

TECHNICAL SPECIFICATION

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

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

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

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

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

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

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

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

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

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

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

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

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

1 Scope

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

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

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

IEC 60480, *Specifications for the re-use of sulphur hexafluoride (SF₆) and its mixtures in electrical equipment*

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

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

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

IEC 62271-102:2018/AMD1:2022

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

3 Terms and definitions

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

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

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

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

3.1 General terms and definitions

3.1.101

switchgear and controlgear

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

[SOURCE: IEC 60050-441:1984, 441-11-01]

3.1.102

indoor switchgear and controlgear

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

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

3.1.103

outdoor switchgear and controlgear

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

[SOURCE: IEC 60050-441:1984, 441-11-05]

3.1.104**ambient air temperature**

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

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

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

3.1.105**temperature rise**

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

3.1.106**external insulation**

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

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

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

3.1.107**internal insulation**

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

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

3.2 Assemblies of switchgear and controlgear

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices**3.4.101****switching device**

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

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

3.4.102**mechanical switching device**

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

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

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

3.4.103

by-pass switch

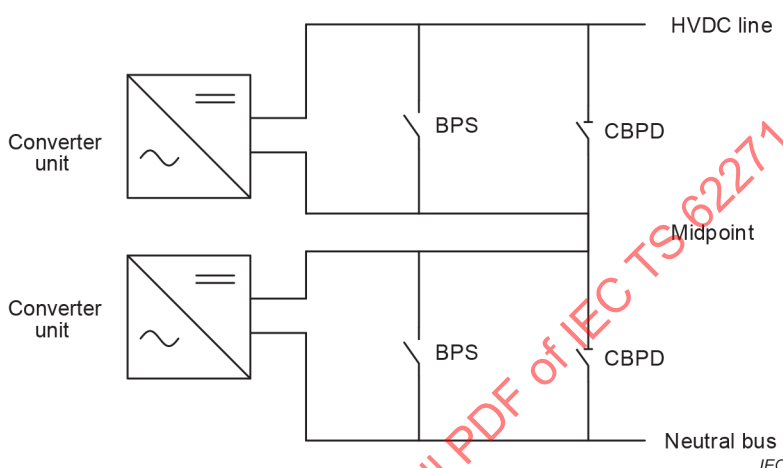
BPS

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

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

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

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



Key

BPS By-pass switch

BPD By-pass disconnector

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

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

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

3.4.104

paralleling switch

PS

mechanical switching device intended for rapid configuration of a HVDC system

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

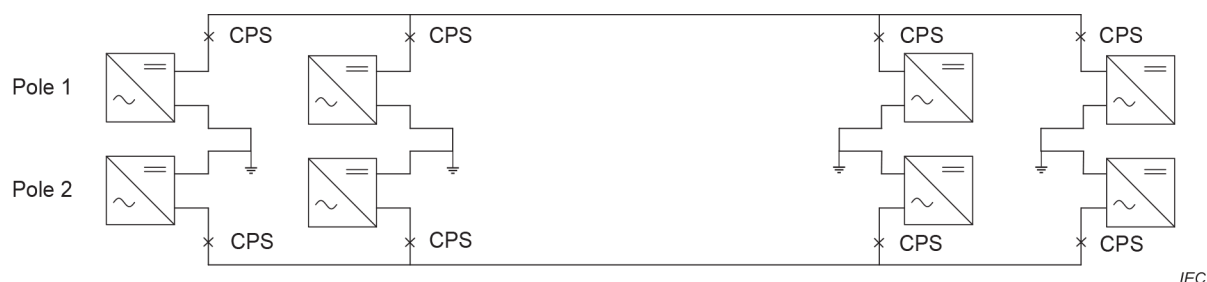
3.4.105

converter paralleling switch

CPS

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

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

**Key**

CPS Converter paralleling switch

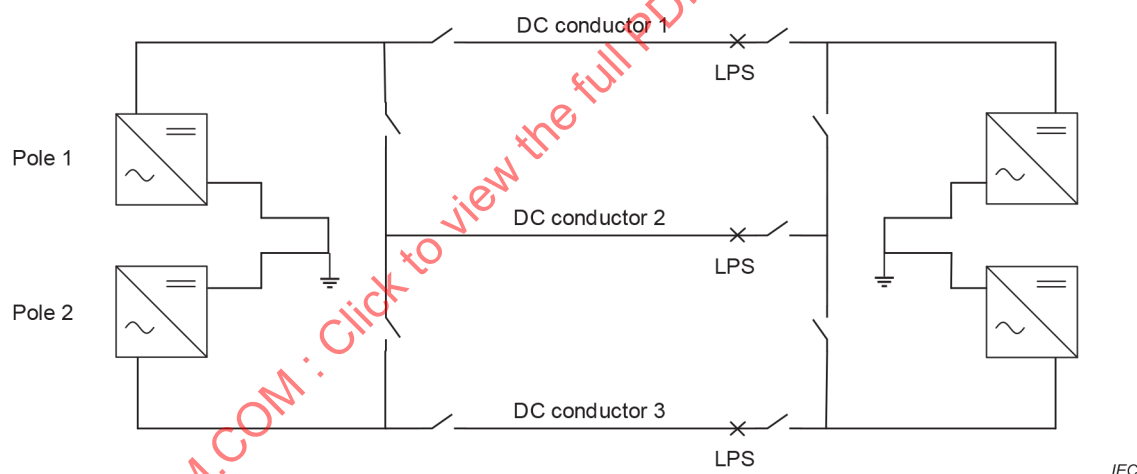
Figure 2 – Example of the location of a CPS in an HVDC transmission system

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

3.4.106**line paralleling switch****LPS**

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

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

**Key**

LPS Line paralleling switch

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

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

3.5 Parts of switchgear and controlgear**3.5.101****main circuit**

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

[SOURCE: IEC 60050-441:1984, 441-15-02]

3.5.102

main contact

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

[SOURCE: IEC 60050-441:1984, 441-15-07]

3.5.103

arcing contact

contact on which the arc is intended to be established

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

[SOURCE: IEC 60050-441:1984, 441-15-08]

3.5.104

"a" contact

make contact

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

[SOURCE: IEC 60050-441:1984, 441-15-12]

3.5.105

"b" contact

break contact

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

[SOURCE: IEC 60050-441:1984, 441-15-13]

3.5.106

release

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

[SOURCE: IEC 60050-441:1984, 441-15-17]

3.5.107

arc control device

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

[SOURCE: IEC 60050-441:1984, 441-15-18]

3.5.108

terminal

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

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

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

**3.5.109
enclosure**

<of an assembly> part of an assembly providing a specified degree of protection of equipment against external influences and a specified degree of protection against approach to or contact with live parts and against contact with moving parts

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

**3.5.110
operating mechanism**

part of the BPS or PS that actuates the main contacts

3.6 Operational characteristics of switchgear and controlgear**3.6.101
operation**

<of a mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a BPS or PS, this may be a closing operation or an opening operation.

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

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

**3.6.102
operating cycle**

<of a mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:1984, 441-16-02]

**3.6.103
operating sequence**

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

[SOURCE: IEC 60050-441:1984, 441-16-03]

**3.6.104
closing operation**

<of a mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:1984, 441-16-08]

**3.6.105
opening operation**

<of a mechanical switching device> operation by which the device is brought from the closed position to the open position

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

3.6.106**dependent power operation**

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

[SOURCE: IEC 60050-441:1984, 441-16-14]

3.6.107**stored energy operation**

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

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

- a) The manner of storing the energy (spring, weight, etc.);
- b) The origin of the energy (manual, electric, etc.);
- c) The manner of releasing the energy (manual, electric, etc.).

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

3.6.108**closed position**

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

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

3.6.109**open position**

<of a mechanical switching device> position in which the predetermined clearance between open contacts in the main circuit of the device is secured

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

3.6.110**shunt release**

release energised by a source of voltage

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

[SOURCE: IEC 60050-441:1984, 441-16-41]

3.6.111**anti-pumping device**

device which

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

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

3.6.112**interlocking device**

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

[SOURCE: IEC 60050-441:1984, 441-16-49]

3.6.113**switching**

making and/or breaking operation of a mechanical switching device

3.7 Characteristic quantities

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

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

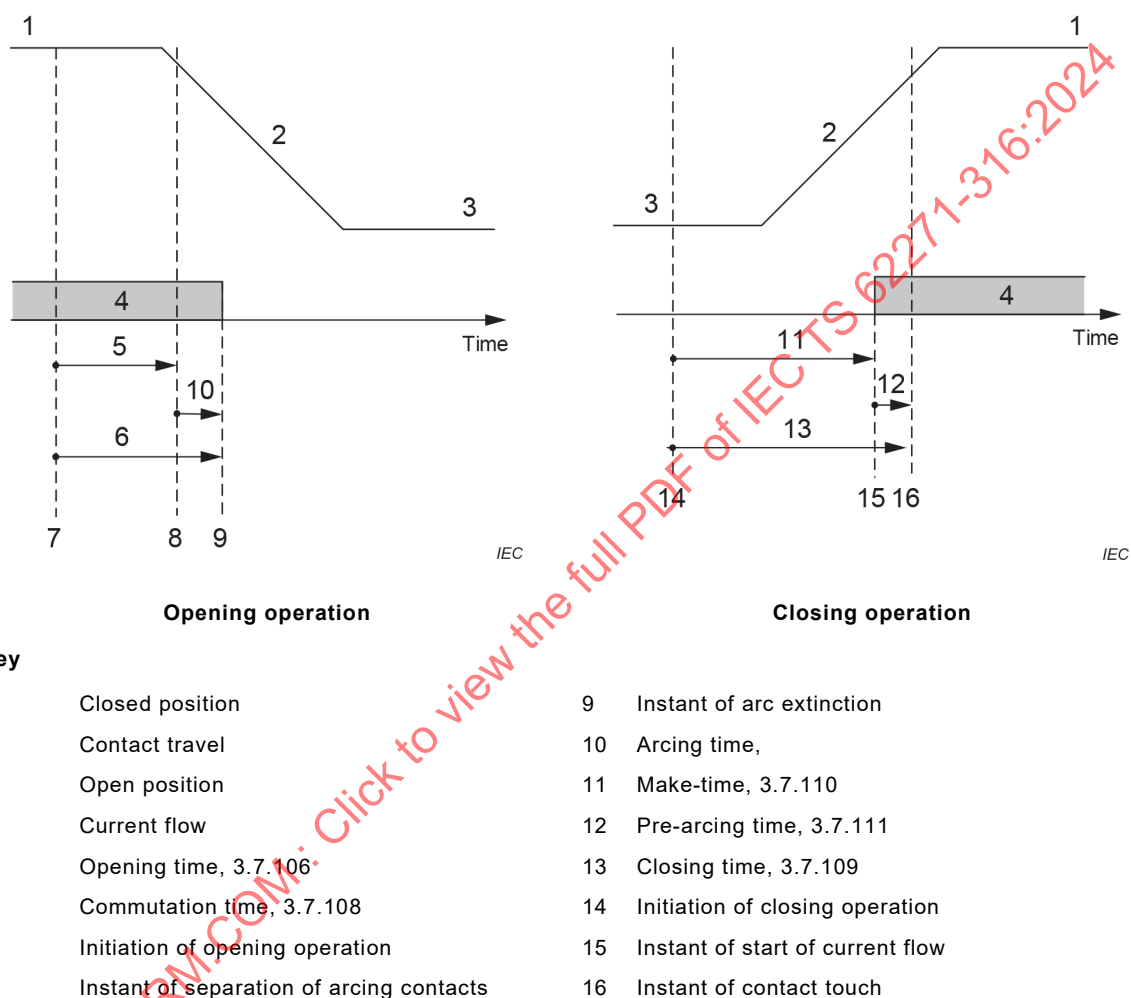
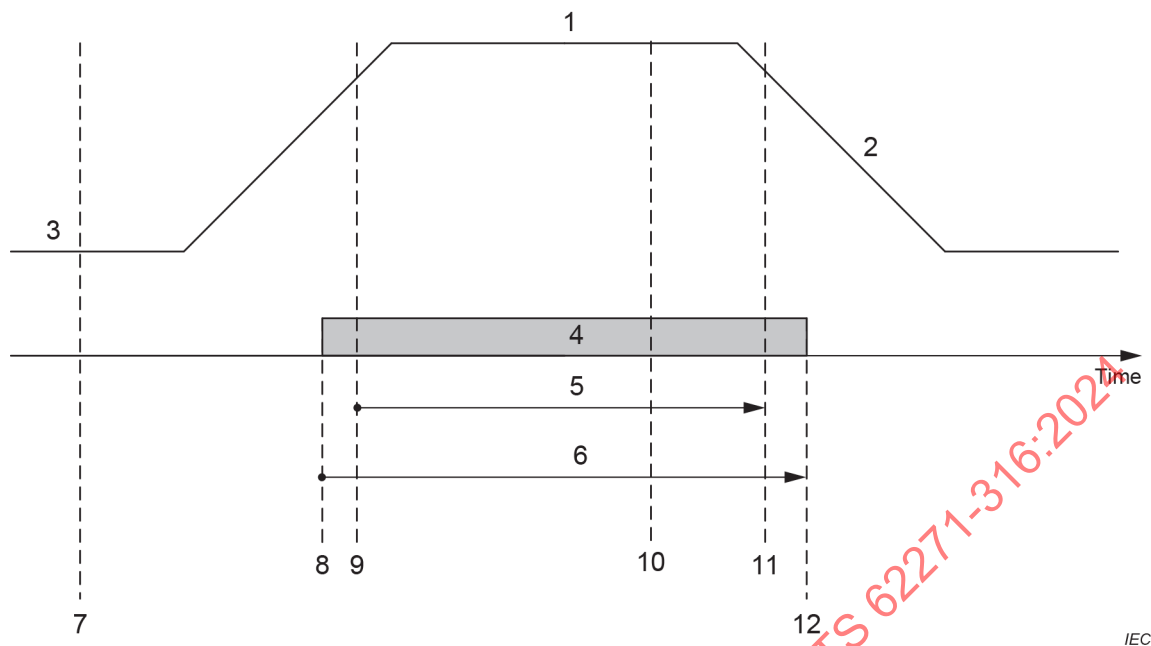


Figure 4 – BPS and PS – Opening and closing operations

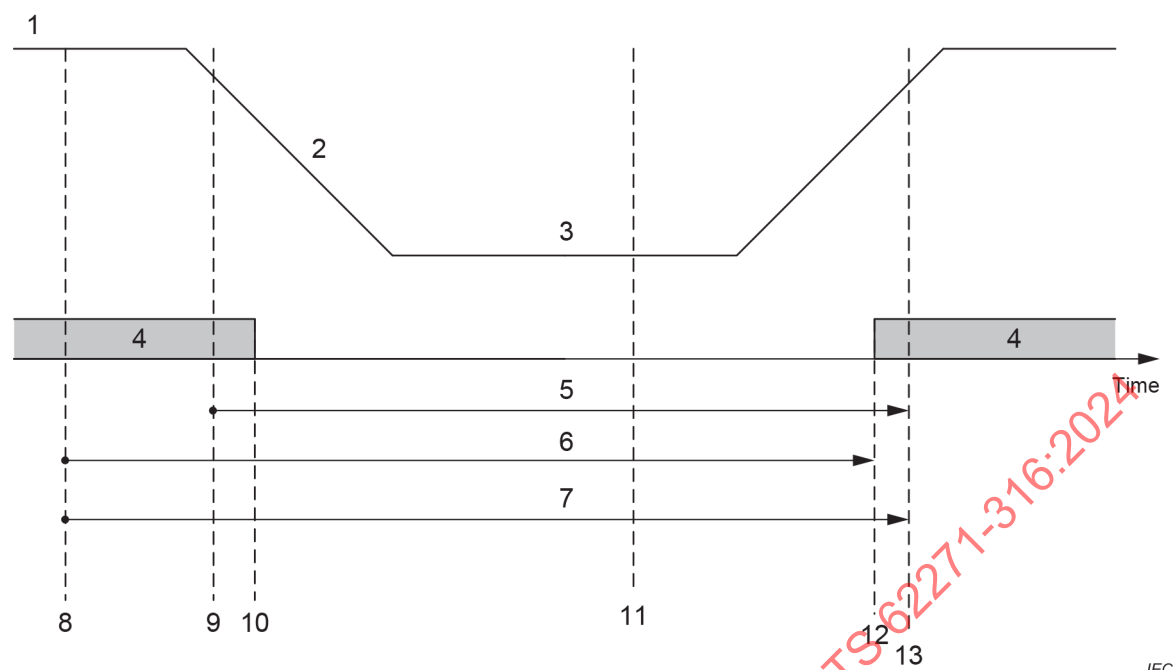


IEC

Key

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

Figure 5 – BPS and PS – Close-open cycle



IEC

Key

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

Figure 6 – BPS and PS – Open-close cycle**3.7.101****rated value**

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

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

3.7.102**short-time withstand current**

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

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

3.7.103**peak withstand current**

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

[SOURCE: IEC 60050-441:1984, 441-17-18]

3.7.104

applied voltage

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

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

3.7.105

clearance

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

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

3.7.106

opening time

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

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

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

3.7.107

arcing time

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

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

3.7.108

commutation time

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

3.7.109

closing time

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

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

3.7.110

make-time

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

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

3.7.111**pre-arcing time**

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

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

3.7.112**close-open time**

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

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

3.7.113**open-close time**

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

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

3.7.114**continuous current**

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

3.7.115**temporary current**

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

3.7.116**insulation level**

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

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

3.7.117**direct withstand voltage**

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

3.7.118**impulse withstand voltage**

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

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

3.7.119

commutation

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

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

[SOURCE: IEC 60633:2019, 5.6]

3.7.120

initiation of (opening or closing) operation

instant of receipt of command for operation at the control circuit

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4 Normal and special service conditions

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

5 Ratings

5.1 General

Subclause 5.1 of IEC TS 62271-5:2024 is replaced by the following.

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

5.1.101 By-pass switches (BPSs)

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

- direct voltage across the open BPS (BPS open). This voltage depends on the number of converter units in series;
direct voltage from terminal to earth (BPS open). This voltage depends on the configuration of the BPS and its connection to the HVDC system. Examples of possible configurations are given in Annex C;
- insulation level (U_{dd} , U_s , U_p). The considerations provided under a) also apply to the insulation level;
- continuous current (I_{rd}) or its temporary current (I_t);
- short-time withstand direct current (I_{kd});
- peak withstand current (I_{pd});
- duration of short-circuit (t_{kd});
- supply voltage of auxiliary and control circuits (U_a);
- supply frequency of auxiliary and control circuits.

5.1.102 Parallelling switches (PSs)

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

- a) direct voltage (U_{rd});
- b) insulation level (U_{dd} , U_s , U_p);
- c) continuous current (I_{rd});
- d) short-time withstand direct current (I_{kd});
- e) peak withstand current (I_{pd});
- f) duration of short-circuit (t_{kd});
- g) supply voltage of auxiliary and control circuits (U_a);
- h) supply frequency of auxiliary and control circuits;
- i) commutation current (for LPS only, see 3.4.106).

5.2 Rated direct voltage (U_{rd})

Subclause 5.2 of IEC TS 62271-5:2024 is applicable with the following addition.

5.2.1 General

Subclause 5.2.1 of IEC TS 62271-5:2024 is applicable with the following addition.

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

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

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

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

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

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

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

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

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

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

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

Subclause 5.3 of IEC TS 62271-5:2024 is applicable with the following addition:

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

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

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

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

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

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

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

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

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

5.4 Rated continuous current (I_{rd})

Subclause 5.4 of IEC TS 62271-5:2024 is applicable with the following addition.

5.4.101 Rated temporary current (I_t)

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

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

5.5 Rated values of short-time withstand current

Subclause 5.5 of IEC TS 62271-5:2024 is applicable.

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

Subclause 5.6 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.

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 commutation current

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

5.102 Rated operating sequence

The operating sequence of a BPS and PS is $C - t - O - t'' - C$, where

O represents an opening operation;

C represents a closing operation;

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

Time t'' is the time required to detect an unsuccessful commutation. t'' is more than the open-close time and less than T_{aw} (see 6.102.7 of IEC TS 62271-315:2024).

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

6 Design and construction

6.1 Requirements for liquids in switchgear and controlgear

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 may be the use of series control contacts arranged so that when the BPS or PS is closed, the close release control contact ("b" contact or break contact) is open and the open release control contact ("a" contact or make contact) is closed, and when the BPS or PS is open, the open release control contact is open and the close release control contact is closed;
- where auxiliary switches are used as position indicators, they shall indicate the end position of the BPS or PS at rest, open or closed. The signalling shall be sustained;
- connections shall withstand the stresses imposed by the BPS or PS, especially those due to mechanical forces during operations;
- where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, switching and/or insulating and operating media, and be able to switch the loads which are stated by the manufacturer of the BPS or PS;
- special items of auxiliary equipment such as liquid indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of interrupting and/or insulating and operating media;
- where anti-pumping devices are part of the BPS or PS control scheme, they shall act on each control circuit, if more than one is installed.

6.5 Dependent power operation

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

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

6.6 Stored energy operation

Subclause 6.6 of IEC TS 62271-5:2024 is applicable with the following addition to the first paragraph of 6.6.1.

A BPS or PS arranged for stored energy closing shall also be capable of closing immediately following the opening operation.

6.7 Independent unlatched operation (independent manual or power operation)

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

6.8 Manually operated actuators

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

6.9 Operation of releases

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

6.10 Pressure/level indication

6.10.1 Gas pressure

Subclause 6.10.1 of IEC TS 62271-5:2024 is applicable with the following addition.

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

6.10.2 Liquid level

Subclause 6.10.2 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 of a BPS or PS and their operating devices shall be marked in accordance with Table 1;
- Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer;
- Releases shall bear the appropriate data.

Table 1 – Nameplate information

	Abbreviation	Unit	BPS	PS	Operating device	Condition: Marking only required if
1	2	3	4	5	6	7
Manufacturer			X	X	X	
Type designation and serial number			X	X	X	
Rated direct voltage	U_{rd}	kV		X		
– To earth ^a	U_{rde}	kV	X	Y		Different from U_{rd}
– Across open switch	U_{rdo}	kV	X	Y		Different from U_{rd}
Rated lightning impulse withstand voltage	U_p	kV		X		
– To earth ^a	U_{pe}	kV	X	Y		Different from U_p
– Across open switch	U_{po}	kV	X	Y		Different from U_p
Rated switching impulse withstand voltage	U_s	kV		X		
– To earth ^a	U_{se}	kV	X	Y		Different from U_s
– Across open switch	U_{so}		X	Y		Different from U_s
Rated direct withstand voltage	U_{dd}	kV		X		
– To earth ^a	U_{dde}		X	Y		Different from U_{dd}
– Across open switch	U_{ddo}		X	Y		Different from U_{dd}
Rated continuous current	I_{rd}	A	Y	X		Rating is assigned
Rated temporary current	I_t	A	X			For BPSs when a temporary current is assigned
Duration of temporary current		min	X			Different from 30 min
Rated short-time withstand direct current	I_{kd}	kA	X	X		
Rated peak withstand current	I_{pd}	kA	X	X		
Rated duration of short-circuit	t_{kd}	s	Y	Y		Different from 1 s
Rated supply voltage of auxiliary and control circuits Specify DC/AC (with rated frequency)	U_a	V Hz			(X)	
Filling pressure for operation	P_m	MPa			(X)	
Filling pressure for insulation and/or switching	P_e	MPa	(X)	(X)		
Mass	M	kg	Y	Y	Y	More than 300 kg
Type and mass of fluid (liquid or gas) for switching	M_f	kg	Y	Y		Contains fluid
Rated operating sequence			X	X		
Year of manufacture			X	X		
Minimum and maximum ambient air temperature			Y	Y	Y	Different from –5 °C and/or 40 °C
Reference to this document			X	X	X	

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

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

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

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

NOTE 1 The abbreviation in column 2 can be used instead of the terms in column 1. When terms in column 1 are used, the word "rated" need not appear.

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

6.12 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 provided 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 with the following addition.

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

6.16 Gas and vacuum tightness

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

6.17 Tightness for liquid systems

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/or operation

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

6.101 Design of BPSs and PSs

6.101.1 BPSs

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

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

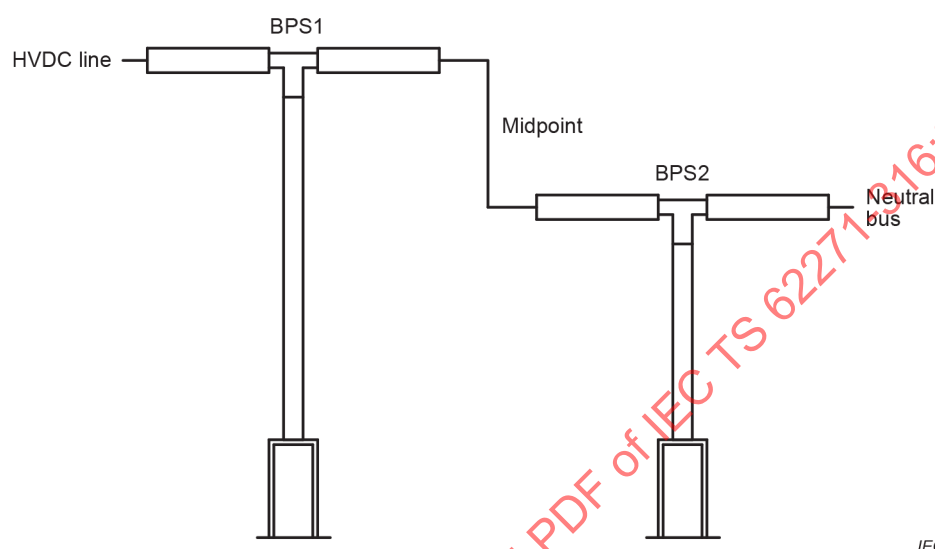


Figure 7 – Example of two series connected BPSs

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

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

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

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

6.101.2 PSs

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

6.102 General requirement for operation

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

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

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

6.103 Pressure limits of fluids for operation

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

6.104 Time quantities

Refer to Figure 4, Figure 5 and Figure 6.

Values may be assigned to the following time quantities:

- opening time (no-load);
- closing time (no-load);
- close-open time (no-load);
- open-close time (no-load)
- commutation time (if applicable, see also 7.102).

Time quantities are based on:

- rated supply voltages of closing and opening devices and of auxiliary and control circuits (see 5.6);
- rated supply frequency of closing and opening devices and of auxiliary circuits (see 5.7);
- filling levels for insulation and/or operation (see 6.22);
- an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$.

6.105 Static mechanical loads

Outdoor BPSs and PSs shall be designed to withstand and operate correctly when mechanically loaded by stresses resulting from ice, wind and connected conductors. If required, this capability is demonstrated by means of calculations.

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

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

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

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

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

7 Type tests

7.1 General

7.1.1 Basics

Subclause 7.1.1 of IEC TS 62271-5:2024 is applicable with the following additions:

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

Tolerances on test quantities are given in Annex A.

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

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

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

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

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

Table 3 – Mandatory type tests

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

¹ Numbers in square brackets refer to the Bibliography.

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC TS 62271-5:2024 is applicable.

7.1.3 Information to be included in type-test reports

Subclause 7.1.3 of IEC TS 62271-5:2024 is applicable with the following addition:

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

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC TS 62271-5:2024 is applicable with the following addition:

No tests are required for the BPS in closed position.

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

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC TS 62271-5:2024 is applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC TS 62271-5:2024 is applicable.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC TS 62271-5:2024 is applicable.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC TS 62271-5:2024 is applicable with the following addition:

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

7.2.6 Application of test voltage and test conditions

Subclause 7.2.6 of IEC TS 62271-5:2024 is applicable with the following addition.

7.2.6.1 General

Subclause 7.2.6.1 of IEC TS 62271-5:2024 is applicable.

7.2.6.2 General case

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

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

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

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

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

- a) Voltage distribution method. This is achieved by including the complete BPS configuration as seen between the pole bus and the neutral. This means that all BPSs for the relevant pole shall be included in the test set-up. If the BPSs are equipped with grading elements, it is permitted to replace the BPSs not subjected to type-test with its (their) grading elements or equivalent components to ensure that the applied voltage will stress both terminals correctly;
- b) Method with two voltage sources. This is achieved by applying a voltage on both terminals using two separate voltage sources. In this case the main part applied consist of the rated withstand voltage to earth and the complementary part consist of a direct voltage, alternating voltage or impulse voltage with the same polarity as the main part.

Alternative 2 is not applicable for BPSs connected to the neutral.

It is allowed to perform the complete set of withstand tests with a combination of both alternatives, for example impulse voltage withstand tests according to Alternative 1 and direct voltage withstand tests according to Alternative 2.

Table 4 – Test conditions in general case for BPSs according to Alternative 1

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1 ^a	Open	A ^b	F	5.3.101 Rated withstand voltage to earth
2	Open	A	aF	5.3.102 Rated withstand voltage across open switching device
3 ^c	Open	A	AF	5.3.102 Rated withstand voltage across open switching device
^a BPSs connected to the neutral may be tested as per test condition 2 but with terminal a connected to earth. In this case all other test conditions may be omitted. ^b In test condition 1 terminal A defines the terminal assigned for the highest voltage to earth. Terminal a is in this test condition floating, i.e. not connected to a voltage source or earth. This test is a verification of the insulation terminal to earth based on the system insulating level and not intended to verify the insulation across the open switching device. ^c Test condition 3 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.				

Table 5 – Test conditions in general case for BPSs according to Alternative 2

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1	Open	A and a ^a	F	5.3.101 Rated withstand voltage to earth
2	Open	A	AF	5.3.102 Rated withstand voltage across open switching device
^a The test voltage to be applied on terminal a should be such that the voltage difference between terminals A and a is equal to the rated withstand voltage across open switching device.				

Table 6 – Test conditions in general case for PSs

Test condition	Switching device	Voltage applied to	Earth connected to	Test voltage
1	Closed	Aa	F	5.3.101 Rated withstand voltage to earth
2	Open	A	aF	5.3.102 Rated withstand voltage across open switching device
3 ^a	Open	A	AF	5.3.102 Rated withstand voltage across open switching device
^a Test condition 3 can be omitted if the arrangement of the terminals is symmetrical with respect to the frame.				

7.2.6.3 Special cases

Subclause 7.2.6.3 of IEC TS 62271-5:2024 is applicable to PSs only.

7.2.7 Tests of switchgear and controlgear**7.2.7.1 General**

Subclause 7.2.7.1 of IEC TS 62271-5:2024 is not applicable.

The test voltage shall be applied according to Table 1 of IEC TS 62271-5:2024 based on the rated insulating levels assigned in 5.3.101 and 5.3.102.

The tests shall be performed with the test conditions stated in 7.2.7.2, 7.2.7.3 and 7.2.7.4, respectively.

7.2.7.2 Direct voltage tests

Subclause 7.2.7.2 of IEC TS 62271-5:2024 is applicable with the following addition.

The BPS and the PS shall be tested with the test conditions described in 7.2.6.2.

7.2.7.3 Switching impulse voltage tests

Subclause 7.2.7.3 of IEC TS 62271-5:2024 is applicable with the following addition.

PSs shall be tested with the test conditions described in 7.2.6.2. For outdoor BPSs or PSs dry tests shall be performed using voltage of positive polarity only.

7.2.7.4 Lightning impulse voltage tests

Subclause 7.2.7.4 of IEC TS 62271-5:2024 is applicable with the following addition.

BPSs and PSs shall be tested as per 7.2.6.2. In addition, the open switching device shall be tested as per 7.2.6.3.1.

7.2.7.5 Superimposed test

Subclause 7.2.7.5 of IEC TS 62271-5:2024 is not applicable.

7.2.7.6 Polarity reversal tests

Subclause 7.2.7.6 of IEC TS 62271-5:2024 is applicable.

7.2.8 Artificial pollution tests for outdoor insulators

Subclause 7.2.8 of IEC TS 62271-5:2024 is applicable.

7.2.9 Partial discharge tests

Subclause 7.2.9 of IEC TS 62271-5:2024 is applicable.

7.2.10 Dielectric tests on auxiliary and control circuits

Subclause 7.2.10 of IEC TS 62271-5:2024 is applicable.

7.2.11 Voltage test as a condition check

Subclause 7.2.11 of IEC TS 62271-5:2024 is applicable.

7.3 Resistance measurement

Subclause 7.3 of IEC TS 62271-5:2024 is applicable.

7.4 Continuous current tests

Subclause 7.4 of IEC TS 62271-5:2024 is applicable with the following addition.

This test applies to PSs only and to BPSs to which a continuous current rating has been assigned.

7.4.101 Temporary current test

Subclause 7.4 of IEC TS 62271-5:2024 is applicable with the following addition.

This test applies to BPSs to which a temporary current has been assigned.

The duration of the test is determined by the time it takes to close the by-pass disconnector (BPD in Figure 1), a typical value is 30 min.

The test shall be performed in accordance with IEC TS 62271-5:2024, 7.4. The current shall be the temporary current and the duration of the test shall be 30 min.

The BPS is considered having passed the test if the temperature rise does not exceed the relevant temperature limits described in IEC TS 62271-5:2024, Table 10.

7.5 Short-time withstand current and peak withstand current tests

7.5.1 General

Subclause 7.5.1 of IEC TS 62271-5:2024 is applicable.

7.5.2 Arrangement of the equipment and of the test circuit

Subclause 7.5.2 of IEC TS 62271-5:2024 is applicable with the following addition.

The use of insulating fluid is not mandatory for short-time withstand current and peak withstand current tests. Air or N₂ may be used as an alternative to gases with high global warming potential. There is also no requirement of minimum pressure for insulation and/or switching.

7.5.3 Test current and duration

Subclause 7.5.3 of IEC TS 62271-5:2024 is applicable.

7.5.4 Conditions of the test object after test

Subclause 7.5.4 of IEC TS 62271-5:2024 is applicable.

7.6 Verification of the protection

Subclause 7.6 of IEC TS 62271-5:2024 is applicable.

7.7 Tightness tests

Subclause 7.7 of IEC TS 62271-5:2024 is applicable.

7.8 Electromagnetic compatibility tests (EMC)

Subclause 7.8 of IEC TS 62271-5:2024 is applicable with the following additions.

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

Subclause 7.8.1.1 of IEC TS 62271-5:2024 is applicable with the following addition.

PSs shall be tested with the test conditions described in Table 6 in 7.2.6.3.

BPSs shall be tested in open position only with test condition 1 described Table 4 or Table 5 in 7.2.6.3.

7.8.3.2 Ripple on DC input power port immunity test

Subclause 7.8.3.2 of IEC TS 62271-5:2024 is applicable with the following addition:

If no electronic components are used in the control unit and the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete BPS or PS equipped with its entire control unit, the ripple on DC input power port immunity test according to subclause 7.8.3.2 of IEC TS 62271-5:2024 is regarded as being covered and additional tests are not required. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

Where electronic components are used, tests according to 7.8.3.2 of IEC TS 62271-5:2024 on the individual components are sufficient.

This subclause is applicable to both complete electronic boards (for example control modules) and devices containing at least one electronic component (for example electronic timing relays).

7.9 Additional tests on auxiliary and control circuits

7.9.1 General

Subclause 7.9.1 of IEC TS 62271-5:2024 is applicable.

7.9.2 Functional tests

Subclause 7.9.2 of IEC TS 62271-5:2024 is applicable with the following addition:

If the mechanical operation test at ambient air temperature in accordance with 7.101.2 is performed on the complete BPS or PS equipped with its entire control unit, the functional tests according to subclause 7.9.2 of IEC TS 62271-5:2024 are regarded as covered and additional tests are not required and may be omitted. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

7.9.3 Verification of the operational characteristics of the auxiliary contacts

Subclause 7.9.3 of IEC TS 62271-5:2024 is applicable.

7.9.4 Environmental tests

Subclause 7.9.4 of IEC TS 62271-5:2024 is applicable with the following addition:

If the mechanical operation test at ambient air temperature in accordance with 7.101.2, the low and high temperature tests in accordance with 7.101.3 and, if applicable, the humidity test in accordance with 7.101.4 are performed on the complete BPS or PS equipped with its entire control unit or in case of the humidity test on the control equipment respectively, the environmental tests according to IEC TS 62271-5:2024, 7.9.4 are regarded as covered and additional tests can be omitted. When testing of the complete BPS or PS is not practicable, component tests in accordance with 7.101.1.2 are acceptable.

Seismic tests are not covered. If a seismic test is requested, it should be performed in accordance with IEC TR 62271-300 by agreement between manufacturer and user.

7.9.5 Dielectric test

Subclause 7.9.5 of IEC TS 62271-5:2024 is applicable with the following addition.

The dielectric test shall be performed on auxiliary and control circuits that are in new condition.

7.10 X-radiation test procedure for vacuum interrupters

Subclause 7.10 of IEC TS 62271-5:2024 is applicable.

7.101 Mechanical and environmental tests

7.101.1 Miscellaneous provisions for mechanical and environmental tests

7.101.1.1 Mechanical characteristics

At the beginning of the type tests, the mechanical characteristics of the BPS or PS shall be established (see Annex D). IEC TR 62271-306 [2] gives examples on how to measure the mechanical characteristics. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the BPS or PS. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical and switching type tests behave mechanically in a similar way, i.e. within the tolerances specified by the manufacturer. The reference mechanical characteristics are also used to confirm that production units behave mechanically in a similar way compared to the test samples used during type tests.

Following are examples of operating characteristics that can be recorded:

- no-load travel curves;
- closing and opening times.

The mechanical characteristics shall be produced during a no-load test made with a single O operation and a single C operation at rated supply voltage of operating devices and of auxiliary and control circuits, filling pressure for operation and at the minimum filling pressure for operation.

7.101.1.2 Component tests

When testing of a complete BPS or PS is not practicable, component tests may be accepted as type tests. The manufacturer should determine the components which are suitable for testing.

Components are separate functional sub-assemblies which can be operated independently of the complete BPS or PS (for example, switching unit, operating mechanism).

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

Parts of auxiliary and control equipment which have been manufactured in accordance with relevant standards shall comply with these standards. The proper function of such parts in connection with the function of the other parts of the BPS or PS shall be verified.

7.101.1.3 Characteristics and settings of the BPS or PS to be recorded before and after the tests

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

- a) closing time;
- b) opening time;
- c) time spread between units (if applicable);
- d) recharging time and consumption of the operating device;

- e) consumption of the control circuit, if applicable;
- f) consumption of the auxiliary circuit;
- g) duration of opening and closing command;
- h) tightness, if applicable;
- i) gas densities or pressures, if applicable;
- j) resistance of the main circuit;
- k) mechanical travel characteristics (if applicable);
- l) other important characteristics or settings as specified by the manufacturer.

The above operating characteristics shall be recorded at

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

7.101.1.4 Condition of the BPS or PS during and after the tests

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

In general, these requirements are fulfilled if

- during the tests, the BPS or PS operates on command and does not operate without command;
- after the tests, the characteristics measured according to 7.101.1.3 are within the tolerances given by the manufacturer;
- after the tests, coated contacts are such that a layer of coating material remains at the contact area. If this is not the case, the contacts shall be regarded as bare and the test requirements are fulfilled only if the temperature rise of the contacts during the continuous current test (according to 7.4) does not exceed the value permitted for bare contacts;
- during and after the tests, it shall be possible to fit any defined replacement part according to the manufacturer's instructions;
- after the tests the insulating properties of the BPS or PS in the open position shall be in essentially the same condition as before the tests. Visual inspection of the BPS or PS after the tests is usually sufficient for verification of the insulating properties. In the case of BPSs or PSs with sealed-for-life interrupters, a voltage test as a condition check in accordance with 7.2.11 replaces this visual inspection;
- for sealed-for-life switches, the increase of the resistance of the main circuit shall be less than or equal to 20 %. If the increase in resistance exceeds 20 % then a continuous current test according to 7.4 is applicable to determine if the test object can carry its rated continuous current without exceeding the temperature limits given in Table 10 of IEC TS 62271-5:2024 by more than 10 K;
- for other BPS or PS types, the resistance condition check of the test object is satisfactory if the resistance increase determined in 7.3.4.1 of IEC TS 62271-5:2024 is not greater than 20 %. If the resistance increase exceeds 20 % a visual inspection shall be performed.

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

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

- during the tests, care should be taken to prevent undue heating;
- during the tests, a set of contacts (both make and break auxiliary contacts) shall be arranged to switch the current of the circuits to be controlled (see 6.4);
- during and after the tests, the auxiliary and control equipment shall fulfil its functions;
- during and after the tests, insulation capability of the auxiliary circuits, of the auxiliary switches and of the control equipment shall not be impaired. In case of doubt, the dielectric tests according to 7.10.5 of IEC TS 62271-5:2024 shall be performed;
- during and after the tests, the contact resistance of the auxiliary switches shall not be affected adversely.

7.101.2 Mechanical operation test at ambient air temperature

7.101.2.1 General

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

The mechanical operation test shall consist of 2 000 operating cycles in accordance with 7.101.2.3.

A BPS or PS design can be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.6 and 5.7. These variants do not need to be tested if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in Annex D.

7.101.2.2 Condition of the BPS or PS before the test

The BPS or PS for test shall be completely mounted on its own support and its operating mechanism shall be operated in the specified manner. It shall be tested according to its type as follows:

Tests shall be conducted at the filling pressure for insulation and/or switching.

7.101.2.3 Operating sequence

The BPS or PS shall be tested in accordance with Table 7.

Table 7 – Number of operating sequences

Operating sequence	Supply voltage	Operating pressure	Number of operating sequences
$C - t_a - O$	Minimum	Minimum functional	500
	Rated	Filling pressure	500
	Maximum	Filling pressure	500
$C - t_a - O - t_b - C - t_a - O$	Rated	Filling pressure	250
O opening; C closing; t_a time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the BPS or PS (this time can be different according to the type of operation). t_b shortest time between an O and subsequent C operation such that the BPS or PS reaches the fully open position prior to closing.			

During the test, lubrication of parts outside of the main circuit is allowed in accordance with the manufacturer's instructions, but no mechanical adjustment or other kind of maintenance is allowed.

7.101.2.4 Acceptance criteria for the mechanical operation tests

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

- five operating cycles at the rated supply voltage of closing and opening devices and of auxiliary and control circuits and/or the filling pressure for operation;
- five operating cycles at the minimum supply voltage of closing and opening devices and of auxiliary and control circuits and/or the minimum pressure for operation;
- five operating cycles at the maximum supply voltage of closing and opening devices and of auxiliary and control circuits and/or the filling pressure for operation.

During these operating cycles, the operating characteristics (see 7.101.1.3) shall be recorded. It is not necessary to publish all the oscillograms recorded. However, at least one oscillogram for each set of conditions given above shall be included in the test report.

In addition, the following checks and measurements shall be performed:

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

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

b) After the total test programme the condition of the BPS or PS shall be in accordance with 7.101.1.4.

7.101.3 Low and high temperature tests

7.101.3.1 General requirements

It is not necessary to perform the two tests in succession, and the order in which they are carried out is arbitrary. If the minimum ambient air temperature of indoor and outdoor switches is higher than or equal to $-5\text{ }^{\circ}\text{C}$, no low temperature test is required. If maximum ambient air temperature is not higher than $+40\text{ }^{\circ}\text{C}$, no high temperature test is required.

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

Liquid or gas supplies for BPS or PS operation are to be at the test air temperature unless the BPS or PS design requires a heat source for these supplies.

No maintenance, replacement of parts, lubrication or readjustment of the BPS or PS is permissible during the tests.

The BPS or PS has passed the test if the conditions stated in 7.101.1.4 and 7.101.1.5 are fulfilled. Furthermore, the conditions in 7.101.3.4 and 7.101.3.5 shall be fulfilled and the leakage rates recorded shall not exceed the limits given in Table 15 of IEC TS 62271-5:2024. In the test report the testing conditions and the condition of the BPS or PS before, during and after the test shall be reported. The recorded quantities shall be presented. To reduce the number of oscillograms in the test report, a single representative oscillogram of every relevant type of operation under each specified testing condition shall be included.

A BPS or PS design may be fitted with several variants of auxiliary equipment (shunt releases and motors) in order to accommodate the various rated control voltages and frequencies as stated in 5.6 and 5.7. It is not necessary to test these variants if they are of similar designs and if the resulting no-load mechanical characteristics are within the tolerance given in 7.101.1.1.

The conditions during and after the tests are given in 7.101.3.6.

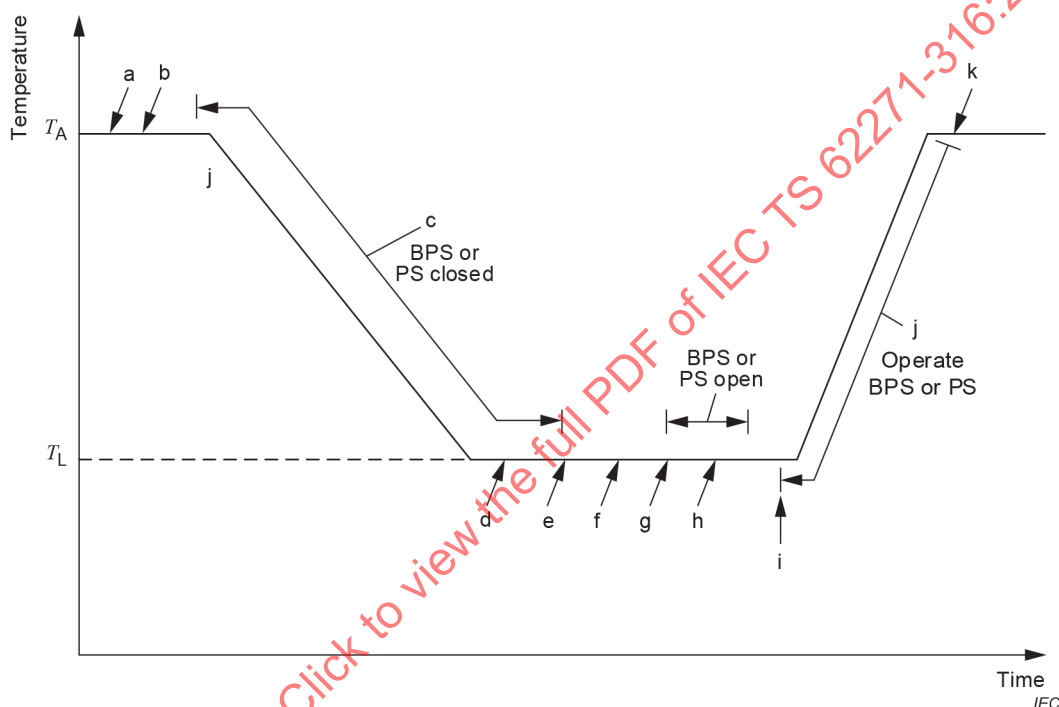
7.101.3.2 Measurement of ambient air temperature

The ambient air temperature of the immediate test environment shall be measured at half the height of the BPS or PS and at a distance of 1 m from the BPS or PS.

The maximum temperature deviation over the height of the BPS or PS shall not exceed 5 K.

7.101.3.4 Low temperature test

The diagram of the test sequences and identification of the application points for the tests specified are given in Figure 8.



NOTE Letters a through k identify application points of tests specified in 7.101.3.4.

Figure 8 – Test sequence for low temperature test

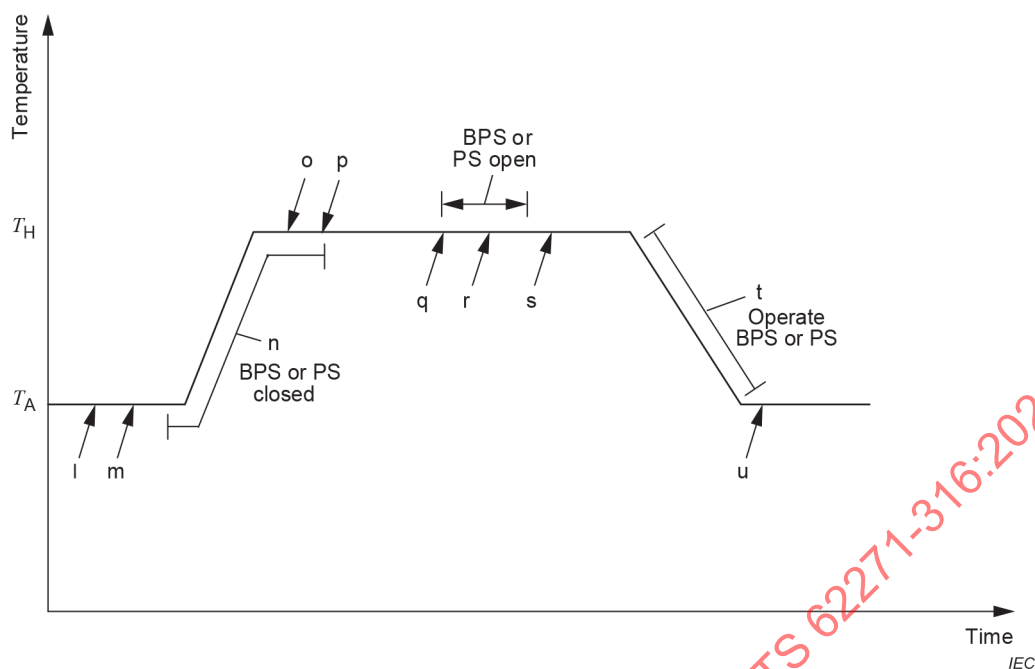
If the low temperature test is performed immediately after the high temperature test, the low temperature test can proceed after completion of item u) of the high temperature test. In this case, items a) and b) in the following list are omitted.

- The test BPS or PS shall be prepared and adjusted in accordance with the manufacturer's instructions;
- Characteristics and settings of the BPS or PS shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.7;
- With the BPS or PS in the closed position, the air temperature shall be decreased to the appropriate, minimum ambient air temperature (T_L), according to the minimum ambient temperature specified as given in 4.1.2, 4.1.3 and 4.2.4 of IEC TS 62271-5:2024. The BPS or PS shall be kept in the closed position for 24 h after the ambient air temperature stabilises at T_L ;

- d) During the 24 h period with the BPS or PS in the closed position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the BPS or PS is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC TS 62271-5:2024;
- e) After 24 h at temperature T_L , the BPS or PS shall be opened, closed and opened at rated values of supply voltage and operating pressure. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances;
- f) The low temperature behaviour of the BPS or PS and its alarms and lock-out systems shall be verified by disconnecting the supply of all heating devices, including also the anti-condensation heating elements, for a duration t_x . During this interval, occurrence of an alarm is acceptable but lock-out is not. At the end of the interval t_x , a closing order, at rated values of supply voltage and operating pressure, shall be given. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances.
The manufacturer shall state the value of t_x (not less than 2 h) up to which the BPS or PS is still operable without auxiliary power to the heaters. In the absence of such a statement, the default value shall be equal to 2 h;
- g) The BPS or PS shall be opened and left in the open position for 24 h;
- h) During the 24 h period with the BPS or PS in the open position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the BPS or PS is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC TS 62271-5:2024;
- i) At the end of the 24 h period, 50 closing and 50 opening operations shall be made at rated values of supply voltage and operating pressure with the BPS or PS at temperature T_L . At least a 3 min interval shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. Following the first opening operation (O) and the first closing operation (C), three OC operating cycles shall be performed. The additional operations shall be carried out by performing O – t_a – C – t_a operating sequences (t_a is defined in Table 7);
- j) After completing the 50 opening and 50 closing operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour.
During the temperature transition period the BPS or PS shall be subjected to alternate O – t_a – C – t_a – O and C – t_a – O – t_a – C operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences should be carried out at 30 min intervals so that the BPS or PS will be in open and in closed position for 30 min periods between the operating sequences;
- k) After the BPS or PS has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the BPS or PS settings. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. The tightness test shall be repeated as in item b) and the leakage rate shall remain within the limits stated in 7.7.
The accumulated leakage during the complete low temperature test sequence from item b) to item j) shall not be such that lock-out pressure is reached (reaching alarm pressure is allowed).

7.101.3.5 High temperature test

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 9.



NOTE Letters l through u identify application points of tests specified in 7.101.3.5.

Figure 9 – Test sequence for high temperature test

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

- l) The test BPS or PS shall be prepared and adjusted in accordance with the manufacturer's instructions;
- m) Characteristics and settings of the BPS or PS shall be recorded in accordance with 7.101.1.3 and at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (T_A). The tightness test (if applicable) shall be performed according to 7.7;
- n) With the BPS or PS in the closed position, the air temperature shall be increased to the appropriate, maximum ambient air temperature (T_H), according to the upper limit of ambient air temperature as given in 4.1.2, 4.1.3 and 4.2.4 of IEC TS 62271-5:2024. The BPS or PS shall be kept in the closed position for 24 h after the ambient air temperature stabilises at T_H ;
- o) During the 24 h period with the BPS or PS in the closed position at the temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the BPS or PS is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC TS 62271-5:2024;
- p) After 24 h at the temperature T_H , the BPS or PS shall be opened and closed at rated values of supply voltage and operating pressure. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances;
- q) The BPS or PS shall be opened and not operated for 24 h at the temperature T_H ;
- r) During this 24 h period at temperature T_H , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the BPS or PS is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed the permissible temporary leakage rate of Table 15 of IEC TS 62271-5:2024;

- s) At the end of the 24 h period, 50 closing and 50 opening operations shall be carried out at rated values of supply voltage and operating pressure with the BPS or PS at the temperature T_H . An interval of at least 3 min shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances.

Following the first closing or opening operation, three O – t_b – C operating cycles shall be performed. The additional operations shall be carried out by performing O – t_a – C – t_a operating sequences (t_a and t_b are defined in Table 7);

- t) After completing the tests indicated in s), the air temperature shall be decreased to ambient air temperature T_A , at a rate of change of approximately 10 K/h.

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

- u) After the BPS or PS has stabilised thermally at ambient air temperature T_A , a recheck shall be made of the BPS or PS settings. The mechanical characteristics shall be recorded and shall be within the manufacturer's specified tolerances. The tightness test shall be repeated as in item m) and the leakage rate shall remain within the limits stated in 7.7.

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

7.101.4 Humidity test

7.101.4.1 General

The humidity test does not apply to equipment which is designed to be directly exposed to precipitation, for example primary parts of outdoor BPSs or PSs. The test shall be performed on BPSs or PSs or on BPS or PS components, where due to sudden changes of the temperature, condensation may occur on insulating surfaces which are continuously stressed by voltage. This is mainly the insulation of the secondary wiring of indoor installed BPSs or PSs. The humidity test is also not necessary where effective means against condensation are provided, for example control cubicles with anti-condensation heaters.

Applying the test procedure described in 7.101.4.2, the withstand of the test object, primarily BPS or PS components, to humidity effects, which may produce condensation on the surface of the test object, is determined in an accelerated manner.

7.101.4.2 Test procedure

The test object shall be arranged in a test chamber containing circulating air and in which the temperature and humidity shall follow the cycle given in the following paragraph:

During about half of the cycle the surfaces of the test object shall be wet, and dry during the other half. To obtain this result the test cycle consists of a period t_4 with low air temperature ($T_{\min} = 25\text{ °C} \pm 3\text{ °C}$) and a period t_2 with high air temperature ($T_{\max} = 40\text{ °C} \pm 2\text{ °C}$) inside the test chamber. Both periods shall be equal in time. The generation of fog shall be maintained for that half of the cycle (see Figure 10) in which the low air temperature is applied.

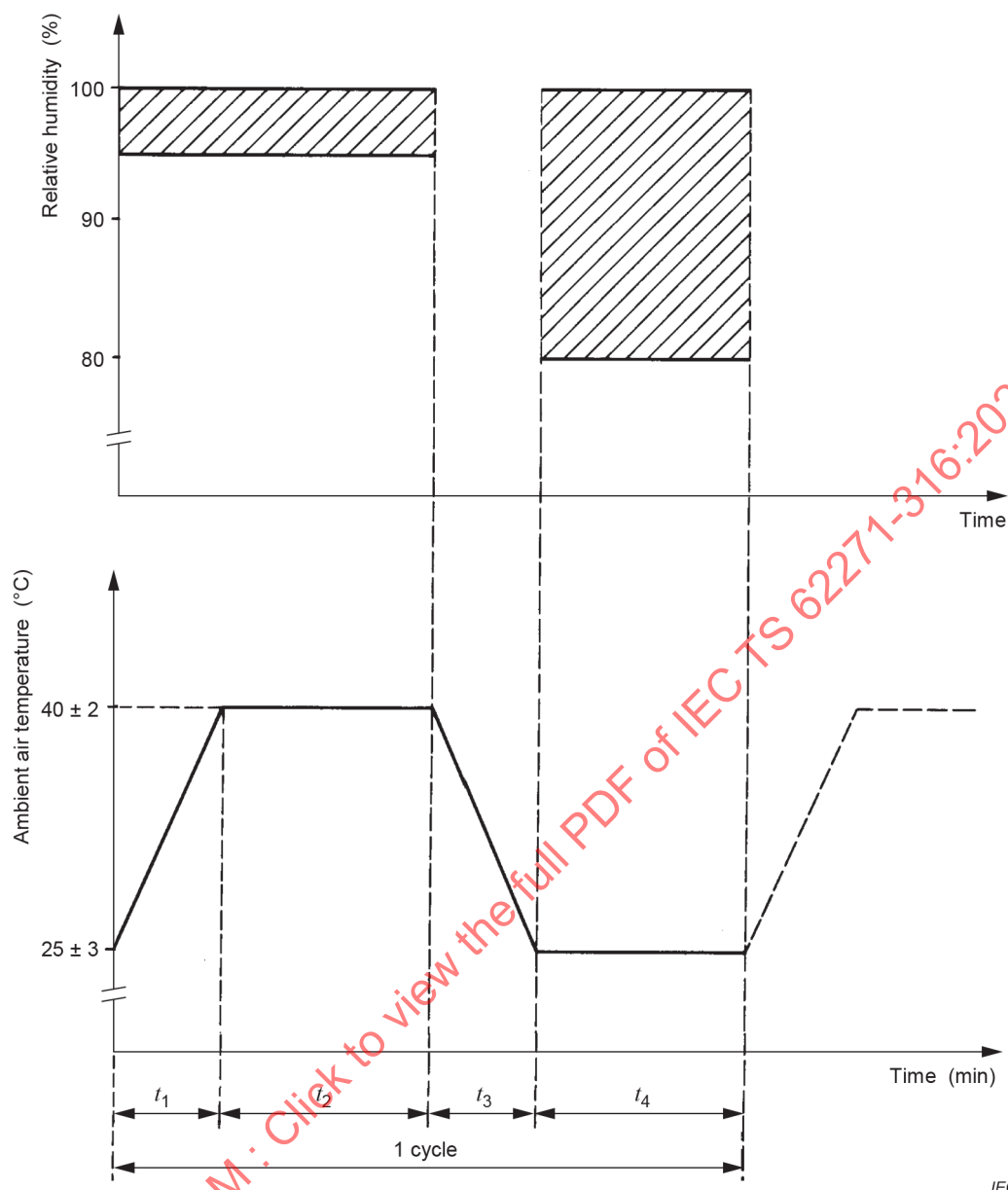


Figure 10 – Humidity test

The beginning of fog generation coincides in principle with the beginning of the low air temperature period. However, to wet the vertical surfaces of materials with a high thermal time constant, it is allowed to start the fog generation later within the low air temperature period.

The duration of the test cycle depends on the thermal characteristics of the test objects, and shall be sufficiently long, both at high and low temperature, to cause wetting and drying of all insulation surfaces. In order to obtain these conditions, steam should be injected directly into the test chamber or heated water should be atomised; the rise from 25 °C to 40 °C may be obtained with the provision of heat coming from the steam or atomised water or, if necessary, by additional heaters. Preliminary cycles shall be carried out with the test object placed in the test chamber in order to observe and to check these conditions.

For low-voltage components of BPS and PSs, usually having time constants smaller than 10 min, the duration of the time intervals given in Figure 10 are: $t_1 = 10$ min, $t_2 = 20$ min, $t_3 = 10$ min and $t_4 = 20$ min.

The fog is obtained by the continuous or periodical atomisation of 0,2 l to 0,4 l of water (with the resistivity characteristics given below) per hour and per cubic metre of test chamber volume. The diameter of the droplets shall be less than 10 µm; such a fog may be obtained by mechanical atomisers. The direction of the spraying shall be such that the surfaces of the test object are not directly sprayed. No water shall drop from the ceiling upon the test object. During the fog generation the test chamber shall be closed, and no additional forced air-circulation is permitted.

The water used to create the humidity shall be such that the water collected in the test chamber has a resistivity equal to or greater than 100 Ωm and contains neither salt (NaCl) nor any corrosive element.

The temperature and the relative humidity of the air in the test chamber shall be measured in the immediate vicinity of the test object and shall be recorded for the whole duration of the test. No value of relative humidity is specified during the drop in temperature; however, the humidity shall be above 80 % during the period when the temperature is maintained at 25 °C. The air shall be circulated in order to obtain uniform distribution of the humidity in the test chamber.

The number of cycles shall be 350.

During and after the test, the operating characteristics of the test objects shall not be affected. This is proven by the dielectric withstand test on the auxiliary and control circuits in accordance with 7.2.11. The degree of corrosion, if any, should be indicated in the test report.

7.101.5 Test to prove the operation under severe ice conditions

The test under severe ice conditions is applicable only to outdoor BPSs or PSs having moving external parts. The test shall be performed according to IEC 62271-102:2018.

7.102 Current commutation test

This test applies to BPSs and LPSs. Currently no laboratory test procedures and test circuits are available. Requirements for testing and test parameters will be added once TC 115 has provided more relevant data.

8 Routine tests

Clause 8 of IEC TS 62271-5:2024 is applicable with the following addition.

8.1 General

Subclause 8.1 of IEC TS 62271-5:2024 is applicable.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC TS 62271-5:2024 is applicable with the following addition.

The dielectric test across the open contacts may be performed on the complete BPS or PS or on single switching units, if the BPS or PS is constructed by assembling identical switching units in series (see also Figure 7, where BPS1 and BPS2 consist of two series connected switching units).

When performing dielectric tests on single units, the test voltage to be applied across each single unit shall be that of the most stressed unit. This test voltage is the higher fraction of the total withstand voltage with the BPS or PS in the open position and one terminal earthed. The test voltage shall be applied to one side of the switching unit with the other terminal earthed.

For BPSs or PSs using compressed gas for insulation and/or switching, the gas pressure during the dielectric test, the main circuit shall be set at the minimum filling pressure for insulation and/or switching. For sealed pressure systems, the gas pressure shall be the filling pressure for insulation and/or switching.

In case of BPSs or PSs using a gas mixture such as SF₆/N₂, the test may be performed using the declared gas mixture at the minimum filling pressure for insulation and/or switching or pure SF₆ at a total absolute pressure not exceeding the equivalent gas pressure (P_{test}) as calculated by the following equation (see Figure 4.1 of CIGRE TB 163 [3]): $P_{\text{test}} = P_{\text{SF}_6} + 0,7 \times P_{\text{add N}_2}$. The equation is valid for mixtures having at least 30 % of SF₆ gas volume (see note);

where

- P_{test} is the total absolute SF₆ pressure at $T = 20\text{ °C}$ during routine dielectric test on the main circuit;
- P_{SF_6} is the partial pressure of SF₆ at $T = 20\text{ °C}$ at the minimum functional pressure for switching according to the declared gas mixture;
- $P_{\text{add N}_2}$ is the partial pressure of N₂ at $T = 20\text{ °C}$ at the minimum functional pressure for switching according to the declared gas mixture.

NOTE See CIGRE TB 163 [3] for mixtures having less than 30 % SF₆.

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC TS 62271-5:2024 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC TS 62271-5:2024 is applicable.

8.5 Tightness test

Subclause 8.5 of IEC TS 62271-5:2024 is applicable.

8.6 Design and visual checks

Subclause 8.6 of IEC TS 62271-5:2024 is applicable with the following addition.

The following items shall be checked as applicable:

- the language and data on the nameplates;
- identification of any auxiliary equipment;
- the colour and quality of paint and corrosion protection of metallic surfaces;
- the values of the resistors and capacitors connected to the main circuit.

8.101 Mechanical operating tests

Mechanical operating tests shall include the following:

- a) at maximum supply voltage of operating devices and of auxiliary and control circuits and filling pressure for operation (if applicable):
 - five closing operations;
 - five opening operations.

- b) at specified minimum supply voltage of operating devices and of auxiliary and control circuits and minimum functional pressure for operation (if applicable):
 - five closing operations;
 - five opening operations.
- c) at rated supply voltage of operating devices and of auxiliary and control circuits and filling pressure for operation (if applicable):
 - five O - t'' - C operating cycles, where t'' is specified in 5.102.

Mechanical operating tests should be carried out on the complete BPS or PS. However, when BPSs or PSs are assembled and shipped as separate units, routine tests may be performed on components according to 7.101.1.2. In such cases, the manufacturer shall produce a programme of commissioning tests for use at site to confirm the compatibility of such separate units and components when assembled as a BPS or PS. Guidance for commissioning tests is given in 11.3.101.

For all required operating sequences the following shall be performed and records made of the closing and opening operations:

- measurement of operating times;
- where applicable, measurement of fluid consumption during operations, for example pressure difference.

Proof shall be given that the mechanical behaviour conforms to that of the test object used for type testing. For example, a no-load operating cycle, as described in 7.101.1.1, may be performed to record the no-load travel curves at the end of the routine tests. Where this is done, the curve shall be within the prescribed envelope of the reference mechanical characteristic, as defined in 7.101.1.1, from the instant of contact separation to the end of the contact travel for an opening operation and from start of movement to contact touch for a closing operation. See also Annex D.

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

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

If applicable, the mechanical characteristics can be recorded directly, using a travel transducer or similar device on the BPS or PS contact system or at other convenient locations on the drive to the contact system where there is a direct connection, and a representative image of the contact stroke can be achieved. The mechanical characteristics shall preferably be a continuous curve. Where the measurements are taken on site, other methods may be applied which record points of travel during the operating period.

In these circumstances, the number of points recorded shall be sufficient to derive the time to, and contact speed at, contact touch and contact separation, together with the total travel time.

After completion of the required operating sequences, the following tests and inspections shall be performed (if applicable):

- connections shall be checked;
- the control and/or auxiliary switches shall correctly indicate the open and closed positions of the BPS or PS;
- all auxiliary equipment shall operate correctly at the limits of supply voltage of operating devices and of auxiliary and control circuits and/or pressures for operation.

Furthermore, the following tests and inspections shall be made (if applicable):

- measurement of the resistance of heaters (if fitted) and of the control coils;
- inspections of the wiring of the control, heater and auxiliary equipment circuits and checking of the number of auxiliary contacts, in accordance with the order specification;
- inspection of control cubicle (electrical, mechanical, pneumatic and hydraulic systems);
- recharging duration(s);
- functional performance of pressure relief valve of the operating mechanism;
- operation of electrical, mechanical, pneumatic or hydraulic interlocks and signalling devices;
- operation of anti-pumping device;
- general performance of equipment within the required tolerance of the supply voltage;
- inspection of earthing terminals of the BPS or PS.

9 Guide to the selection of switchgear and controlgear (informative)

Clause 9 of IEC TS 62271-5:2024 is applicable with the following addition.

9.1 General

A BPS or PS suitable for a given duty in service is best selected by considering the individual rated values required by load conditions and fault conditions.

The complete list of rated characteristics is given in Clause 5. The following individual ratings are dealt with in this Clause 9.

Type of rating and/or characteristics:

- Voltage, see 5.2;
- Insulation level (can be different to earth and across open contacts), see 5.3;
- Continuous current, see 5.4;
- Temporary current, see 5.4.101;
- Duration of short-circuit, see 5.5;
- Operating sequence, see 5.102.

For rated characteristics not dealt with in Clause 9, reference should, if applicable, be made to Clause 5 as follows:

Other parameters to be considered when selecting a BPS or PS are, for example:

- Local atmospheric and climatic conditions, see 9.2.105;
- Use at high altitudes, see 9.2.106;
- Opening and/or closing time.

9.2 Selection of rated values

Subclause 9.2 of IEC TS 62271-5:2024 is applicable with the following addition.

9.2.101 Selection of rated voltage

The rated voltage of the BPS or PS should be chosen so as to be at least equal to the highest voltage of the system at the point where the BPS or PS is to be installed.

NOTE 1 Reference is made to Annex C for BPSs.

NOTE 2 In some applications PSs are connected in series with a disconnector that always operates and with a short time delay after PS, to reduce the duration of voltage stress across the open PS. For such applications, a lower value of the rated direct voltage across the open PS can be chosen, whereby dielectric capabilities and creepage distance across open switching device are reduced.

The rated voltages of a BPS or PS according 5.2.101 and 5.2.102 should be selected from the values given in 5.2 of IEC TS 62271-5:2024.

9.2.102 Insulation coordination

The rated insulation level of a BPS or PS should be selected according to 5.3.

The values in the tables stated there apply to both indoor and outdoor BPSs and PSs. It should be specified in the enquiry whether the BPS or PS is to be of indoor or outdoor type.

The insulation coordination in an electrical system serves to minimise damage to the electrical equipment due to overvoltages and tends to confine flashovers (when these cannot be economically avoided) to points where they will cause no damage.

In accordance with IEC TS 60071-11 and IEC TS 60071-12 precautions should be taken to limit the overvoltages on the terminals of the BPS or PS to stated values below the insulation level.

Where a BPS or PS is required for a position necessitating a higher insulation level, this should be specified in the enquiry (see 10.101).

9.2.103 Selection of rated continuous current

The continuous current of a PS should be selected from the standard values given in 5.4.

It should be noted that PSs have no specified continuous overcurrent capability. When selecting a PS therefore, the rated continuous current should be such as to make it suitable for any load current that may occur in service. Where intermittent over-currents are expected to be frequent and severe, the manufacturer should be consulted.

9.2.104 Selection of temporary current

The temporary current of a BPS and its duration should be specified by the user. The duration depends on the time it takes to close the by-pass disconnector. A typical value for the duration is 30 min.

9.2.105 Local atmospheric and climatic conditions

The normal atmospheric and climatic conditions for BPSs and PSs are given in Clause 4.

For outdoor BPSs and PSs, the atmospheric conditions in certain areas are unfavourable due to smoke, chemical fumes, salt-laden spray and the like. Where such adverse conditions are known to exist, special consideration should be given to the design of those parts of the BPS or PS, especially the insulators, normally exposed to the atmosphere.

The performance of an insulator in such atmospheres also depends on the frequency of washing or cleaning operations and on the frequency of natural washing by rain. Since the performance of an insulator under such conditions is dependent on so many factors, it is not possible to give precise definitions of normal and heavily polluted atmospheres. Experience in the area where the insulator is to be used is the best guide.

The manufacturer should be consulted when the BPS or PS is to be located where the wind speed exceeds 34 m/s.

If a BPS or PS is to be located where an ice-coating exceeding 20 mm is expected, agreement should be reached between manufacturer and user as to the ability of the BPS or PS to perform correctly under such conditions.

Where applicable, the seismic qualification level should be specified by the user. Subclause 4.2.5 of IEC TS 62271-5:2024 should be taken into account.

For indoor installations, the humidity conditions are given in 4.1.2 e) of IEC TS 62271-5:2024. When selecting the BPS or PS for service, it is recommended to indicate the cases where the high values of humidity are expected and condensation can occur.

BPSs and PSs installed in indoor installations can be exposed to high ambient temperatures and low humidity.

For outdoor BPSs or PSs, the manufacturer should be consulted for any special service conditions, for example when chemical fumes, aggressive atmosphere, salt laden spray, etc., are present.

9.2.106 Use at high altitudes

The normal service conditions specified in Clause 4 of IEC TS 62271-5:2024 provide for BPSs and PSs intended for use at altitudes not exceeding 1 000 m.

For installation at altitudes above 1 000 m, 4.2.2 of IEC TS 62271-5:2024 is applicable.

9.2.107 Operating sequence in service (not a rating)

The operating sequence of a BPS or PS is given in 7.102.

When the operating sequence in service is more severe than that which is provided for in this document, this should be specified by the user in their enquiry and/or order in such a way that the manufacturer can modify the rating of the BPS or PS appropriately.

9.2.108 Selection of rated duration of short-circuit

The standard value of rated duration of short-circuit is given in 5.5.4 of IEC TS 62271-5:2024.

For short-circuit durations greater than the rated duration, the relation between current and time, unless otherwise stated by the manufacturer, is in accordance with the equation:

$$I^2 \times t = \text{constant}$$

9.3 Cable-interface connections

Subclause 9.3 of IEC TS 62271-5:2024 is applicable.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC TS 62271-5:2024 is not applicable.

9.5 Environmental aspects

Subclause 9.5 of IEC TS 62271-5:2024 is applicable.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

Subclause 10.1 of IEC TS 62271-5:2024 is applicable.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC TS 62271-5:2024 is applicable with the following addition.

When enquiring for or ordering a BPS or PS, the following particulars should be supplied by the enquirer:

- a) particulars of systems, i.e. nominal and highest voltages;
- b) service conditions including minimum and maximum ambient air temperatures, altitude if over 1 000 m and any special conditions likely to exist or arise, for example unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 9.2.105 and 9.2.106);
- c) characteristics of the BPS or PS.

The following information should be given:

Type of information	Reference
1) indoor or outdoor	9.2.105
2) voltage	9.2.101
3) insulation level: where a choice exists between different insulation levels corresponding to a given rated voltage, or, if other than standard, the desired insulation level	9.2.102
4) continuous current	9.2.103
5) temporary current	9.2.104
6) operating sequence	9.2.107
7) the type tests specified under special request (for example artificial pollution and radio interference, etc.)	7.2.8, 7.8
The following information should be given, if the required performance is other than standard	
8) desired duration of short-circuit	9.2.108
The following information should be given in the case of applicability	
9) any test exceeding the standardised type, routine and commissioning tests	

- d) characteristics of the operating mechanism of BPS or PS and associated equipment, in particular:

- 1) method of operation, whether manual or power;
- 2) number and type of spare auxiliary switches;
- 3) rated supply voltage and rated supply frequency;
- 4) number of releases for tripping, if more than one;
- 5) number of releases for closing, if more than one.

- e) requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels.

The enquirer should give information of any special conditions not included above, that might influence the tender or order.

10.3 Information to be given with tenders

Subclause 10.3 of IEC TS 62271-5:2024 is applicable with the following addition.

When the enquirer requests technical particulars of a BPS or PS, the following information (those which are applicable) should be given by the manufacturer, with the descriptive matter and drawings:

a) rated values and characteristics:

Type of information	Reference
1) indoor or outdoor, temperature, ice-coating	9.2.105
2) voltage	9.2.101
3) insulation level	9.2.102
4) rated continuous current	9.2.103
5) temporary current and duration	9.2.104
6) short-time withstand current	9.2.108
7) operating sequence	9.2.107
8) opening time and closing time	6.104
9) the type tests specified under special request (for example artificial pollution and radio interference, etc.)	7.2.8, 7.8
The following information should be given if the required performance is other than standard:	
10) rated duration of short-circuit	9.2.108
The following information should be given in the case of applicability	
11) any test exceeding the standardised type, routine and commissioning tests	

b) type tests:

certificate or report on request;

c) constructional features:

The following details are required where they are applicable to the design:

- 1) mass of complete BPS or PS without fluids for insulation, switching and operation;
- 2) mass/volume of fluid for insulation, its quality and operating range, including the minimum functional value;
- 3) mass/volume of fluid for switching (where different fluid to items 2) and/or 4)), its quality and operating range, including the minimum functional value;
- 4) mass/volume of fluid for operation (where different fluid to items 2) and/or 3)), its quality and operating range, including the minimum functional value;
- 5) tightness qualification;
- 6) mass/volume of fluids to fill to a level sufficient to prevent deterioration of internal components during storage and transportation;
- 7) number of units in series;
- 8) minimum clearances in air:
 - to earth;
 - the safety boundaries during a switching operation, for BPSs with an external exhaust for ionised gasses or flame;
- 9) any special arrangements (for example heating or cooling) to maintain the rated characteristics of the BPS or PS at the required temperatures of the ambient air;

d) operating mechanism of BPS or PS and associated equipment:

- 1) type of operating mechanism;
- 2) rated supply voltage and/or pressure of closing mechanism, pressure limits where different to or expanding data required in c) 4) of 10.3;
- 3) current required at rated supply voltage to close the BPS or PS;
- 4) energy consumed to close the BPS or PS, for example measured as a fall in pressure;
- 5) rated supply voltage of closing and shunt opening release;
- 6) current required at rated supply voltage for closing and shunt opening release;
- 7) number and type of spare auxiliary switches;
- 8) current required at rated supply voltage by other auxiliaries;
- 9) setting of high and low pressure interlocking devices;
- 10) number of releases for opening, if more than one;
- 11) number of releases for closing, if more than one;

e) overall dimensions and other information:

The manufacturer should give the necessary information as regards the overall dimensions of the BPS or PS and details necessary for the design of the foundation.

General information regarding maintenance of the BPS or PS and its connections should be given.

11 Transport, storage, installation, operation instructions and maintenance

11.1 General

Subclause 11.1 of IEC TS 62271-5:2024 is applicable.

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC TS 62271-5:2024 is applicable.

11.3 Installation

Subclause 11.3 of IEC TS 62271-5:2024 is applicable, with the following addition.

11.3.101 Commissioning tests

After a BPS or PS has been installed and all connections have been completed, commissioning tests are recommended to be performed. The purpose of these tests is to confirm that transportation and storage have not damaged the BPS or PS. In addition, when a large part of the assembly and/or of the adjustment is performed on site, as identified in 8.101, the tests are required to confirm compatibility of the sub-components and the satisfactory nature of both the site work and the functional characteristics dependent upon it.

In addition to the requirements of 11.3.102, a minimum of 50 no-load operations shall be performed on site on the BPS or PS where major sub-assemblies are combined at site without previous routine tests on the complete BPS or PS. These operations shall be performed after assembly, all connections and checks having been made and the programme of commissioning tests having been completed. These operations may include deferred routine test operations forming part of the commissioning programme only where they are made after all site adjustments and tightness checks are complete. The purpose of these tests is to reduce occurrences of maloperation and failure early in the operational life of the BPS or PS.

The manufacturer shall produce a programme of site commissioning checks and tests. Repetition of the full programme of routine tests, already performed in the factory, shall be avoided as the purpose of commissioning tests is for confirmation of

- absence of damage;
- compatibility of separate units;
- correct assembly;
- correct performance of the assembled BPS or PS.

In general, this is achieved when the commissioning tests include, but are not limited to, the programme given in 11.3.102. The results of the tests shall be recorded in a test report.

11.3.102 Commissioning checks and test programme

11.3.102.1 Checks after installation

Subclause 11.3.101 requires the manufacturer to produce a programme of commissioning checks and tests. This should be based on, but is not limited to, the programme of checks and tests given in this document.

11.3.102.1.1 General checks

- assembly conforms to manufacturer's drawings and instructions;
- tightness of BPS or PS, its fastenings, fluid systems and control devices;
- external insulation and, where applicable, internal insulation are undamaged and clean;
- paint and other corrosion protection are sound;
- operating devices, especially operating releases, are free from contamination;
- adequacy and integrity of the earth connection up to and including the interface with the substation earthing system;

and, where applicable:

- record the number on the operations counter(s) at delivery;
- record the number on the operations counter(s) at completion of all site testing;
- record the number on the operations counter(s) at first energisation.

11.3.102.1.2 Checks of electrical circuits

- Conformity to the wiring diagram.
- Correct operation of signalling (position, alarms, lockouts, etc.).
- Correct operation of heating and lighting.

11.3.102.1.3 Checks of the insulation and/or switching fluid(s)

Oil	Type, dielectric strength (in accordance with IEC 60296), level
Gas	Filling pressure/density, and quality checks, to confirm the acceptance levels of IEC 60376 and IEC 60480, as applicable. These quality checks are not required on sealed equipment and new gas used from sealed bottles. A dewpoint check and a check of the total impurities shall be carried out to confirm the manufacturer's acceptance levels
Gas mixtures	Quality is to be confirmed prior to energisation
Compressed air	Quality (if applicable) and pressure

11.3.102.1.4 Checks on operating fluid(s), where filled or added to on site

Hydraulic oil Level and, unless otherwise agreed, confirmation that the moisture content is sufficiently low to prevent internal corrosion or other damage to the hydraulic system

Nitrogen Filling pressure and purity (for example oxygen free or 1 % tracer gas)

11.3.102.1.5 Site operations

Confirmation shall be given that the programme of commissioning checks and tests required by 8.101 has been completed and, where applicable, extended by the additional 50 operations required by 11.3.101.

11.3.102.2 Mechanical tests and measurements**11.3.102.2.1 Measurements of the characteristic insulating and/or switching fluid pressures (where applicable)****11.3.102.2.1.1 General**

The measurements in 11.3.102.2.1.2 shall be taken in order to compare them with the values both recorded during the routine tests and guaranteed by the manufacturer. These values serve as the reference for future maintenance and other checks and will enable any drift in operating characteristics to be detected.

These measurements involve a check of the operation of the alarm and lockout devices (pressure switches, relays, transducers, etc.) where applicable.

11.3.102.2.1.2 Measurements to be taken

- a) Where applicable, on rising pressure (density):
- the reset value of the closing lockout pressure;
 - the reset value of the opening lockout pressure;
 - disappearance of the low-pressure alarm.
- b) Where applicable, on dropping pressure:
- appearance of a low-pressure alarm;
 - operating value of lockout pressure for opening;
 - operating value of lockout pressure for closing.

11.3.102.2.2 Measurements of characteristic operating fluid pressures (if applicable)**11.3.102.2.2.1 General**

The following measurements (list to be adapted as necessary) should be taken, in order to compare them with the values both recorded during routine tests and guaranteed by the manufacturer. These values may serve as a reference during later checks (maintenance) and will enable any drift in operating characteristics to be detected.

The measurements involve a check of the operation of the lockout or alarm devices (pressure switches, relays, etc.).

11.3.102.2.2.2 Measurements to be taken

- a) On a rise in pressure with the pumping device (pump, compressor, controlled valve, etc.) in service:
- the reset value of the closing lockout;
 - the reset value of the opening lockout;
 - disappearance of the low-pressure alarm;
 - cut-off of the pumping device;
 - opening of the safety valve (if applicable).

NOTE The measurements can be combined with the measurements of the recharging time of the operating mechanism (see 11.3.102.2.5.2).

- b) On a drop in pressure with the pumping device switched off:
- closing of the safety valve (if applicable);
 - starting of the pumping device;
 - appearance of the low-pressure alarm;
 - lockout of the opening;
 - lockout of the closing.

In the case of a hydraulic control, the pre-inflation pressure of the accumulators should be indicated together with the ambient air temperature before the tests are performed.

11.3.102.2.3 Measurement of consumption during operations (if applicable)

With the pumping device switched off and the individual reservoir at the cut-in pressure of the pumping device, the consumption during each of the following operations or operating sequences should be evaluated:

- O;
- C;
- OC.

The steady-state pressure after each operation or operating sequence should be noted.

11.3.102.2.4 Verification of the operating sequence

The ability of the BPS or PS to perform its specified operating sequence should be verified. The tests should be performed with the recharging device in service, with site supply voltage and, if applicable, starting with the cut-in pressure of the pumping device, as in 11.3.102.2.3.

Evidence should be given to demonstrate the coordination between the interlocking device intervention levels and the minimum pressures for operation measured during the rated operating sequence.

The site supply voltage is the on-load voltage available at the BPS or PS from the normal site supply and should be compatible with the rated supply voltage of auxiliary and control circuits.

11.3.102.2.5 Measurement of time quantities

11.3.102.2.5.1 Characteristic time quantities

a) Closing and opening times, time spread

The following measurements should be made at maximum pressure (cut-off of pumping device) and at the supply voltage of the auxiliary and control circuits, measured at the terminals of the equipment and under typical load conditions of the supply voltage source:

- closing time and when possible time spread of the switching units or groups of units;
- opening time and when possible time spread of the switching units or groups of units.

These measurements should be carried out for separate opening and closing operations.

In the case of multiple trip coils, all should be tested and the times recorded for each.

The supply voltage before and during the operations should be recorded. Furthermore, the instant at which the control relay, if any, is energised should also be recorded (relay time plus closing or opening time).

b) Operation of control and auxiliary contacts

The timing of the operation of one of each kind (make and break) of control and auxiliary contacts should be determined in relation to the operation of the main contacts, on closing and on opening of the BPS or PS.

11.3.102.2.5.2 Recharging time of the operating mechanism

a) Fluid-operated mechanism

The operation time of the pumping device (pump, compressor, control valve, etc.) should be measured:

- between minimum and maximum pressure (cut-in and cut-off of the pumping device);
- during the following operations or operating sequence, starting each time with minimum pressure (cut-in of the pumping device):
 - C;
 - O;
 - OC.

b) Spring-operated mechanism

The recharging time of the motor should be measured at the site supply voltage.

11.3.102.2.6 Record of mechanical characteristics

As required by 8.101, a record can be made of the mechanical characteristics where the BPS or PS has been assembled for the first time on site or where all or part of the routine tests are performed on site. The record shall confirm satisfactory performance by comparison with the reference mechanical characteristics obtained during the reference no-load tests detailed in 7.101.4.1.

11.3.102.2.7 Checks of certain specific operations

11.3.102.2.7.1 Closing at the minimum filling pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for closing and a closing operation should be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted.

In case of doubt, an alternative test to the one described above may be performed, starting with a lower pressure than the minimum functional pressure for operation for closing (short-circuited contact).

11.3.102.2.7.2 Opening at the minimum filling pressure for operation (if applicable)

With the pumping device out of service, the control pressure should be lowered as far as the lockout value for opening and an opening operation should be carried out. The test should be conducted at the supply voltage of the equipment. The supply voltage before and during the operations should be recorded. The final pressure should be noted. There should be sufficient safety margin to the minimum functional pressure for closing.

In case of doubt, an alternative test may be performed, starting with a lower pressure than the minimum functional pressure for operation for opening (short-circuited contact). It should then be verified that closing operation is still possible.

11.3.102.2.7.3 Check of anti-pumping device

Measurement should be taken of the time during which the BPS or PS remains closed on a CO operating cycle or open after an OC operating cycle with the trip close circuit energised by the closing of the auxiliary contact.

The test also allows checking of the anti-pumping device operation and the absence of malfunction for any mechanical, hydraulic or pneumatic reasons, caused by the rapid application of the opening or closing command.

The opening or closing command should be maintained for 1 s to 2 s so that the anti-pumping device can be checked for effective operation.

NOTE A simplified anti-pumping test can also be executed, using the local control. In this case, a closing or opening command is applied and maintained, while a consecutive opening or closing command is applied.

11.3.102.2.7.4 Behaviour on a closing (or opening) command while an opening (or closing) command is already present

It should be verified that the switch meets the technical specifications in the presence of a closing (or opening) command when previously an opening (or closing) command is applied and maintained.

11.3.102.2.7.5 Application of an opening or closing command on both releases simultaneously (if applicable)

It can happen that both releases (normal and emergency) are energised simultaneously (or virtually simultaneously).

It should be ensured that the operations are not subject to any mechanical, hydraulic or pneumatic interference, particularly if the releases do not operate at the same level.

11.3.102.3 Electrical tests and measurements

11.3.102.3.1 Dielectric tests

Dielectric tests on auxiliary circuits shall be performed to confirm that transportation and storage of the BPS or PS have not damaged these circuits. However, it is recognised that such circuits contain vulnerable sub-components and the application of the full testing voltage for the full duration can cause damage. In order to avoid this, and to avoid the temporary removal of proven connections, the supplier shall detail the test process that demonstrates that damage has not occurred as well as the method of recording the results from this test process.

For dielectric tests on the main circuit of metal-enclosed switchgear and controlgear, IEC 62271-200 and IEC 62271-203 are applicable.

11.3.102.3.2 Measurement of the resistance of the main circuit

Measurement of the resistance of the main circuit is only required if switching units have been assembled on site. The measurement shall be made with a direct current in accordance with 8.4 of IEC TS 62271-5:2024.

11.4 Operating instructions

Subclause 11.4 of IEC TS 62271-5:2024 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC TS 62271-5:2024 is applicable with the following addition:

In addition, the manufacturer should give information regarding the maintenance of BPS or PSs following

- a) switching operations;
- b) operations in normal service.

This information should include the number of operations according to items a) and b) after which the BPS or PS is to be overhauled.

Subclauses 11.5.1 to 11.5.5 of IEC TS 62271-5:2024 are applicable. The checks required in 11.3.102.1 apply.

11.101 Resistors and capacitors

When checking resistors and capacitors, permitted variations of the values should be given. Users should be aware of the Garton effect that can lead to incorrect values of $\tan\delta$, see CIGRE TB 368 [4].

12 Safety

Clause 12 of IEC TS 62271-5:2024 is applicable with the following addition:

Any known chemical and environmental impact hazards should be identified in the handbook/manual of the BPS or PS.

13 Influence of the product on the environment

Clause 13 of IEC TS 62271-5:2024 is applicable.

Annex A

(normative)

Tolerances on test quantities during type tests

During type tests, the following types of tolerances may normally be distinguished:

- tolerances on test quantities which directly determine the stress of the test object;
- tolerances concerning features or the behaviour of the test object before and after the test;
- tolerances on test conditions;
- tolerances concerning parameters of measurement devices to be applied.

In Table A.1, only tolerances on test quantities are considered.

A tolerance is defined as the range of the test value specified in this document within which the measured test value should lie for a test to be valid.

Any deviation of the measured test value and the true test value caused by the uncertainty of the measurement are not taken into account in this respect.

The basic rules for application of tolerances on test quantities during type tests are as follows:

- a) testing stations shall aim wherever possible for the test values specified;
- b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses of the BPS or PS exceeding those tolerances are permitted only with the consent of the manufacturer. Lower stresses render the test invalid;
- c) where, for any test quantity, no tolerance is given within this document, or the standard to be applied, the type test shall be performed at values not less severe than specified. The upper stress limits are subject to the consent of the manufacturer;
- d) if, for any test quantity, only one limit is given, the other limit shall be considered to be as close as possible to the specified value.