µm; such a fog can be obtained by mechanical atomizers. 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 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 to prove the operation under severe ice conditions is applicable only to outdoor transfer switches having movable external parts. The test shall be performed according to IEC 62271-102:2018.

The test to prove the operation under severe ice conditions shall be established for the commutation switch and all other mechanical switching devices inside the DC transfer switch only.

In cases where a making switch is used in series with the oscillation branch in parallel to the commutation switch, the test to prove the operation under severe ice conditions shall performed for the making switch also.

7.102 Seismic tests

The seismic test should be performed on a fully assembled DC transfer switch as far as possible.

If a test on a fully assembled DC transfer switch is not possible for dimensional reasons in testing station, tests on single component of DC transfer switch should be performed as agreed between manufacturer and client.

The tests shall be performed in accordance with IEC 62271-207.

NOTE By agreement of manufacturer and client this test could be substituted by calculation.

7.103 Direct current commutation tests

7.103.1 General

The purpose of this test is to verify the specified direct current transfer capability of DC transfer switches.

NOTE 1 This test verifies whether the DC transfer switch can successfully transfer the direct current within the rated value, the DC transfer switch can withstand the specified voltage, having a specific rate of rise, across its open contacts and the capability of energy dissipation device.

NOTE 2 Simulations could be used for determination of the settings of oscillating branch, but they do not replace this test.

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The value of transfer current as test result, is the current in the main test circuit, measured outside of the transfer switch, at the instant of arc extinction in the commutation switch.

7.103.2 Arrangement of the transfer switch during test

As preferred method direct current transfer tests should be performed on a fully assembled DC transfer switch. During the direct current commutation test, if the energy of the test circuit is insufficient to verify the capability of the energy dissipation device, it should be proofed/demonstrated in a different way like test on arrester discs.

NOTE 1 Due to limitations of testing stations full energy dissipation capability of energy dissipation device may not being tested sufficiently during test on a fully assembled DC transfer switch. Therefore, the energy dissipation device can be adapted to handle the energy of test circuit only.

As an alternative method for testing a passive DC transfer switch, the commutation switch can be tested in an arrangement of oscillation circuit, having same capacitance and inductance as the original one, and an energy dissipation device adapted to the test circuit.

NOTE 2 In passive DC transfer switches, the capability to transfer a direct current depends on the interaction between the arc voltage of commutation switch and the oscillation branch in parallel. Also, the voltage stress after arc extinction is defined by the oscillation branch. Therefore, only the capacitance and the inductance of the elements inside the oscillation branch are considered during the test.

Values for capacitance, inductance and resistance of the test setup or the transfer switch under test shall be established and mentioned in the test document.

NOTE 3 Stray inductances within the oscillating branch and between the DC switch and the oscillating branch can be significant for the DC current commutation performance. If an equivalent circuit having the same inductance and same capacitance is used, then the stray inductance of the oscillating circuit can be represented as close as possible (e.g. same cable lengths between the oscillating branch and the DC commutation switch).

If an energy dissipation device is used during current transfer test having a residual voltage less than the rated commutation voltage, the dielectric withstand capability of the commutation switch and current zero device will not be tested correctly. In this case the dielectric withstand capability of commutation switch and current zero device shall be demonstrated in additional tests. During these tests the peak value of test voltage shall not be less than the rated commutation voltage and its rate of rise shall not be less than the specified value calculated from circuit components. For the current zero device this can be an impulse voltage withstand test. For commutation switch an AC breaking test is recommended with same current peak value as during current transfer test. The current derivative (di/dt) at current zero should not be less than the current derivative obtained during current transfer tests.

For DC transfer switches using compressed fluids for insulation or commutation, the test shall be performed at minimum functional pressure (density) for insulation or commutation. The kind of fluid, its temperature and pressure during the test shall be noted and recorded in the test report.

For separate commutation voltage withstand tests, it should be clear that these additional tests shall be performed with, at least, the maximum arcing time obtained during the commutation tests. Moreover, the number of additional tests demonstrating the commutation voltage withstand capability shall be the same number of tests as the number of tests specified for the commutation test.

For DC transfer switches using compressed fluids for operation, the test shall be performed at filling pressure for operation and minimum functional pressure for operation (refer to 7.103.4). The temperature and pressure of the fluid during the test shall be noted and recorded in the test report.

The supply voltage of opening and closing releases during the test shall be set to rated supply voltage.

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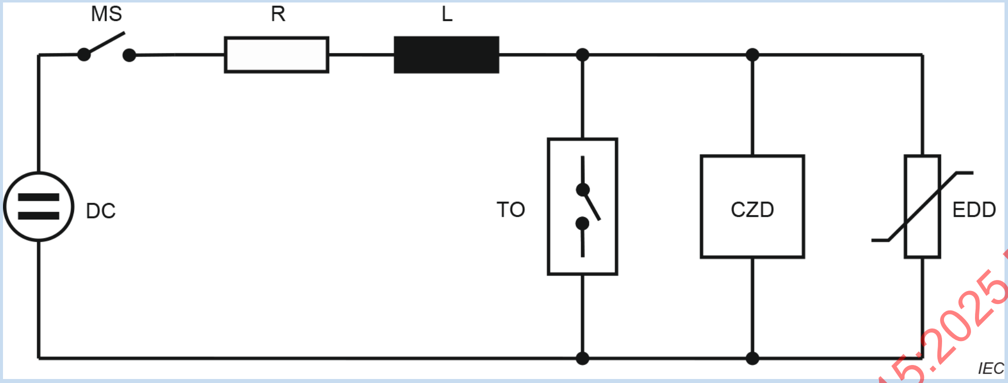
7.103.3 Test circuit

The general layout of a test circuit for current transfer test is shown in Figure 4.



Key

DC DC source

MS Master switch

R Resistor

L Inductor

TO Test object (Commutation switch)

CZD Current zero device, will be

- an oscillation branch in case of passive DC transfer switch
- a current impulse generator in case of active DC transfer switch

EDD Energy dissipation device

Figure 4 – General layout of test circuit for direct current commutation test

NOTE 1 Further information on test circuits can be found in Annex B, Clause B.1.

If test facilities are limited, an equivalent low-frequency alternating current may be used for the test. In this case only one-half period of current shall be used and the interval of commutation (arcing time of commutation switch) should be close to the maximum current. The current in the main test circuit during the commutation time in the commutation switch, measured outside of the transfer switch, shall not be less than 100 % of the rated transfer current (see Figure 5).

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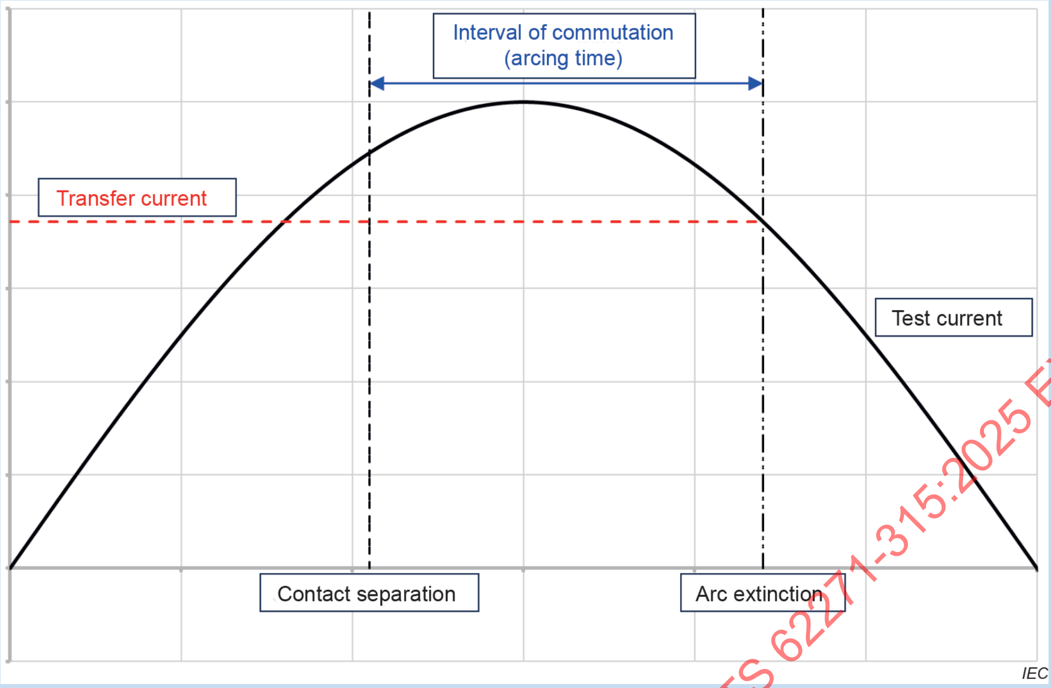

Figure 5 – Current commutation test with low-frequency alternating current

NOTE 2 Suitable frequency (wavelength of current) depends on needed arcing time, for example, 16 2/3 Hz could be used.

7.103.4 Test procedure

Before and after the direct current commutation test the mechanical characteristics and the resistance of the main circuit shall be established.

In the test series 15 commutation operations shall be performed consisting of:

– 5 operations at minimum functional pressure for operation;
– 10 operations at filling pressure for operation.

In case of active current injection transfer switches or transfer switches having a current limitation branch, test with reduced current shall be performed, also, the number of required commutation operations for each polarity is given as follows:

– 5 operations with 100 % of rated transfer current at minimum functional pressure for operation;
– 5 operations with 100 % of rated transfer current at filling pressure for operation;
– 5 operations with 50 % of rated transfer current at filling pressure for operation;
– 5 operations with 10 % of rated transfer current at filling pressure for operation;

In case of active current injection transfer switches with predetermined unipolar current impulse the number of required commutation operations is 20.

In case of active current injection transfer switches with bipolar injection current wave the number of required commutation operations is 40, that means 20 operations in each polarity.

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7.103.5 Behaviour of DC transfer switch during test

During direct current commutation test, the DC transfer switch shall not

- show signs of distress;
- show harmful interaction to earth;
- show harmful interaction with adjacent laboratory equipment;
- exhibit behavior which could endanger an operator.

If faults occur that are neither persistent nor due to defect in design, but rather are due to errors in assembly or maintenance, the faults can be rectified and the DC transfer switch subjected to the repeated direct current transfer test concerned. In those cases, the test report shall include reference to the invalid tests.

7.103.6 Criteria to pass the test

The DC transfer switch shall pass the direct current transfer test if the required number of transfer operations have been performed successfully without damage (beside the usually acceptable wear of contacts), and it is capable of opening and closing normally after the tests. This will be confirmed by checks of mechanical characteristics, resistance of main circuit, dielectric withstand capability and a visual inspection of switching units.

The mechanical travel characteristic and the opening and closing time before and after test shall be compared.

- The difference of opening and closing time at rated condition after test is within the limits given by the manufacturer;
- The mechanical travel characteristic for opening and closing, before and after test shall be within an envelope of not more than 10 % around the mechanical reference curve.

The resistance of main circuit before and after test shall be compared.

- Difference of resistance of main circuit after test measured according to 7.3.4 is within not more than 100 % of before the test.

The dielectric withstand capability after direct current transfer test shall be demonstrated.

- Dielectric condition check, according to 7.2.11 shall be performed.

NOTE Dielectric condition check can be omitted if it will be performed after ‘Direct arc withstand test’.

The switching units of DC transfer switch shall be inspected.

For other than sealed for life switching units, visual inspection is usually sufficient for verification of the capability of the commutation switch to carry the rated continuous current.

- The main contacts shall be in such a condition, in particular with regard to wear, contact area, pressure and freedom of movement, that they are capable of carrying the rated normal current of the transfer switch without their temperature rise exceeding by more than 10 K the values specified for them in Table 10 of IEC TS 62271-5:2024.
- Contacts shall be considered as "silver-faced" only if there is still a layer of silver at the contact points after the test; otherwise, they shall be treated as "not silver-faced".

7.104 Direct arc withstand tests

7.104.1 General

The purpose of this test is to verify the arc withstand capability of the DC transfer switch should it fail to commutate the rated transfer current. The time duration of the direct arc is the interval of time between the instant when the contacts have separated during the opening operation and the instant when the contacts touch during the following closing operation.

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For blank DC transfer switches which have an inherent arc quenching capability, it is not possible for the arc to be sustained for an extended period. Usually, the arc will be quenched by these commutation switches within the required time span. In these cases, the test shall be considered compliant, despite the arcing time achieved.

7.104.2 Arrangement of the transfer switch during test

The test shall only be performed on the commutation switch without auxiliary circuits fitted and the insulation platform.

For DC transfer switches using compressed fluids for insulation or commutation, the test shall be performed at minimum functional pressure (density) for insulation or commutation. The kind of fluid, its temperature and pressure during the test shall be noted and recorded in the test report.

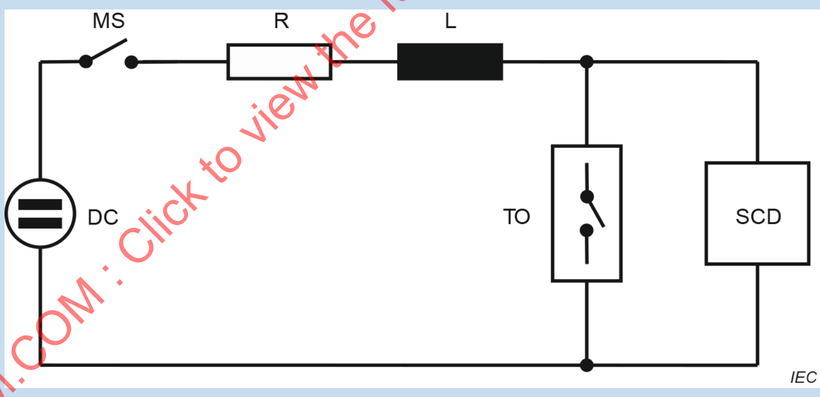
For DC transfer switches using compressed fluids for operation, the test shall be performed at filling pressure for operation and minimum functional pressure for operation (refer to sub-clause 7.104.4). The temperature and pressure of the fluid during the test shall be noted and recorded in the test report.

The supply voltage of opening and closing releases during the test shall be set to rated supply voltage.

7.104.3 Test circuit

The test circuit shall be equivalent to the actual service condition of DC transfer switches.

The general layout of a test circuit for direct arc withstand test is shown in Figure 6.



Key

DC DC source

MS Master switch

R Resistor

L Inductor

TO Test object

SCD Short circuit device, to by-pass test object in case of failed closing operation.

Figure 6 – General layout of test circuit for direct arc withstand test

NOTE Further information on test circuits can be found in Annex B, Clause B.2.

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7.104.4 Test procedure

Before and after the direct arc withstand test the mechanical characteristics and the resistance of the main circuit shall be established.

The test requirements are as follows:

– Test current: rated transfer current;
– Operating sequence: O – t – C;
– Time intervals t: assigned by the manufacturer;
– Time duration of the arc: not less than T_{aw};
– 1 operation cycle (O – t – C) at minimum functional pressure for operation;
– 1 operation cycle (O – t – C) at filling pressure for operation;

7.104.5 Behaviour of DC transfer switch during test

During direct arc withstand test, the DC transfer switch shall not

– show signs of distress;
– show harmful interaction to earth;
– show harmful interaction with adjacent laboratory equipment;
– exhibit behavior which could endanger an operator.

If faults occur which are neither persistent nor due to defect in design, but rather are due to errors in assembly or maintenance, the faults can be rectified and the DC transfer switch subjected to the repeated direct arc withstand test concerned. In those cases, the test report shall include reference to the invalid tests.

7.104.6 Criteria to pass the test

The DC transfer switch shall pass the direct arc withstand test if the required number of opening operations were performed successfully without damage, and it is capable of opening and closing normally after the tests. This will be confirmed by checks of mechanical characteristics, resistant of main circuit, dielectric withstand capability and a visual inspection of switching units.

NOTE After the direct arc withstand tests, the current commutation capability can be impaired due to the internal pollution.

The mechanical travel characteristic and the opening and closing time before and after test shall be compared.

– The difference of opening and closing time at rated condition after test is within the limits given by the manufacturer.
– The mechanical travel characteristic for opening and closing, before and after test shall be within an envelope of not more than 10 % around the mechanical reference curve.

The resistance of main circuit before and after test shall be compared.

The difference of resistance of the main circuit after the test measured according to 7.3.4 shall be within 100 % of that measured before the test.

The dielectric withstand capability after the direct current transfer test shall be demonstrated.

Dielectric condition check, according to 7.2.11 shall be performed.

The switching units of DC transfer switch shall be inspected.

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For other than sealed for life switching units, visual inspection is usually sufficient for verification of the capability of the commutation switch to carry the rated continuous current.

– The main contacts shall be in such a condition, in particular with regard to wear, contact area, pressure and freedom of movement, that they are capable of carrying the rated normal current of the transfer switch without their temperature rise exceeding by more than 10 K the values specified for them in Table 10 of IEC TS 62271-5:2024.
– Contacts shall be considered as "silver-faced" only if there is still a layer of silver at the contact points after the test; otherwise, they shall be treated as "not silver-faced".

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.

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.

Each component of DC transfer switches, like commutation switches, reactors, capacitors, energy dissipation device, etc., shall pass the routine tests specified in Annex A or specific product standards (if available).

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.

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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.

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.

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 open-close operating cycles with the closing mechanism energised by the auxiliary contacts.

The mechanical operation tests shall be performed on the commutation switch and all other mechanical switching devices inside the DC transfer switch only 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.

Mechanical operating tests should be made on the complete switching devices. However, when these switching devices 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 complete switching devices.

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, can be performed to record the no-load travel curves at the end of the routine tests. Where this is done, the curve shall be within the prescribed envelope of the reference mechanical travel characteristic, as defined in 7.101.1.1, from the instant of contact separation to the end of the contact travel for an opening operation and from start of movement to contact touch for a closing operation.

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Where the mechanical routine tests are performed on sub-assemblies, the reference mechanical travel characteristics shall be confirmed to be correct, as above, at the end of the commissioning tests on site.

If the measurement is performed on site, the manufacturer shall state the preferred measuring procedure. If other procedures are used, the results may be different and the comparison of the instantaneous contact stroke may be impossible to achieve.

The mechanical travel characteristics can be recorded directly, using a travel transducer or similar device on the DC transfer switches contact system or at other convenient locations on the drive to the contact system where there is a direct connection, and a representative image of the contact stroke can be achieved. The mechanical travel characteristics shall be preferably a continuous curve. 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 DC transfer switches;
– 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 the control cubicle (electrical, mechanical, pneumatic and hydraulic systems);
– recharging duration(s);
– functional performance of the 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 DC transfer switches.

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).

For the selection of DC transfer switches, the following conditions and requirements at site should be considered:

– application (MRTS, ERTS, NBS, NBES);
– continuous current load and overload conditions;
– existing fault conditions;

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– environmental conditions (climate, pollution, etc.);
– altitude of the substation.

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 General

All rated characteristics and classes of a DC transfer switch given in Clause 5 should be considered.

9.2.102 Selection of rated direct voltage of transfer switch and rated insulation level

The rated direct voltage of transfer switch should be chosen so as to be at least equal to the highest voltage of neutral bus system to be installed. The rated direct voltage of transfer switch and insulation level of the neutral bus for different converter station are different. The selected rated direct voltage of transfer switch and insulation level should meet the engineering requirements.

The rated direct voltage of transfer switch can be selected from the standard values in subclause 5.101 and their related insulation levels are given in 5.3.

For DC transfer switches installed at high altitudes, refer to 4.2.2 of IEC TS 62271-5:2024.

9.2.103 Selection of rated operating sequence

The operating sequence depends on the specific application of the DC transfer switch in the system. The rated operating sequence should be selected from those sequences given in 5.105.

9.2.104 Selection of rated continuous current

The rated continuous current of a DC transfer switch should be selected from the standard values given in 5.4 of IEC TS 62271-5:2024.

The overload requirements of the HVDC system should be considered when selecting the rated continuous current.

9.2.105 Selection of rated values of short time withstand current

The rated values of short time withstand current should be selected from those given in 5.5 of IEC TS 62271-5:2024.

9.2.106 Selection of rated transfer current

The rated transfer current should be selected in accordance with 5.102.

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9.2.107 Selection of rated commutation voltage

The commutation voltage of a transfer switch at each location in the system is determined by its energy dissipation branch. This value can be determined by simulation of current commutation process.

The commutation voltage is normally lower than the protection level of the surrounding surge arresters where DC transfer switch is installed.

The rated commutation voltage for a specific DC transfer switch shall be equal to or higher than the maximum commutation voltage determined by simulation.

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

Equipment could be required to carry a load current above its rated continuous current during a short period of time or when ambient temperatures are favourable to do it provided the temperature does not exceed the maximum temperature value specified in Table 10; reference is made to IEC TR 62271-306 [62].

NOTE For certain switching devices the temporary overload could result in a load current that exceeds their switching capability.

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.

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

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temperature and pressure rise limits. Tests with simulated solar gain can be used to demonstrate if measures or derating are required.

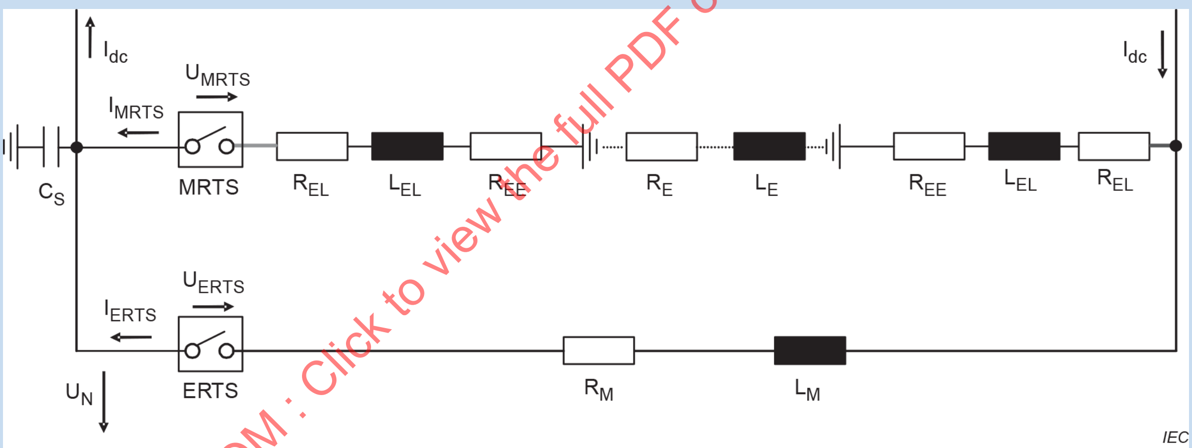
9.101 Selection of the application

9.101.1 MRTS

The MRTS forms part of the electrode line circuit (earth return) in a HVDC system with both earth and metallic returns. For current transfer purpose, it starts from the closed position and transfers current from earth return to metallic return through its coordinated opening operation with the ERTS. In the sequence, the ERTS closes first from its original open position, which results in current transfer from the earth return to the metallic return. After the current in the earth return reaches new steady state, the MRTS opens, which completes the current transfer from electrode line (earth return) to metallic return. Figure 7 shows the equivalent circuit where the MRTS is defined.

9.101.2 ERTS

The ERTS forms part of metallic return in a HVDC system with both earth and metallic returns. For current transfer purpose, it starts from the closed position and transfers current from metallic return to earth return through its coordinated opening operation with the MRTS. In the sequence, the MRTS closes first from its original open position, which results in current transfer from the metallic return to the earth return. After the current in the metallic return reaches new steady state, the ERTS opens, which completes the current transfer from metallic return to electrode line (earth return). Figure 7 shows the equivalent circuit where the ERTS is defined.



Key

EL electrode line

EE electrode earth

M metallic return

E earth return

C_s surge capacitor

N Neutral bus

Figure 7 – Equivalent transfer circuit of MRTS and ERTS

9.101.3 NBS

At an earth fault within the converter in one pole during normal bipolar operation, the faulty pole is blocked with by-pass pairs. The NBS is used to transfer direct current which is generated by the operating pole flowing through the short-circuit point and the blocked pole to the electrode line. Figure 8 shows the equivalent transfer circuit of the NBS.

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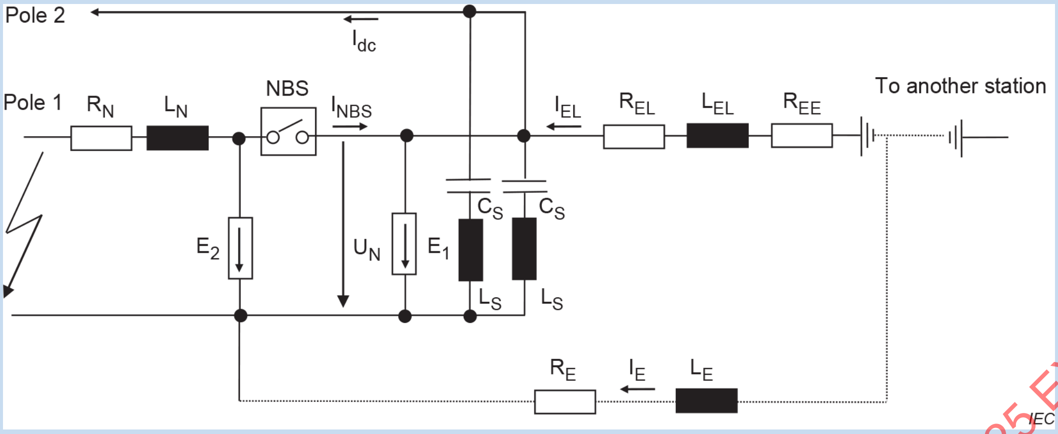

Key

EL electrode line

EE electrode earth

N neutral bus

E earth return

C_s surge capacitor

L_s leakage inductance of surge capacitor

Figure 8 – Equivalent transfer circuit of NBS

9.101.4 NBES

The NBES is used to prevent bipolar operation from stopping and blocked and improve the reliability of HVDC transmission system. When the electrode line is open, the neutral bus voltage rises because of the unbalanced current. The NBES is closed to provide converter station temporary earth. The system could continue operating in bipolar mode. When the electrode line can be used again, the NBES transfers the current from the converter station earth to the electrode line. Figure 9 shows the equivalent transfer circuit of the NBES.

NOTE The NBES can also be used when a fault occurs on one pole during bipolar operation and supports the NBS to isolate the faulted pole by sharing the current.

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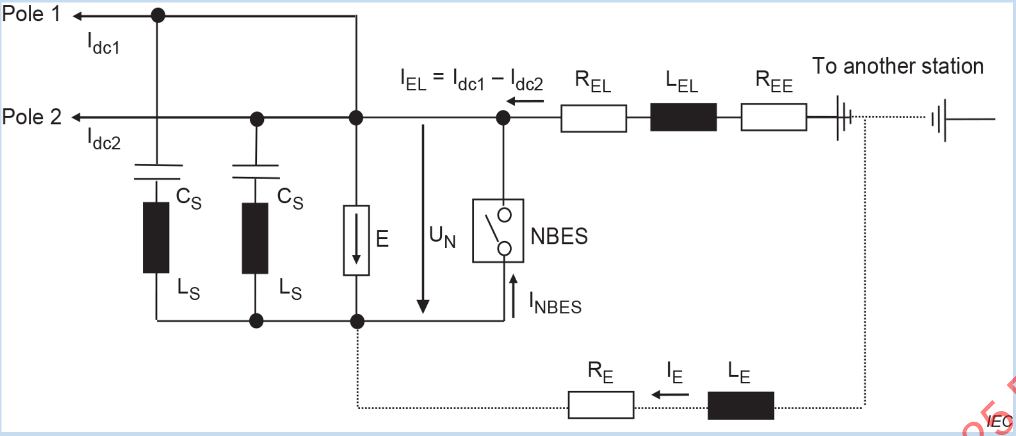

Key

EL electrode line

EE electrode earth

N neutral bus

E earth return

C_s surge capacitor

L_s leakage inductance of surge capacitor

Figure 9 – Equivalent transfer circuit of NBES

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.

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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});
   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 transfer switch, the following particulars should be supplied by the enquirer:

a) particular of systems, i.e. normal and highest voltages, normal and maximum continuous currents. Unusual characteristics of the system in which the transfer switch is to be applied should be noted;

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, seismic activity

c) characteristics of transfer switch.

   The following information should be given:
   1) indoor or outdoor installation;
   2) type and class of transfer switch as defined in Clause 3;
   3) current transferring capability: unidirectional or bidirectional;
   4) rated direct voltage of transfer switch (5.101);
   5) rated insulation level (5.3);

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6) rated continuous current (5.4);
7) rated values of short-time withstand current (5.5);
8) rated transfer current (5.102);
9) rated commutation voltage (5.103)
10) rated dissipated energy during transfer operation (5.104)
11) rated operating sequence (5.105);
12) rated open-close time (5.106);
13) class of mechanical endurance (6.102.6);
14) the type tests required on special request.

d) characteristics of the operating mechanism of transfer switch and associated equipment, in particular:
   1) method of operation;
   2) number and type of spare auxiliary switches;
   3) rated supply voltage and rated supply frequency;
   4) number of releases for opening, if more than one;
   5) number of releases for closing, if more than one.
e) requirements concerning the use of compressed fluids and requirements for design and test of pressure vessels.

The enquirer should give information of any special conditions not included above, that might influence the tender or order (see also the note in 9.101).

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;

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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 transfer switch, the following information, if applicable, should be given by the manufacturer, with any explanatory text and drawings:

a) rated values and characteristics:
   1) indoor or outdoor installation; type and class of transfer switch as defined in Clause 3
   2) rated direct voltage of transfer switch (5.101);
   3) rated insulation level (5.3);
   4) rated continuous current (5.4);
   5) rated values of short-time withstand current (5.5);
   6) rated transfer current (5.102);
   7) rated commutation voltage (5.103)
   8) rated dissipated energy during transfer operation (5.104)
   9) rated operating sequence (5.105);
   10) rated open-close time (5.106);
   11) class of mechanical endurance (6.102.6);
   12) cooling down time of energy dissipation device.

b) type tests

   List of certificates or report on request, including the special tests requested by the inquirer;

c) constructional features:

   The following details are required where they are applicable to the design:
   1) mass of complete transfer switch without fluids for insulation, and transfer switching operation;
   2) mass/volume of fluid for insulation, its quality and operating range, including the minimum functional value;
   3) mass/volume of fluid for transfer switching operation (where different fluid to items 2) and/or 4)), its quality and operating range, including the minimum functional value;
   4) mass/volume of fluid for operation (where different fluid to items 2) and/or 3)), its quality and operating range, including the minimum functional value;
   5) tightness qualification;
   6) mass/volume of fluids per pole to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
   7) number of units in series;
   8) minimum clearances in air:
      – to earth
      – the safety boundaries during a switching operation for transfer switches with external exhaust for ionised gasses or flame;

d) operating mechanism of transfer switch and associated equipment:
   1) type of operating mechanism;
   2) whether the transfer switch is suitable for trip-free or fixed trip operation and whether it is provided with lock-out preventing closing;
   3) rated supply voltage and/or pressure of closing mechanism, pressure limits where different to or expanding data required in c) 4) of 10.3;

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4) current required at rated supply voltage to close the transfer switch;
5) energy expended to close the transfer switch, for example measured as a fall in pressure;
6) rated supply voltage of releases for opening;
7) current required at rated supply voltage for releases for opening;
8) number and type of spare auxiliary switches;
9) current required at rated supply voltage by other auxiliaries;
10) setting of high and low pressure interlocking devices;
11) number of releases for opening, if more than one;
12) 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 transfer switch and details necessary for the design of the foundation.

General information regarding maintenance of the transfer switch 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.

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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 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

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– -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.

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;

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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;
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.

11.4 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

11.5.1 General

The effectiveness of maintenance depends mainly on the way instructions are prepared by the manufacturer and implemented by the user.

After a reclosing operation with arcing (in case of failed commutation operation), the current commutation capability may be impaired due to the internal pollution. In such cases, early maintenance becomes necessary.

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.

a) Extent and frequency of maintenance. For this purpose, the following factors should be considered:

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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.

j) How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

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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.

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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;
   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.

12 Safety

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 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;

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– 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);
– 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;

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– 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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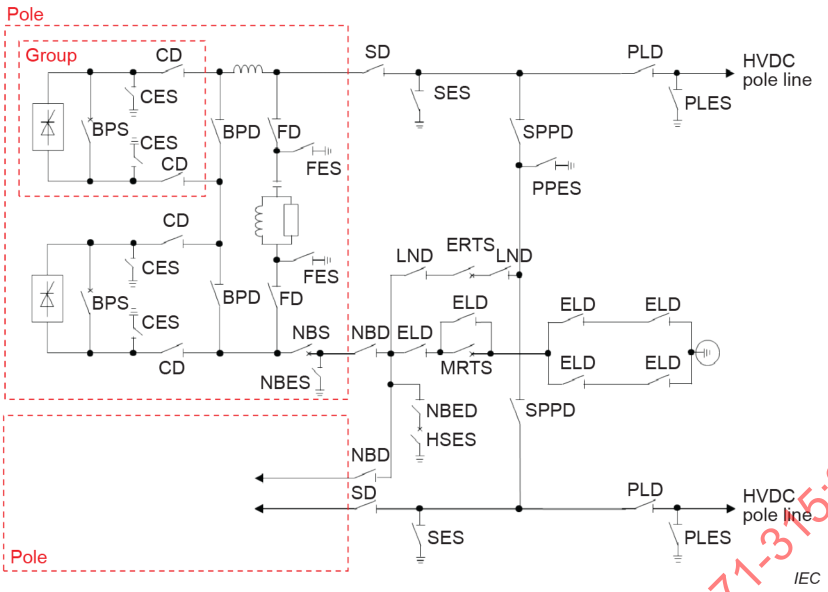
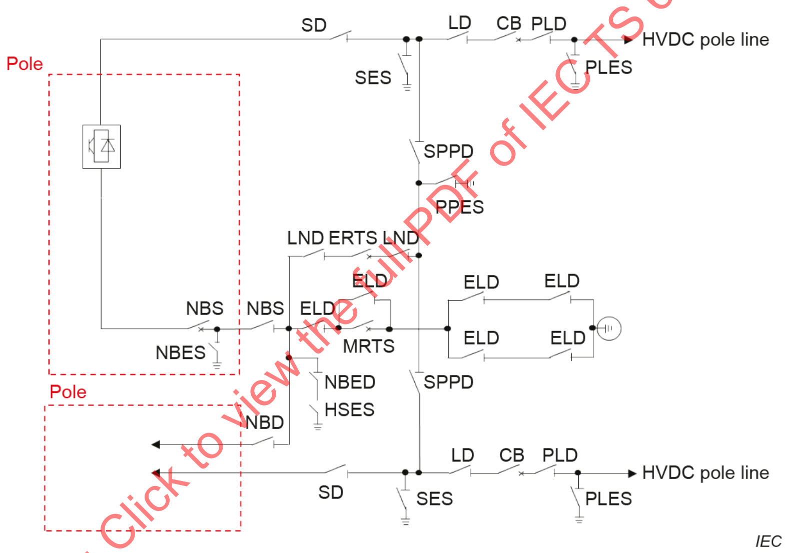


Line Commutated Converter (LCC)



Voltage Sourced Converter (VSC)

Key

CD	Converter Disconnector
BPD	Bypass Disconnector
FD	Filter Disconnector
SD	Substation Disconnector
LD	Line Disconnector
PLD	Pole Line Disconnector
LND	Line to Neutral Disconnector
NBD	Neutral Bus Disconnector
NBED	Neutral Bus Earthing Disconnector
ELD	Electrode Line Disconnector
SPPD	Substation Pole Paralleling Disconnector
PLES	Pole Line Earthing Switch
NBES	Neutral Bus Earthing Switch
FES	Filter Earthing Switch
CES	Converter Earthing Switch
SES	Substation Earthing Switch
PPES	Pole Paralleling Earthing Switch
NBS	Neutral Bus Switch
MRTS	Metallic Return Transfer Switch
ERTS	Earth Return Transfer Switch
BPS	Bypass Switch
HSES	High Speed Earthing Switch
CB	Circuit Breaker

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.

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,

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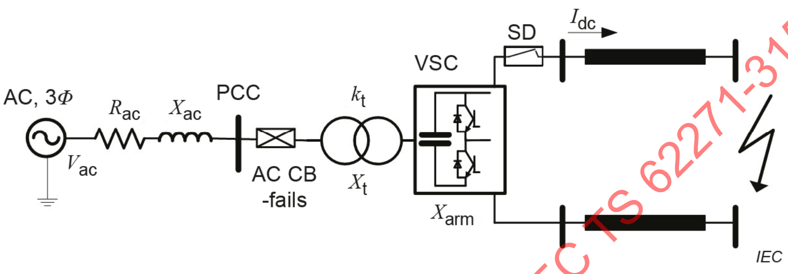
Annex D
(informative)

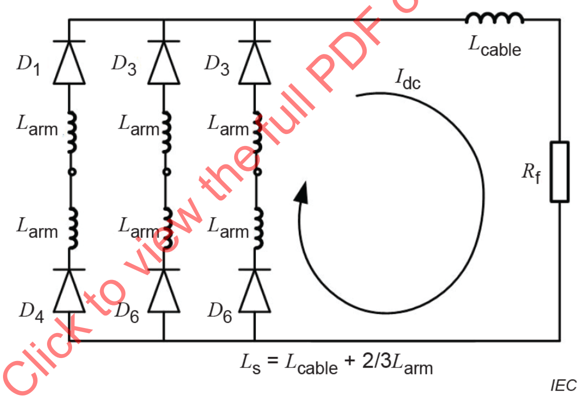
Short-circuit current in HVDC systems

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} = $2\pi f L_{ac}$) 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]):

$$I_f = \frac{6V_{ac} \big/ \left(k_t \sqrt{3}\right)}{\pi \sqrt{\left(R_{ac}\right)^2 + \left(X_{ac} + X_t + k_t^2 X_{arm} \big/ 2\right)^2}} \qquad \text{(D.1)}$$

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).

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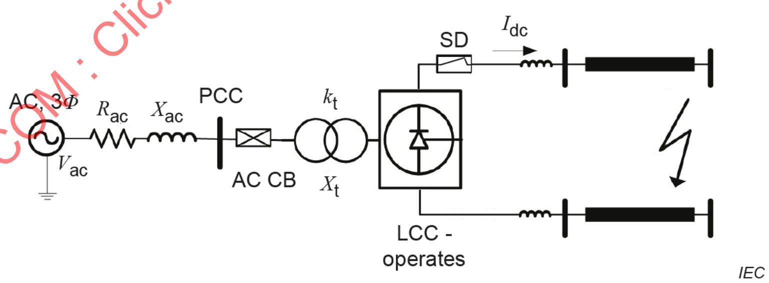


Figure D.2 – LCC HVDC under worst-case, pole-pole DC fault

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.

The diode bridge current feed is determined as:

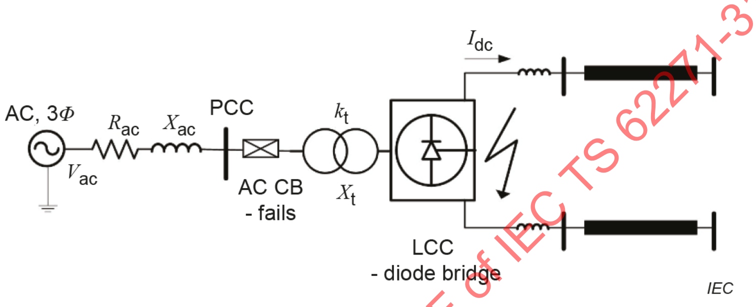
$$I_\mathrm{f} = \frac{6V_\mathrm{ac} / \left(k_\mathrm{t}\sqrt{3}\right)}{\pi\sqrt{\left(R_\mathrm{ac}\right)^2 + \left(X_\mathrm{ac} + X_\mathrm{t}\right)^2}} \tag{D.4}$$

The preferred value for the rated peak withstand current is $10I_\mathrm{rd}$.

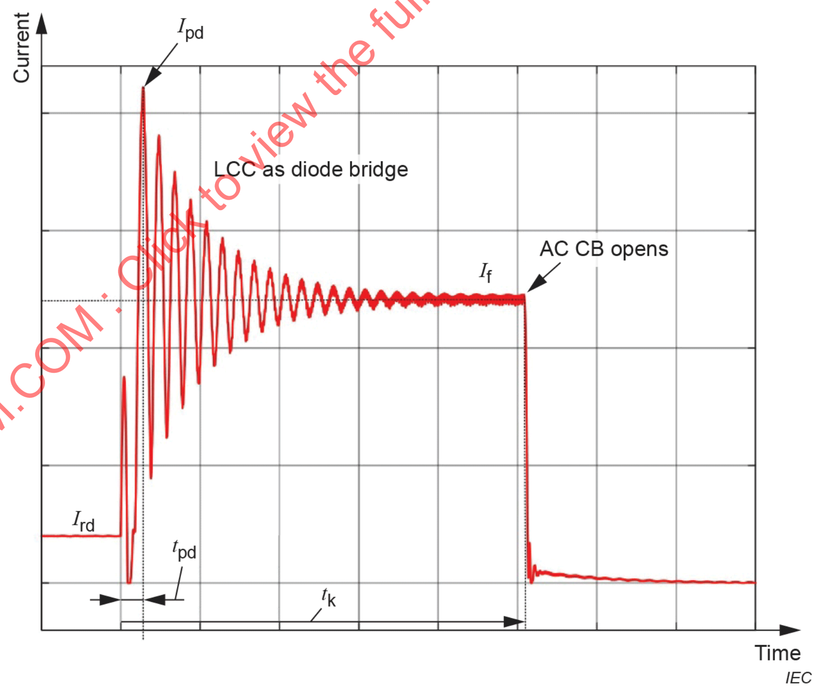
The preferred value for rated duration of short circuit is 0,5 s.

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]).

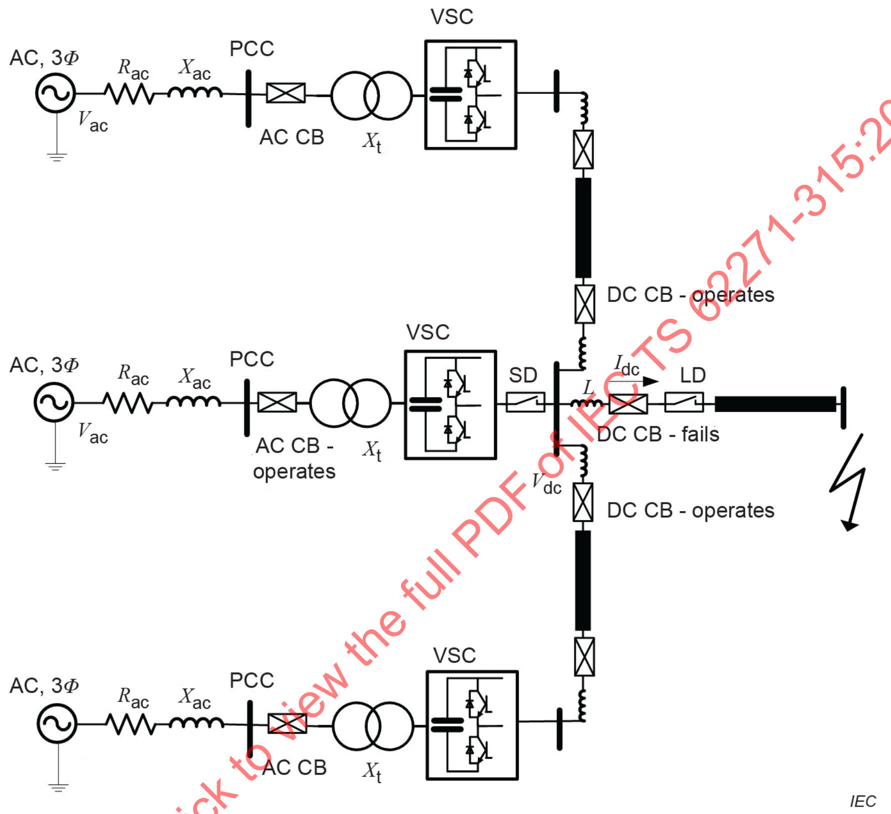

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Figure D.4 – HVDC system with DC circuit-breaker under worst-case, pole-pole DC fault

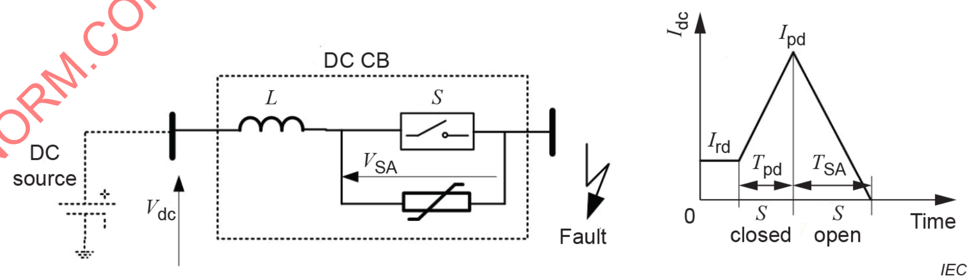

Figure D.5 – DC circuit-breaker simple model

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.

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

$$0{,}1\frac{V_{DC}}{L} < S_{p2} < 0{,}5\frac{V_{DC}}{L} \quad (D.6)$$

Whereas the slope on remaining DC lines will be lower:

$$0{,}05\frac{V_{DC}}{L} < S_{p1} < 0{,}3\frac{V_{DC}}{L} \quad (D.7)$$

The rated duration of short circuit (t_{kd}) is expressed as:

$$t_{kd} = \frac{L + L_s}{R_f} \quad (D.8)$$

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.

$$I_{kd} = \sqrt{E_f / t_{kd}} \quad (D.9)$$

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.

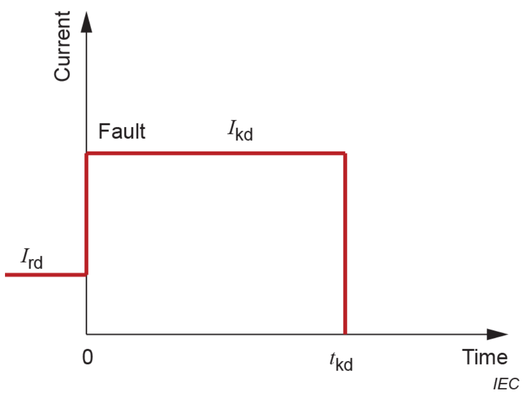

Figure D.6 – Equivalent fault current for calculation of rated short time withstand direct current

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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	$F_{\mathrm{p(liq)}}$	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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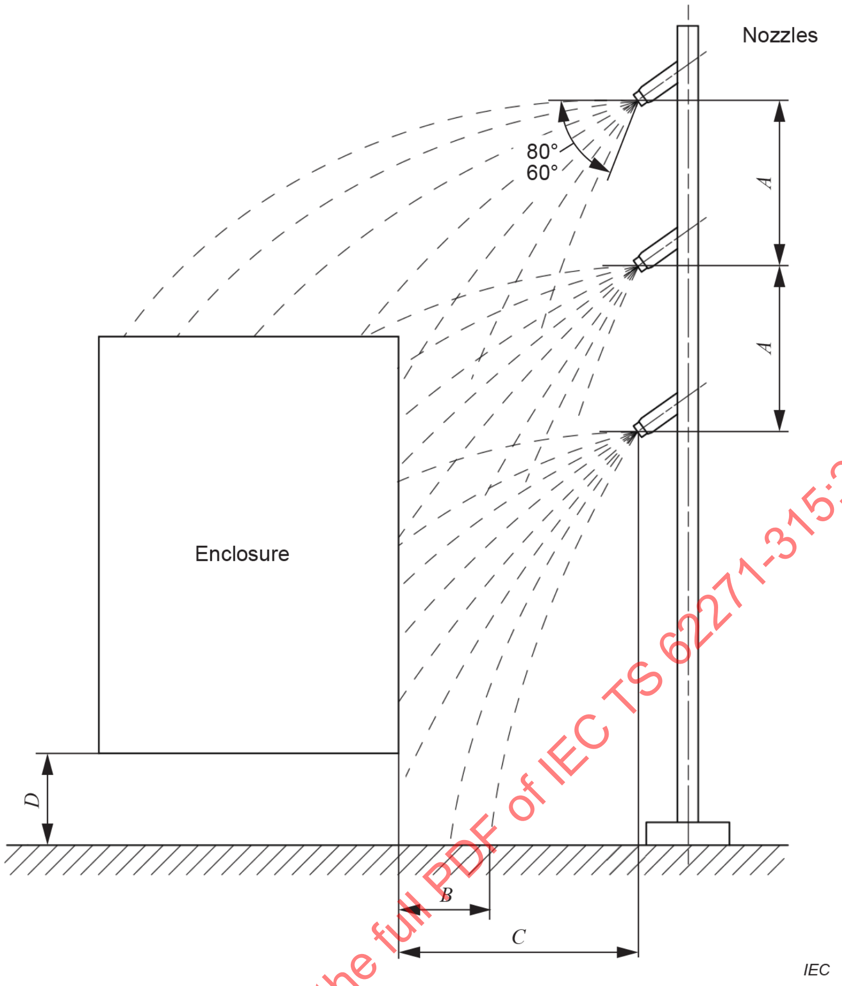

A	About 2 m
B	1 m
C	2,5 m to 3 m
D	Minimum height above floor

Figure G.1 – Arrangement for weatherproofing test

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Dimensions in millimetres

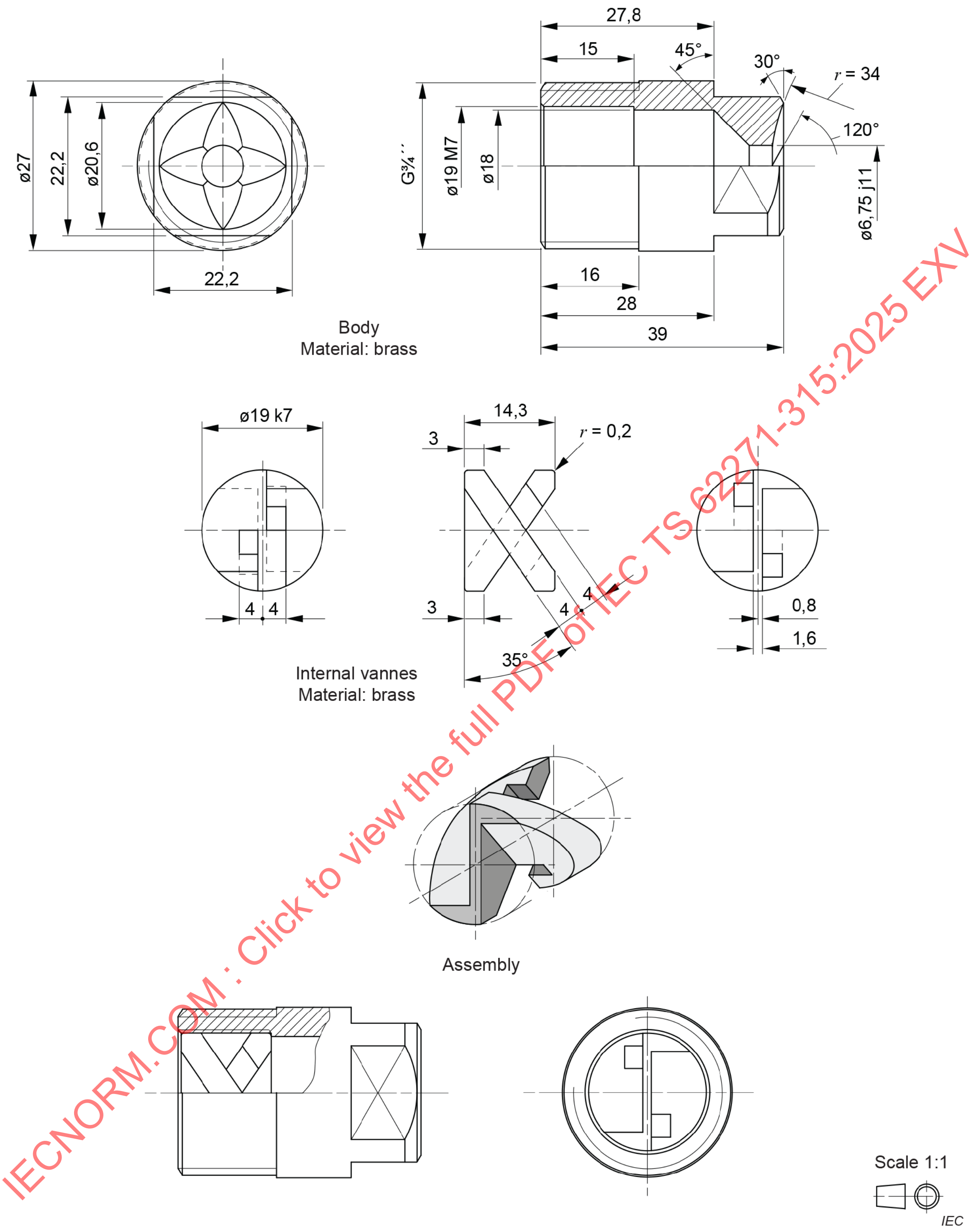

Figure G.2 – Nozzle for weatherproofing test

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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.

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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

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.

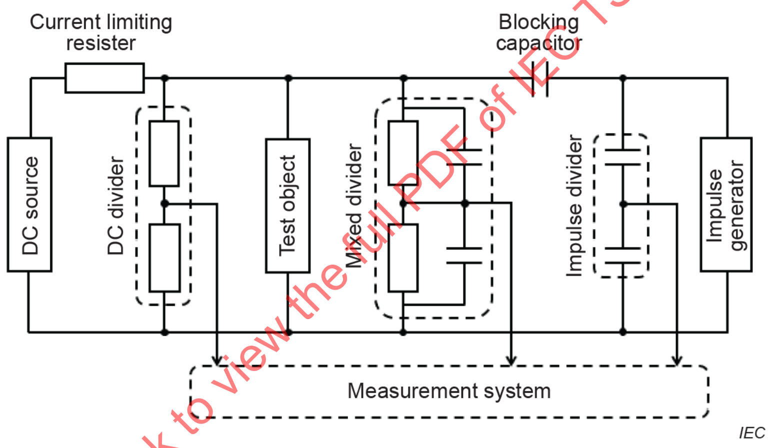

Figure K.1 – Test circuit for superimposed impulse tests using blocking capacitor

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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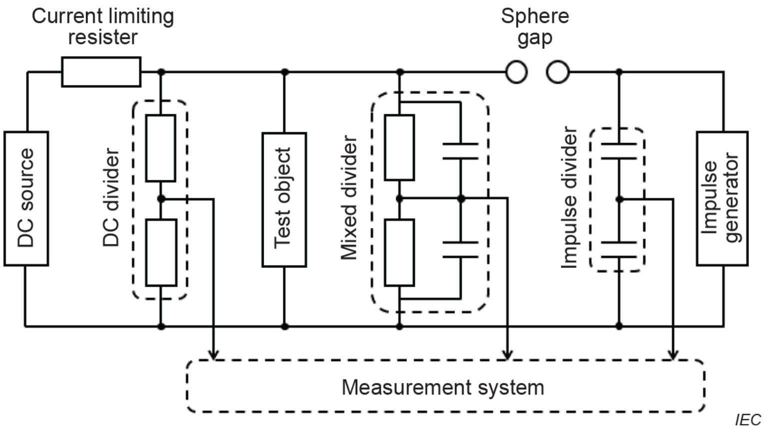

Figure K.2 – Test circuit for superimposed impulse tests using sphere gap

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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)

Test requirements for components of DC transfer switches

A.1 Commutation switch

The type test requirements given in Clause 7, except 7.103, are applicable for commutation switches.

NOTE DC commutation switch normally cannot complete DC commutation test alone.

The routine test requirements given in 8.2 to 8.101 are applicable for commutation switches.

A.2 Making switch

The type test requirements given in Clause 7, except those of 7.4, 7.103 and 7.104, are applicable for making switches.

The routine test requirements given in 8.2 to 8.101 are applicable for making switches.

A.3 Commutation capacitor

Test requirements in IEC 60871 are applicable for commutation capacitor with the following addition.

For the commutation capacitors in passive circuit which will not be exposed to any continuous voltage stresses, the equivalent AC rated voltage of commutation capacitors (U_{R}) could be calculated according to the following equation:

$$U_{\mathrm{R}} = \frac{U_{\mathrm{LIWL}}}{4{,}3 \times S}$$

where

U_{LIWL} is the lightning impulse withstand voltage level across open terminals of DC transfer swithces;

S is the number of capacitor units in series.

Since the capacitors in passive DC transfer switches are not subjected to any continuous duty, the following type tests as specified in IEC 60871-1 do not apply to commutation capacitors of passive DC transfer switches:

– thermal stability test;

– measurement of capacitance and tan δ at elevated temperature;

– aging test.

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A.4 Energy dissipation device

Test requirements in IEC 60099-9 are applicable for energy dissipation devices in DC transfer switches with the following addition.

Since the energy dissipation device is not subjected to any continuous duty, the following type tests as specified in IEC 60099-9 do not apply to the energy dissipation device:

– steep current impulse residual voltage test;
– test to verify long term stability under continuous operating voltage;
– heat dissipation behaviour of test sample;
– test to verify the thermal energy rating, W_{th}.

The test to verify the repetitive charge transfer rating (Q_{rs}) for MRTS and ERTS arresters shall be made by applying two consecutive energy impulses per group. The time between each energy impulses in one group shall be less than 60 s and the time between groups shall be long enough for the test samples to cool down to ambient temperature. The tests shall be carried by applying a total of 200 impulses in 100 groups. In order to shorten the testing duration, the test energy can be raised to 120 % of the required energy in order to reduce the number of impulse groups to 50. The test should be performed on three prorated sections without failure.

A.5 Reactor

Test requirements in IEC 60076-6 are applicable for reactors in DC transfer switches with the following addition.

Since the reactor is not subjected to any continuous duty, temperature rise test as specified in IEC 60076-6 do not apply to the reactor in DC transfer switch.

A.6 Charging device

A.6.1 Type tests for charging device

A.6.1.1 General

The following type tests should be considered as minimum for charging device. If necessary, the supplier shall propose additional type tests and submit detailed test procedures for approval.

A.6.1.2 Lightning impulse voltage test between terminals and earth

The lightning impulse voltage test between terminals and earth should be performed with the standard lightning impulse 1,2/50 µs. The test includes three full voltage impulses and a reduced (50 %) voltage impulse with each polarity. If the waveforms of test voltage and current under full voltage are same as that of 50 % voltage, the device is considered to have passed the test successfully.

A.6.1.3 DC polarity reversal test (dry) with partial discharge measurement

During the test, positive polarity test voltage should be applied to the negative terminal and negative polarity should be applied to the positive terminal. As a result, the voltage on the unconnected terminal is equal to the test voltage plus the rated voltage between terminals.

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At first, a negative direct voltage shall be applied to the positive terminal of the charging device for 60 min. Then the polarity is reversed to positive and kept for a further 60 min. Finally, the polarity is reversed again and negative polarity is applied for 30 min. The measurement of partial discharge shall be performed throughout the test in accordance with Clause 11 of IEC 60270:2000.

Criteria for successful testing shall be the following:

During the final 29 min after the last polarity reverse, the number of the measured partial discharge impulse which is >1 000 pC shall not be more than 29. And the number of the measured partial discharge impulses which is >500 pC shall not be more than 10 in the last 10 min.

Some discharge activity is normal during the polarity reverse. The partial discharge counted during the first 1 min after the last reversal of polarity should be disregarded.

A.6.1.4 Direct voltage test (dry) between terminals and partial discharge measurement

The test duration shall be 60 min. In the last 29 min, the number of the measured partial discharge impulse which is >1 000 pC shall not be more than 29 and the number of the measured partial discharge impulse which is >500 pC shall not be more than 10 in the last 10 min.

A.6.2 Routine test for charging device

A.6.2.1 General

The following routine tests should be considered as minimum for charging device. If necessary, the supplier shall propose additional routine tests and submit detailed test procedures for approval.

A.6.2.2 Functional test

The equipment shall be functionally tested after the high voltage tests. The output signals shall be within the values as specified. The monitoring and control system shall be tested also.

A.6.2.3 Direct voltage withstand test between terminal and earth, dry

The equipment shall be subjected to a 2 min direct voltage withstand test with negative polarity.

The test voltage shall be applied on the positive terminal.

It is not applicable to type tested units.

A.6.2.4 Direct voltage withstand test between terminals, dry

The equipment shall be subjected to a 2 min direct voltage withstand test with normal polarity.

It is not applicable to type tested units.

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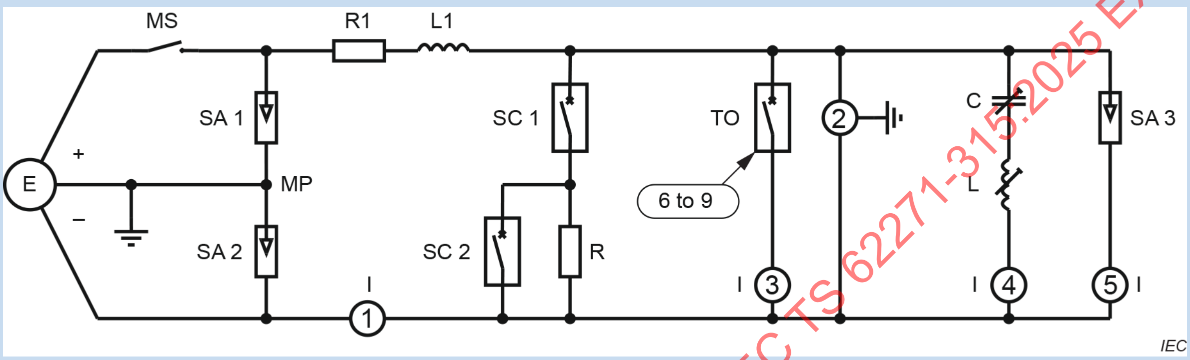
Annex B
(informative)

Additional information about test circuit and measured signals for DC transfer switches having an oscillation branch

B.1 Test circuits for direct current transfer test

Figure B.1 presents a more detailed view of a generic test circuit than in Figure 4 in 7.103.3.



Key

E	DC power supply (six-pulse rectifier)
MS	Make switch
SA 1, SA 2	Surge arrester of power-supply
MP	Middle point
R1, L1	Inductance and resistance of test-circuit
SC1, SC2	Short-circuiting devices (in case of failed test)
R	Damping resistor for short-circuiting device SC 1
TO	Test object (HVDC commutation switch under test)
C, L	Oscillating circuit (adjustable capacitor and reactors)
SA 3	Energy dissipation device of test circuit
I	Current measurements (see Figure B.2 and Figure B.3)
U	Voltage measurements (see Figure B.2 and Figure B.3)
1 to 9	Measuring points (see Figure B.2 and Figure B.3)

Figure B.1 – Test circuit with measuring points

Figure B.2 (overview) and Figure B.3 (expanded view) present the measured signals during test.

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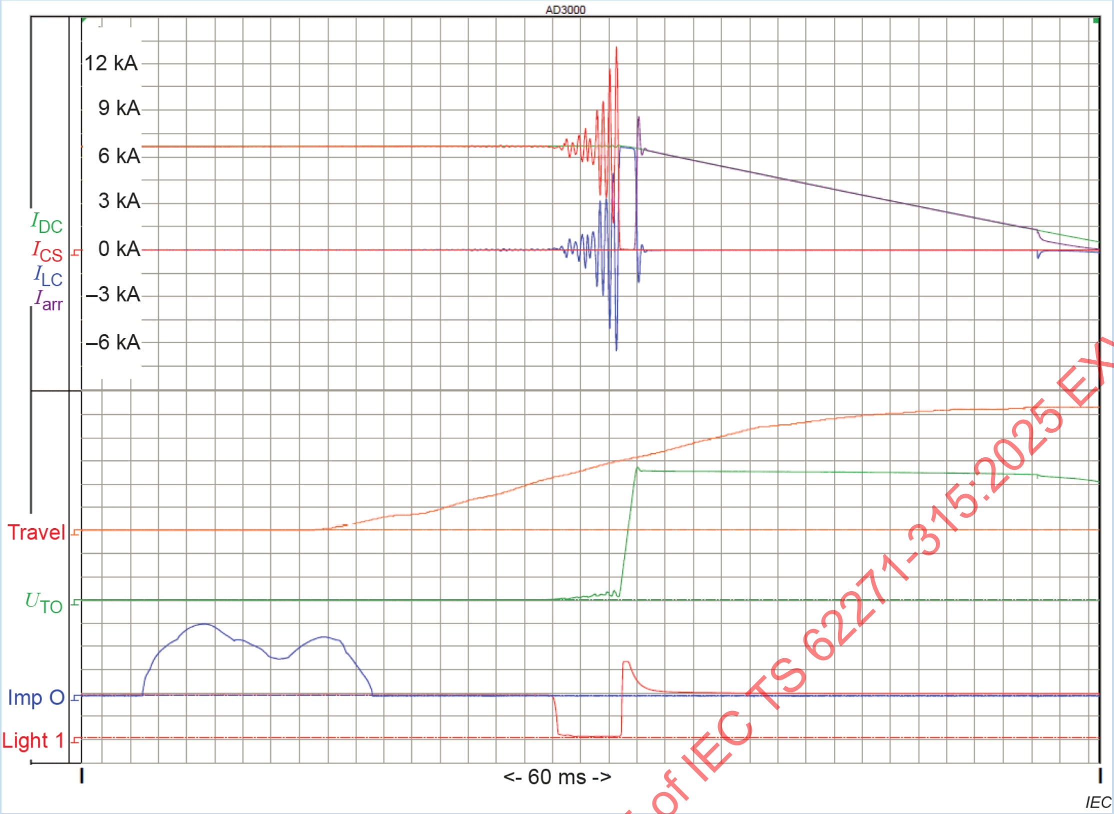

Key

1	Current in main circuit	I_{DC}
2	Voltage across HVDC commutation switch	U_{TO}
3	Current in HVDC commutation switch	I_{CS}
4	Current in oscillating circuit	I_{LC}
5	Current in energy dissipation device	I_{arr}
6	Contact travel of HVDC commutation switch	travel
7	Closing command for HVDC commutation switch	Imp C (not shown)
8	Opening command for HVDC commutation switch	Imp O
9	Arc detection of HVDC commutation switch	Light 1

Figure B.2 – Measured signals during test (overview)

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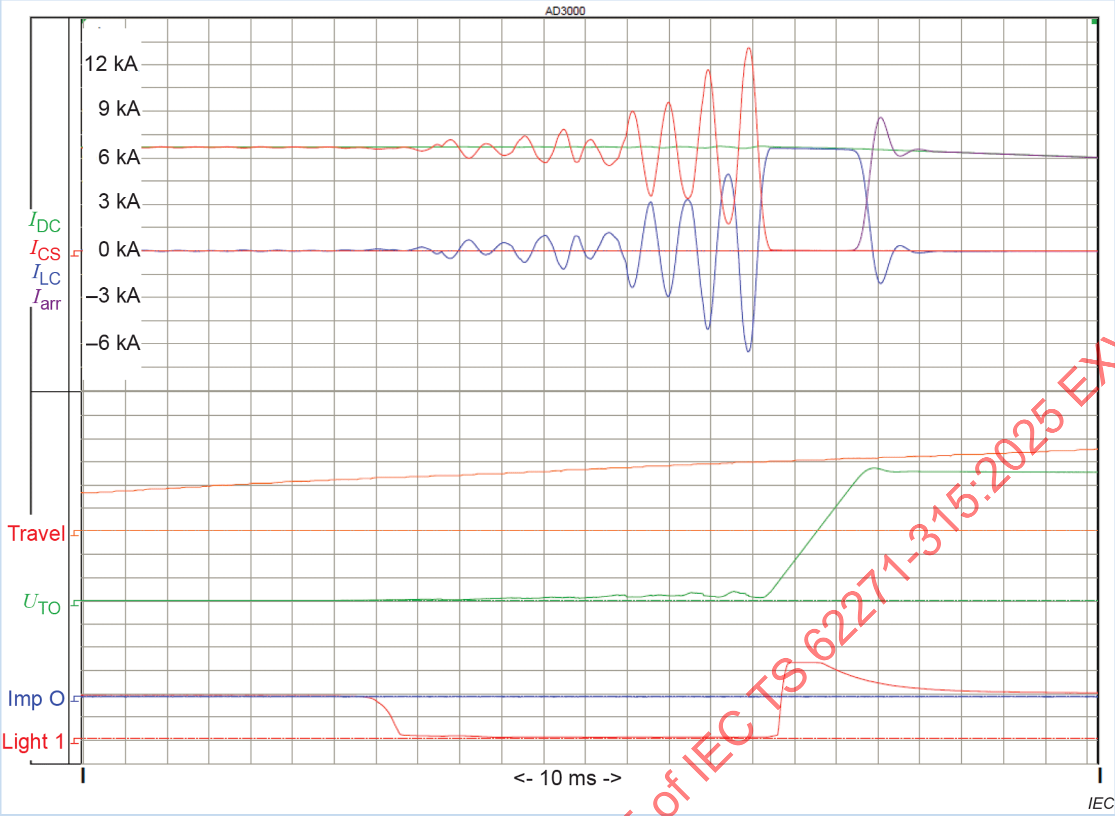

Key

1	Current in main circuit	I_{DC}
2	Voltage across HVDC commutation switch	U_{TO}
3	Current in HVDC commutation switch	I_{CS}
4	Current in oscillating circuit	I_{LC}
5	Current in energy dissipation device	I_{arr}
6	Contact travel of HVDC commutation switch	travel
7	Closing command for HVDC commutation switch	Imp C (not shown)
8	Opening command for HVDC commutation switch	Imp O
9	Arc detection of HVDC commutation switch	Light 1

Figure B.3 – Measured signals during test (expanded in time)

B.2 Test circuits for direct arc withstand test

Figure B.4 presents a more detailed view of a generic test circuit than in Figure 6 in 7.104.3. The measuring points are detailed in Table B.1.

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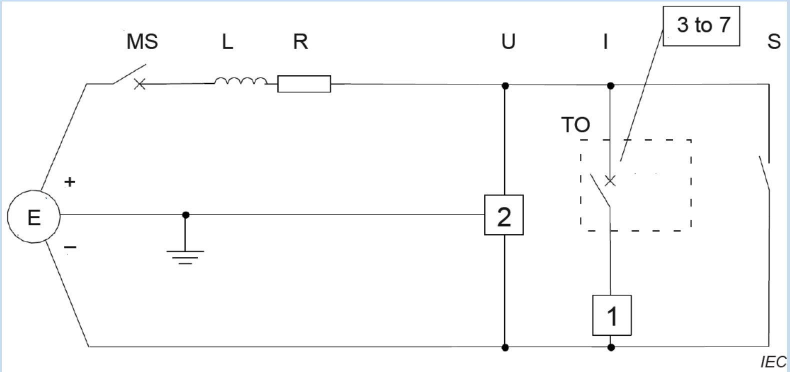

Key

E DC power supply (six-pulse rectifiers in series connection)

MS Making switch

L, R Inductance and resistance of the power supply and of the test installation

TO Test object

S Short-circuit switch

U Voltage measurement

I Current measurement

1 – 7 Measuring points

Figure B.4 – Test circuit of direct arc withstand tests

Table B.1 – Legend of measuring points

Number	Measurement category
1	Current in HVDC commutation switch
2	Voltage across HVDC commutation switch
3	Contact travel of HVDC commutation switch
4	Closing command for HVDC commutation switch
5	Opening command for HVDC commutation switch
6	Arc detection of HVDC commutation switch, channel 1
7	Arc detection of HVDC commutation switch, channel 2

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Annex C
(normative)

Tolerances on test quantities during 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.

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;

where, for any test quantity, no tolerance is given within this standard, 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.

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Table C.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, 7.2.11	Direct voltage tests	Test voltage	Rated direct withstand voltage	±1 %	IEC 60060-1:2010
7.2.7.3	Lightning impulse voltage tests	Peak value	Rated lightning impulse withstand voltage	±3 %	IEC 60060-1:2010
		Front time	1,2 μs	±30 %	
		Time to half-value	50 μs	±20 %	
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	

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
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	Oscillatory wave immunity test	Damped oscillatory wave tests	Test frequency 100 kHz, 1 MHz	±30 %	IEC 61000-4-18:2019
7.9	Auxiliary contact rated short-time withstand current	Test current amplitude		−0 %, +5 %	
		Test current duration		−0 %, +10 %	
	Auxiliary contact breaking capability	Test voltage amplitude		−0 %, +10 %	
		Test current amplitude		−0 %, +5 %	
		Circuit time constant		−0 %, +20 %	
	Cold tests	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-1:2007
	Dry heat test	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-2:2007
	Cyclic humidity test	Minimum temperature of cycle		±3 K	IEC 60068-2-30:2005
		Maximum temperature of cycle		±2 K	
	Vibration response and seismic tests				IEC 60255-21-1:1988
	Power-frequency voltage test	Test voltage (RMS value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1:2010
		Frequency	–	45 Hz to 65 Hz	
		Wave shape	Peak value / RMS value = √2	±5 %	
7.10	Radiation instrument	Accuracy measurement of radiation		±25 %	
	Energy response	Accuracy measurement of energy		±15 %	

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Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.103	Direct current transfer tests	Transfer current	I_C × 10 %	-0 %, +10 %	If applicable
			I_C × 50 %	-0 %, +10 %	If applicable
			I_C × 100 %	-0 %, +5 %	
		Commutation voltage	U_C	±5 %	
7.104	Direct arc withstand tests	Transfer current	I_C	≥ I_C	
		Arcing time	T_{aw}	≥ T_{aw}	

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Annex D
(normative)

Records and reports of type tests

D.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 D.2 shall be made of all operations during direct current commutation and direct arc withstand tests.

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 DC transfer switch during each test-duty and of the condition of the DC transfer switch after each test-duty, in so far as an examination is made, and at the end of the series of test-duties. The statement shall include the following particulars:

a) condition of DC transfer switch, 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 test-duty, including observations regarding emission of oil, gas, or flame.

D.2 Information to be included in type test reports

D.2.1 General

The following general data shall be given:

a) date of tests;
b) reference of report number;
c) test numbers;
d) oscillogram numbers.

D.2.2 Apparatus tested

Subclause 7.1.3 and Annex J of IEC TS 62271-5:2024 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 travel characteristic, if applicable, shall be included or reference shall be made in the test report using a drawing number or in an equivalent way.

D.2.3 Rated characteristics of DC transfer switch, including its operating devices and auxiliary equipment

The values of rated characteristics specified in Clause 5 and the minimum opening time shall be given by the manufacturer.

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D.2.4 Test conditions (for each series of tests)

a) generator neutral (earthed or isolated);
b) diagram of test circuit including connection(s) to earth;
c) details of connection of DC transfer switch to the test circuit (for example orientation);
d) pressure of fluid for insulation and/or commutation;
e) pressure of fluid for operation.

D.2.5 Direct current commutation tests

a) operating sequence and time intervals;
b) applied voltage, in kV;
c) commutation current (peak value, measure before transfer switch), in kA;
   1) at the beginning of arcing phase
   2) at the end of arcing phase
d) commutation voltage;
e) arcing time, in ms;
f) opening time, in ms;
g) commutation-time, in ms;
h) behaviour of DC transfer switch during tests, including, where applicable, emission of flame, gas, oil, etc.; shall be noted;
i) condition after tests;
j) resistance of the main circuit before and after tests, in μΩ.

D.2.6 Direct arc withstand tests

a) operating sequence and time intervals;
b) applied voltage, in kV;
c) test current (peak value), in kA;
   1) at the beginning of arcing phase
   2) at the end of arcing phase
d) arc voltage, peak in kV
e) arcing time, in ms;
f) opening time, in ms;
g) closing time, in ms (if applicable);
h) behaviour of commutation switch during tests, including, where applicable, emission of flame, gas, oil, etc.; shall be noted;
i) condition after tests;
j) resistance of the main circuit before and after tests, in μΩ.

D.2.7 Short-time withstand current test

a) current
   1) RMS value, in kA,
   2) peak value, in kA;
b) duration, in s;
c) behaviour of DC transfer switch during tests;
d) condition after tests;
e) resistance of the circuit before and after tests, in μΩ.

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D.2.8 No-load operation

- Before direct current commutation and direct arc withstand tests;
- After direct current commutation and direct arc withstand tests.

D.2.9 Oscillographic and other records

Oscillograms shall record the whole of the operation. The following quantities shall be recorded. Certain of these quantities can be recorded separately from the oscillograms, and several oscillographs with different time scales can be necessary:

a) applied voltage;
b) current in test circuit and each branch
   1) before transfer switch;
   2) through commutation switch
   3) in energy dissipation branch (if applicable);
   4) in current zero device (if applicable)
c) voltage across transfer switch;
d) current in closing coil;
e) current in opening coil;
f) amplitude and timing scale appropriate for the required accuracy;
g) mechanical travel characteristics (where applicable).

All cases in which the requirements of this document are not strictly complied with and all deviations shall be explicitly mentioned at the beginning of the test report.

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Annex E
(informative)

Extension of validity of type tests

E.1 General

An individual type test need not 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 Clause E.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 Clause E.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.

E.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.

E.3 Continuous current test

A test performed on a single unit covers larger arrangements (i.e. multiple units) provided that the influence with other units is negligible, as it is generally the case for non-enclosed switchgear and controlgear; this provision is applicable, for instance, to some outdoor transmission devices.

E.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 [4] 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.

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E.5 Environmental tests on auxiliary and control circuits

Environmental tests on auxiliary and control circuits need not be repeated if performance requirements are validated during environmental tests on a whole switchgear and controlgear.

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.

E.6 DC transfer current test

Type tests are still valid also if values of capacitance and inductance of oscillating branch in specific application differ from tested valued not exceeding tolerance window of ±3% for capacitors and ±5 % for reactors.

Type tested DC transfer switches are suitable for current transfer operations up to the tested values using the same equipment or parameters as during the test. Therefore, the commutation switch (represented by its arcing voltage capability) and the capacitance and inductance of the oscillation branch are fixed parameters for an application. Nevertheless, the amount of energy to dissipate and the voltage stresses of the components vary in different applications.

Network calculation/simulation can be performed to determine these parameters. Additional current transfer tests on the complete DC transfer switch could be omitted if:

– the transfer current in simulation is less than the minimum transfer current during type test;
– the voltage across open commutation switch in simulation is less as in type test;
– the energy dissipation capability of energy dissipation devices for application will be set to a higher value than calculated;
– the dielectric performance of any component is tested according to the results of calculation/simulation.

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IEC TS 62271-315

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TECHNICAL SPECIFICATION

High-voltage switchgear and controlgear –
Part 315: Direct current (DC) transfer switches

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 315: Direct current (DC) transfer switches

FOREWORD

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IEC TS 62271-315 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/1412/DTS	17A/1417/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 is to be read in conjunction with IEC TS 62271-5:2024, to which it refers and which is applicable unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC TS 62271-5. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

A list of all parts of IEC 62271 series, 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 315: Direct current (DC) transfer switches

1 Scope

This part of IEC 62271 is applicable to direct current (DC) transfer switches designed for indoor or outdoor installation and for operation on HVDC transmission systems having direct voltages of 100 kV and above.

DC transfer switches normally include metallic return transfer switches (MRTS), earth return transfer switches (ERTS), neutral bus switches (NBS) and neutral bus earthing switches (NBES).

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 60060-1:2010, *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*

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IEC 60076-6, *Power transformers– Part 6: Reactors*

IEC 60099-9, *Surge arresters – Part 9: Metal-oxide surge arresters without gaps for HVDC converter stations*

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

IEC 62271-207, *High-voltage switchgear and controlgear – Part 207: Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV*

IEC TS 63014-1, *High-voltage direct current (HVDC) power transmission – System requirements for DC-side equipment Part 1: Using line-commutated converters*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in in IEC 60633, IEC TS 63014-1 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

3.1 General terms and definitions

Subclause 3.1 of IEC TS 62271-5:2024 is applicable.

3.2 Assemblies of switchgear and controlgear

Subclause 3.2 of IEC TS 62271-5:2024 is applicable.

3.3 Parts of assemblies

Subclause 3.3 of IEC TS 62271-5:2024 is applicable.

3.4 Switching devices

Subclause 3.4 of IEC TS 62271-5:2024 is applicable with the following additions:

3.4.101
active DC transfer switch
DC transfer switch with charging device in oscillating branch, installed in parallel to the commutation switch

3.4.102
blank DC transfer switch
DC transfer switch with a sole commutation switch only, without any additional external branches or components

Note 1 to entry: Some commutation switches use internal components to increase voltage drop across the switching units during transfer operation.

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3.4.103
passive DC transfer switch
DC transfer switch without charging device in oscillating branch, installed in parallel to the commutation switch

3.4.104
earth return transfer switch
ERTS
DC transfer switch used to transfer direct current from a metallic return path to an earth return path

Note 1 to entry: “DC transfer switch” is used instead of “DC commutation switch” to refer to whole switch, including oscillating branch and energy dissipation branch.

Note 2 to entry: Although the term “earth return transfer breaker” (ERTB) has been widely used in the industry for many years, it is misleading since such switches have no ability to interrupt fault current.

[SOURCE: IEC 60633:2019, 9.23, modified – The terms “earth return transfer breaker” and “ERTB” have been removed, “DC commutation switch” has been replaced by “DC transfer switch”, DC current is replaced by direct current, Note 1 to entry and reference to Figure 7 have been deleted.]

3.4.105
metallic return transfer switch
MRTS
DC transfer switch used to transfer direct current from an earth return path to a metallic return path

Note 1 to entry: “DC transfer switch” is used instead of “DC commutation switch” to refer to whole switch, including oscillating branch and energy dissipation branch.

Note 2 to entry: Although the term “metal return transfer breaker” (MRTB) has been widely used in the industry for many years, it is misleading since such switches have no ability to interrupt fault current.

[SOURCE: IEC 60633:2019, 9.22, modified – The terms “metallic return transfer breaker” and “MRTB” have been removed, “DC commutation switch” has been replaced by “DC transfer switch”, DC current is replaced by direct current, Note 1 to entry is moved to Note 2, and reference to Figure 7 has been deleted.]

3.4.106
neutral bus switch
NBS
DC transfer switch connected in series with the neutral bus on a bipolar HVDC scheme, designed to commutate current out of the pole conductor or neutral bus and into the electrode line or dedicated metallic return conductor or earth e.g. in response to a fault in a converter or neutral bus

Note 1 to entry: “DC transfer switch” is used instead of “DC commutation switch” to refer to whole switch, including oscillating branch and energy dissipation branch.

[SOURCE: IEC 60633:2019, 9.26, modified, “DC commutation switch” has been replaced by “DC transfer switch” and Note 1 has been replaced by a new Note 1.]

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3.4.107
neutral bus earthing switch
NBES
DC transfer switch connected from the neutral bus to the station earth mat on a bipolar HVDC scheme, designed to provide a temporary earth connection, e.g. in the event of an open circuit fault on the electrode line until the imbalance of current between the two poles can be reduced to a safe minimum level or the electrode line connection can be restored

Note 1 to entry: Although the term “Neutral Bus Grounding Switch” (NBGS) has been widely used in the industry for many years.

Note 2 to entry: In some applications, NBES and high-speed earthing switch (HSES) are used in series.

[SOURCE: IEC 60633:2019, 9.27, modified – The terms “neutral bus grounding switch” and “NBGS” have been removed, “DC commutation switch” has been replaced by “DC transfer switch”, Note 1 and Note 2 have been replaced by new notes.]

3.5 Parts of switchgear and controlgear

Subclause 3.5 of IEC TS 62271-5:2024 is applicable with the following additions:

3.5.101
commutation switch
mechanical switching device used in the main current path of DC transfer switches

Note 1 to entry: A single pole of an AC circuit-breaker or its modification was often used as commutation switch in DC transfer switch.

Note 2 to entry: Some commutation switches use internal components to increase voltage drop across the switching units during transfer operation.

3.5.102
oscillating branch
circuit in parallel with the commutation switch in DC transfer switches, consisting of

– capacitors and reactors, in case of passive DC transfer switches;
– capacitors including a charging device and a making switch, in case of active DC transfer switches.

Note 1 to entry: The oscillating branch forces a current oscillation between itself and the commutation switch branch in order to produce current zeros in the last one.

Note 2 to entry: Depending on the stray inductance of the arrangement reactors are not necessarily needed to be installed.

Note 3 to entry: Passive DC transfer switches having a making device in series with the oscillating branch are also known.

3.5.103
current zero device
oscillating circuit in case of passive DC transfer switch or current impulse generator in case of active DC transfer switch

3.5.104
energy dissipation branch
impedance circuit in parallel with the commutation switch of DC transfer switches which dissipates the energy stored in the energy storage components (e.g. reactors, stray inductance, stray capacitance, etc.) in DC system after successful commutation of current from commutation switch branch to oscillating branch

Note 1 to entry: In real transfer switch, metal oxide surge arrester commonly is used as energy dissipation device.

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3.5.105
charging device
device used in active DC transfer switches to charge capacitors in current zero device

3.5.106
making switch
mechanical switch in series with oscillating branch or current injection branch, designed for fast closing

Note 1 to entry: A making switch is used to close the oscillation branch to excite oscillation during current transfer operation.

3.5.107
platform
support for the oscillating branch and the energy dissipation branch

Note 1 to entry: Two versions are known:

- insulated platform with certain insulation level to earth;
- earthed platform.

3.6 Operational characteristics of DC transfer switches

Subclause 3.6 of IEC TS 62271-5:2024 is applicable.

3.7 Characteristic quantities

Subclause 3.7 of IEC TS 62271-5:2024 is applicable with the following additions:

3.7.101
initiation of (opening or closing) operation
instant of receipt of command for operation at the control circuit

[SOURCE: IEC 62271-100:2021, 3.7.153]

3.7.102
opening time
<of 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

[SOURCE: IEC 60050-441:1984, 441-17-36, modified – “in all poles” and the Note to entry have been deleted.]

3.7.103
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 words “(of a pole or a fuse)” has been removed from the term and from the definition itself.]

3.7.104
commutation time
interval of time between the beginning of the opening time of the commutation switch and the end of the arcing time

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3.7.105
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 – The words “in all poles” have been removed at the end of the definition.]

3.7.106
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 cycle

3.7.107
arcing withstand capability
maximum duration of commutation switches capable of withstanding an arc with specified current in case of an unsuccessful commutation

Note 1 to entry: This time shall include the open-close time of commutation switch and the time delay of control and protection system.

3.7.108
continuous current
direct current flowing through DC transfer switches with the DC transmission system operating

3.7.109
transfer current
direct current which the DC transfer switch is able to transfer in an adjacent return path

3.7.110
commutation voltage
transient voltage across the terminals of a DC transfer switch during the current commutation process, describing the time development of the voltage

Note 1 to entry: The commutation voltage depends mainly on the characteristics of the DC transfer switch and is characterised by two effects. Until arc extinguishing in the commutation switch the commutation voltage is equal to its arcing voltage, after arc extinguishing the commutation voltage is equal to the charging voltage of current zero device and will be limited in peak by the energy dissipation device.

Note 2 to entry: The value of commutation voltage at the end of commutation process depends on the HVDC transmission system and is equal to the voltage drop across the current path to which the current was transferred.

3.8 Index of definitions

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4 Normal and special service conditions

Clause 4 of IEC TS 62271-5:2024 is applicable.

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5 Ratings

5.1 General

Subclause 5.1 of IEC TS 62271-5:2024 is applicable with the following additions:

j) rated direct voltage of transfer switch (U_{rts});

k) rated transfer current (I_t);

l) rated commutation voltage (U_c);

m) rated dissipated energy during transfer operation (E_{rd});

n) rated operating sequence;

o) rated open-close time.

5.2 Rated direct voltage (U_{rd})

Subclause 5.2 of IEC TS 62271-5:2024 is not applicable and is replaced by 5.101: Rated direct voltage of transfer switch (U_{rts}).

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

Subclause 5.3 of IEC TS 62271-5:2024 is not applicable.

The insulation levels for transfer switches shall be selected from the values given in Table 1.

Withstand values given in Table 1 cover the application of transfer switches under normal service conditions defined in 4.1 of IEC TS 62271-5:2024 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 60071-11:2022. For special service conditions, refer to IEC TR 62271-306 [1][1].

NOTE According to IEC 60071-11:2022 the insulation levels in Table 1 cover the temperature range of −40 °C up to 40 °C.

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

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

Table 1 – Rated insulation levels for transfer switches

Rated direct voltage of transfer switch U_{rts} kV	Rated direct withstand voltage U_{dd} kV	Rated lightning impulse withstand voltage U_{p} kV
	Terminal-to-earth and across open transfer switch	Terminal-to-earth and across open transfer switch
(1)	(2)	(3)
5	7,5	60
10	15	95
25	37,5	200
50	75	325
75	112,5	450
100	150	550
150	225	650
200	300	750

5.4 Rated continuous current (I_{rd})

Subclause 5.4 of IEC TS 62271-5:2024 is applicable.

5.5 Rated values of short-time withstand current

5.5.1 Typical waveform of short-circuit current

Subclause 5.5.1 of IEC TS 62271-5:2024 is applicable.

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

Subclause 5.5.2 of IEC TS 62271-5:2024 is applicable.

5.5.3 Rated peak withstand current (I_{pd})

Subclause 5.5.3 of IEC TS 62271-5:2024 is applicable.

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

Subclause 5.5.4 of IEC TS 62271-5:2024 is applicable.

5.6 Rated supply voltage of auxiliary and control circuits (U_{a})

5.6.1 General

Subclause 5.6.1 of IEC TS 62271-5:2024 is applicable.

5.6.2 Rated supply voltage (U_{a})

Subclause 5.6.2 of IEC TS 62271-5:2024 is applicable.

5.7 Rated supply frequency of auxiliary and control circuits

Subclause 5.7 of IEC TS 62271-5:2024 is applicable.

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5.8 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.8 of IEC TS 62271-5:2024 is applicable.

5.101 Rated direct voltage of transfer switch (U_{rts})

The rated direct voltage of transfer switch (U_{rts}) is the highest direct voltage terminal-to-earth that includes harmonics for which the transfer switch is designed in respect of its insulation as well as other characteristics, to operate as specified for indefinite period of time (lifetime).

NOTE 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.

The rated direct voltages of transfer switch are 5 kV – 10 kV – 25 kV – 50 kV – 75 kV – 100 kV – 150 kV – 200 kV.

5.102 Rated transfer current (I_t)

The values of rated transfer current should be selected from the R10 series, specified in IEC 60059 [2].

NOTE 1 The R10 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 For certain projects or special applications other values than from R10 series could be chosen by agreement between manufacturer and user.

5.103 Rated commutation voltage (U_c)

The rated commutation voltage is the highest voltage which the transfer switch shall be capable of withstanding after commutating the current into the oscillating branch or after extinguishing the arc inside of the commutation switch.

NOTE 1 The rated commutation voltage of a transfer switch will be defined by its energy dissipation branch.

NOTE 2 Specific ratings can generally not be assigned because they are specific parameters to each project. The commutation voltage for each transfer switch in a specific project will be defined by system studies.

As an estimation the rated commutation voltage could be calculated from the rated voltage of transfer switch (U_{rts}) multiplied with a factor of 1,2.

NOTE 3 The rated commutation voltage is the determining factor for successful current commutation. Lower or higher factors than 1,2 between U_c and the U_{rts} at location of installation could arise for specific applications. In existing projects, this factor is mostly between 0,6 and 2,5. Further information can be found in Clause 9.

5.104 Rated dissipated energy during transfer operation (E_{rd})

The rated dissipated energy during transfer operation is the highest amount of energy which the energy dissipation device inside the DC transfer switch can manage in a single operating sequence without sustained deterioration. The value will be stated by the manufacturer of DC transfer switch according to the requirements at location of installation, usually based on system studies.

NOTE 1 The rated dissipated energy during transfer operation of a DC transfer switch normally regards to the energy dissipation device or the current limitation branch.

NOTE 2 The rated dissipated energy during transfer operation should be higher than the maximum energy which the transmission system could supply during current transfer operation at location of installation of DC transfer switch.

NOTE 3 Depending on the margin between the rated dissipated energy during transfer operation and the maximum energy which the transmission system could supply during current transfer operation at location of installation of DC transfer switch, specific cooling time between two transfer operations has to be considered. Further information should be supplied by the manufacturer.

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5.105 Rated operating sequence

The rated operating sequence of direct current transfer switches are as follows:

a) O – t – C: for ERTS, MRTS and NBES

b) C – 0,1 s – O – t – C: for NBS

NOTE 1 sequence b) gives a typical operating sequence when NBS is used to connect converter neutral to an already energized current return path in a bipolar or DC grid system.

NOTE 2 The final closing operation in each operation sequence is to protect the commutation switch itself in case of unsuccessful transfer operation.

with:

t is more than the rated open-close time and less than T_{aw} (see 6.102.7).

where

– O represents an opening operation;

– C represents a closing operation.

5.106 Rated open-close time

This value shall be provided by manufacturer.

NOTE All ratings except subclause 5.104 are applicable for commutation switches also.

6 Design and construction

6.1 Requirements for liquids in switchgear and controlgear

Subclause 6.1 of IEC TS 62271-5:2024 is applicable.

6.2 Requirements for gases in switchgear and controlgear

Subclause 6.2 of IEC TS 62271-5:2024 is applicable.

6.3 Earthing of switchgear and controlgear

Subclause 6.3 of IEC TS 62271-5:2024 is applicable.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC TS 62271-5:2024 is applicable with the following additions:

– 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 can be the use of series control contacts arranged so that when the transfer switch is closed, the close release control contact ("b" contact or break contact) is open and the open release control contact ("a" contact or make contact) is closed, and when the transfer switch 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 transfer switch at rest, open or closed. The signal shall be sustained;

– connections shall withstand the stresses imposed by the transfer switch, 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, making and commutating and/or insulating and operating media, and be able to switch the loads which are stated by the transfer switch manufacturer;

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– 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 making and commutating and/or insulating and operating media;
– where anti-pumping devices are part of the transfer switch control scheme, they shall act on each control circuit, if more than one is installed.

6.5 Dependent power operation

Subclause 6.5 of IEC TS 62271-5:2024 is applicable with the following addition:

A transfer switch arranged for dependent power operating with external energy supply shall also be capable of closing immediately following the opening according to its rated operating sequence.

6.6 Stored energy operation

Subclause 6.6. of IEC TS 62271-5:2024 is applicable with the following addition:

A transfer switch arranged for stored energy operating shall also be capable of closing immediately following the opening according to its rated operating sequence.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC TS 62271-5:2024 is applicable.

6.8 Manually operated actuators

Subclause 6.8 of IEC TS 62271-5:2024 is not applicable.

6.9 Operation of releases

Subclause 6.9 of IEC TS 62271-5:2024 is applicable.

6.10 Pressure/level indication

Subclause 6.10 of IEC TS 62271-5:2024 is applicable.

6.11 Nameplates

Subclause 6.11 of IEC TS 62271-5:2024 is applicable with the following additions:

The nameplates for all assemblies of the DC transfer switch should be in accordance with their relevant standards. The nameplate of the DC transfer switch, commutation switch and making switch shall be provided at least as the following (see Table 2):

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Table 2 – Nameplate information

Item		Symbol	Unit	(**)			Condition: Marking only required if
				Transfer switch	Commutation switch	Making switch	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Name of manufacturer			X	X	X	
2	Type designation and serial number			X	X	X	
3	Rated direct voltage of transfer switch	U_{rts}	kV	X	X	X	
4	Rated direct withstand voltage	U_{dd}	kV	X	X	X	
5	Rated lightning impulse withstand voltage	U_p	kV	X	X	X	
6	Rated continuous current	I_{rd}	A	X	X		
7	Rated short-time withstand direct current	I_{kd}	kA	X	X		
8	Rated peak withstand current	I_{pd}	kA	X	X		
9	Rated duration of short-circuit	t_{kd}	s	X	X		
10	Rated transfer current	I_t	A	X			
11	Rated commutation voltage	U_c	kV	X	X		
12	Rated dissipated energy during transfer operation	E_{rd}	MJ	X			
13	Filling pressure for insulation(*)	p_e	MPa	X	X	X	
14	Filling pressure for operation(*)	p_m	MPa	X	X	X	
15	Rated supply voltage(s) of auxiliary and control circuits. Specify DC / AC (with rated frequency)	U_a	V	X	X	X	
16	Rated operating sequence			X	X	X	
17	Rated open-close time		ms	X	X		
18	Closing time		ms	X	X	X	
19	Type and mass of fluid (liquid or gas) for insulation	M_f	kg	X	X	X	
20	Mass of switchgear and controlgear (including any fluid)	M	kg	Y	Y	Y	more than 300 kg
21	Year of manufacture			X	X	X	
22	Minimum and maximum ambient air temperature		°C	Y	Y	Y	If 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 (8).

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 appear.

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6.12 Locking devices

Subclause 6.12 of IEC TS 62271-5:2024 is applicable.

6.13 Position indication

Subclause 6.13 of IEC TS 62271-5:2024 is applicable.

6.14 Degrees of protection by enclosures

Subclause 6.14 of IEC TS 62271-5:2024 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC TS 62271-5:2024 is applicable.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC TS 62271-5:2024 is applicable.

6.17 Tightness for liquid system

Subclause 6.17 of IEC TS 62271-5:2024 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC TS 62271-5:2024 is applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC TS 62271-5:2024 is applicable.

6.20 X-ray emission

Subclause 6.20 of IEC TS 62271-5:2024 is applicable.

6.21 Corrosion

Subclause 6.21 of IEC TS 62271-5:2024 is applicable.

6.22 Filling levels for insulation, switching and operation

Subclause 6.22 of IEC TS 62271-5:2024 is applicable.

6.101 Seismic requirement for operation

DC transfer switch shall be able to withstand the specified seismic stress and meet the requirements in IEC 62271-207.

6.102 Commutation switch

Subclauses 6.1 to 6.101 of this specification are applicable with the following additions:

6.102.1 General requirement for operation

A commutation switch, including its operating devices, shall be capable of completing its rated operating sequence 5.105 in accordance with the relevant provisions of 6.5 to 6.10 and 6.102.2 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.

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