IEC TS 62271-318

Edition 1.0 2024-09

TECHNICAL SPECIFICATION

colour inside

High-voltage switchgear and controlgear – Part 318: DC gas-insulated metal-enclosed switchgear for rated voltages including and above 100 kV

IEC TS 62271-318:2024-09(en)

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High-voltage switchgear and controlgear – Part 318: DC gas-insulated metal-enclosed switchgear for rated voltages including and above 100 kV

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ELECTROTECHNICAL
COMMISSION

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CONTENTS

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Part 318: DC gas-insulated metal-enclosed switchgear for rated voltages including and above 100 kV

FOREWORD

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IEC TS 62271-318 has been prepared by subcommittee 17C: Assemblies, 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
17C/930/DTS	17C/937/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/standardsdev/publications.

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

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

The reader's attention is drawn to the fact that Annex E lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this document.

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

- reconfirmed,
- withdrawn, or
- revised.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 318: DC gas-insulated metal-enclosed switchgear for rated voltages including and above 100 kV

1 Scope

This part of IEC 62271 specifies requirements for gas-insulated metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas or gas mixture other than air at atmospheric pressure, for direct current of rated voltages including and above 100 kV, for indoor and outdoor installation. This document includes rules for service conditions, ratings, design, and construction requirements. Test requirements and criteria for proof for passing type and routine tests are defined in this document for development and manufacturing of DC switchgear.

For the purpose of this document, the terms "DC GIS" and "DC switchgear" are used for "DC gas-insulated metal-enclosed switchgear".

This specification is applicable for both Line Commutated Converter (LCC) and Voltage Sourced Converter (VSC) for HVDC systems.

The DC gas-insulated metal-enclosed switchgear covered by this document consists of individual components intended to be directly connected together and able to operate only in this manner.

This document completes and amends, if applicable, the various relevant documents applying to the individual components constituting DC gas-insulated metal-enclosed switchgear.

2 Normative references

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

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

IEC 60068-2-11:2021, *Environmental testing – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-17:2023, *Environmental testing – Part 2-17: Tests – Test Q: Sealing*

IEC/IEEE 60076-57-129:2017, *Power transformers – Part 57-129: Transformers for HVDC applications*

IEC 60099-4:2014, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 60099-9:2014, *Surge arresters – Part 9: Metal-oxide surge arresters without gaps for HVDC converter stations*

IEC 60137:2017, *Insulated bushings for alternating voltages above 1 000 V*

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*
IEC 60270:2000/AMD1:2015

IEC 60376:2018, *Specification of technical grade sulphur hexafluoride (SF_6) and complementary gases to be used in its mixtures for use in electrical equipment*

IEC 60480:2019, *Specifications for the re-use of sulphur hexafluoride (SF_6) and its mixtures in electrical equipment*

IEC TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

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

IEC 61869-14:2018, *Instrument transformers – Part 14: Additional requirements for current transformers for DC applications*

IEC 61869-15:2018, *Instrument transformers – Part 15: Additional requirements for voltage transformers for DC applications*

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

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

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

IEC 62271-209:2019, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable terminations*
IEC 62271-209:2019/AMD1:2022

IEC 62271-211:2014, *High-voltage switchgear and controlgear – Part 211: Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC TR 62271-306:2012, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*
IEC TR 62271-306:2012/AMD1:2018

IEC TS 62271-313, *High-voltage switchgear and controlgear – Part 314: Direct current disconnectors and earthing switches*

IEC TS 62271-314:2024, *High-voltage switchgear and controlgear – Part 314: Direct current disconnectors and earthing switches*

IEC TS 62271-315:20–[1], *High voltage switchgear and controlgear – Part 315: Direct current (DC) transfer switches*

IEC 62895:2017, *High voltage direct current (HVDC) power transmission – Cables with extruded insulation and their accessories for rated voltages up to 320 kV for land applications – Test methods and requirements*

ISO 22479:2019, *Corrosion of metals and alloys – Sulfur dioxide test in a humid atmosphere (fixed gas method)*

IEC/IEEE 65700-19-03:2014, *Bushings for DC application*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62271-5:2024 and the following, apply.

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

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

3.101
metal-enclosed switchgear and controlgear
switchgear and controlgear assemblies with an external metal enclosure intended to be earthed, and complete except for external connections

[SOURCE: IEC 60050-441:1984, 441-12-04, modified – The note was deleted.]

3.102
DC gas-insulated metal-enclosed switchgear
metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas or gas mixture other than air at atmospheric pressure and used for DC applications

Note 1 to entry: This term generally applies to high-voltage switchgear and controlgear.

[SOURCE: IEC 60050-441:1984, 441-12-05, modified – "or gas mixture" and "and used for DC applications" has been added in the definition.]

3.103
DC gas-insulated switchgear enclosure
part of DC gas-insulated metal-enclosed switchgear retaining the insulating gas under the prescribed conditions necessary to maintain safely the highest insulation level, protecting the equipment against external influences and providing a high degree of protection to personnel

[SOURCE: IEC 62271-203:2022, 3.103, modified – Addition of "DC” in the main term and in the definition.]

[1] Under preparation. Stage at the time of publication: IEC CDTS 62271-315:2024.

3.104
isolating link
part of the conductor which can easily be opened or removed in order to isolate two parts of the GIS from each other

Note 1 to entry: The open gap is designed to withstand the test voltages across isolating distance according to IEC TS 62271-5:2024, Table 1.

Note 2 to entry: The purpose of an isolating link is to ensure electrical isolation between sections of a GIS e.g., during maintenance and repair work.

[SOURCE: IEC 62271-203:2022, 3.104, modified – New reference to Table 1 of IEC TS 62271-5:2024 in Note 1 to entry.]

3.105
removable link
part of the conductor which can easily be opened or removed in order to isolate two parts of the GIS from each other

Note 1 to entry: The open gap is designed to withstand the phase-to-earth test voltages according to IEC TS 62271-5:2024, Table 1.

[SOURCE: IEC 62271-203:2022, 3.105, modified – In the definition, "separate" was replaced with "isolate"; addition of a new reference to Table in Note 1 to entry; deletion of Note 2 to entry.]

3.106
compartment
part of DC gas-insulated metal-enclosed switchgear, which is gastight and enclosed

Note 1 to entry: A compartment can be designated by the main component contained therein, e.g., busbar compartment.

[SOURCE: IEC 62271-203:2022, 3.106, modified – Addition of "DC" in the definition; deletion of "circuit-breaker compartment" as an example in Note 1 to entry.]

3.107
component
essential part of the main or earthing circuits of DC gas-insulated metal-enclosed switchgear which serves a specific function

Note 1 to entry: Examples for components are disconnector, switch, DCVT, DCCT, bushing, busbar.

[SOURCE: IEC 62271-203:2022, 3.107, modified – Addition of "DC" in the definition; deletion of "circuit-breaker compartment", "switch", "fuse", "instrument transformer" as examples and addition of "DCVT" and "DCCT" as examples.]

3.108
support insulator
internal insulator supporting one or more conductors

[SOURCE: IEC 62271-203:2022-05, 3.108]

3.109
partition
gas tight support insulator of DC gas-insulated metal-enclosed switchgear separating two adjacent compartments

[SOURCE: IEC 62271-203:2022-05, 3.109, modified – Addition of "DC" in the definition.]

3.110
bushing
device that enables one or several conductors to pass through an enclosure and insulate the conductors from it

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – In the definition, "an enclosure" inserted after "pass through" and "a partition such as a wall or a tank" deleted. Deletion of Note 1 to entry and Note 2 to entry.]

3.111
main circuit
all the conductive parts of DC gas-insulated metal-enclosed switchgear included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:1984, 441-13-02, modified – "DC gas-insulated metal-enclosed switchgear" inserted after "parts of" and "an assembly" deleted.]

3.112
auxiliary circuit
all the conductive parts of DC gas-insulated metal-enclosed switchgear included in a circuit intended to control, measure, signal and regulate

Note 1 to entry: The auxiliary circuits of DC gas-insulated metal-enclosed switchgear include the control and auxiliary circuits of the switching devices.

[SOURCE: IEC 62271-203:2022, 3.112, modified – Addition of "DC" in the definition and in Note 1 to entry.]

3.113
enclosure design temperature
maximum temperature that the enclosures can reach under specified maximum service conditions

[SOURCE: IEC 62271-203:2022, 3.113]

3.114
enclosure design pressure
relative pressure used to determine the design of the enclosure

Note 1 to entry: It is at least equal to the maximum pressure in the enclosure at the highest temperature that the gas used for insulation can reach under specified maximum service conditions.

[SOURCE: IEC 62271-203:2022, 3.114, modified – Note 2 to entry deleted.]

3.115
partition design pressure
relative pressure across the partition

Note 1 to entry: It is at least equal to the maximum differential pressure across the partition during maintenance activities.

[SOURCE: IEC 62271-203:2022, 3.115, modified – In the definition, deletion of "used to determine the design of the partition"; Note 2 to entry deleted.]

3.116
operating pressure
<pressure relief device> relative pressure chosen for the opening operation of pressure relief devices

[SOURCE: IEC 62271-203:2022, 3.116]

3.117
routine test pressure
<enclosures and partitions> relative pressure to which all enclosures and partitions are subjected after manufacturing

[SOURCE: IEC 62271-203:2022, 3.117]

3.118
type test pressure
<enclosures and partitions> relative pressure to which all enclosures and partitions are subjected for type test

[SOURCE: IEC 62271-203:2022, 3.118]

3.119
fragmentation
damage to enclosure due to pressure rise with projection of solid material

[SOURCE: IEC 62271-203:2022, 3.119]

3.120
disruptive discharge
phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or almost zero

[SOURCE: IEC 62271-203:2022, 3.120]

3.121
transport unit
part of DC gas-insulated metal-enclosed switchgear suitable for shipment without being dismantled

[SOURCE: IEC 62271-203:2022, 3.121, modified – Addition of "DC" in the definition.]

3.122
functional unit
part of metal-enclosed switchgear and controlgear comprising all the components of the main circuits and auxiliary circuits that contribute to the fulfilment of a single function

Note 1 to entry: Functional units may be distinguished according to the function for which they are intended, for example complete bay or functional parts of a bay like complete, disconnector, earthing switch, current transducer, operating mechanism, enclosure, etc.

[SOURCE: IEC 60050-441:1984, 441-13-04, modified – "metal-enclosed" inserted after "part of" and "an assembly of" deleted. In the note the examples have been exchanged with examples relevant for GIS.]

3.123
zero-load
ZL
no current flowing through conductor

3.124
high-load
HL
continuous heating period at rated continuous current, which duration is not less than the thermal stabilization time (time d_ϑ)

3.125
thermal stabilisation time
duration $\boldsymbol{d}_\vartheta$
period of time from load current applied to reach thermal steady state

3.126
thermal steady state
thermal steady state is defined as when the increase of temperature rise does not exceed 1 K in 1 h

3.127
DC steady state
DC steady state is defined as when minimum 90 % of the resistive field distribution is reached

Note 1 to entry: DC steady state is reached at the end of the transition from a capacitive to a resistive field distribution in the DC GIS. Depending on insulating material properties that are affected by temperature, electric field strength, etc., the transition to a resistive field distribution takes from hours to months.

3.128
electric field transition time
duration $\boldsymbol{d}_{\mathbf{DC}}$
period of time from direct voltage application to the DC steady state

3.129
superimposed impulse voltage test
S/IMP
simultaneous stress consisting of the direct voltage and the lightning or switching impulse voltage superimposed upon it

4 Normal and special service conditions

4.1 Normal service conditions

Subclause 4.1 of IEC TS 62271-5:2024 is applicable, taking into account the recommended values presented in Table 1 of this document.

4.2 Special service conditions

Subclause 4.2 of IEC TS 62271-5:2024 is applicable, taking into account the recommended values presented in Table 1 of this document.

In the cases where higher than (>) is used in the table, the values shall be specified by the user as described in IEC TS 62271-5:2024.

NOTE Seismic evaluation is part of IEC 62271-207.

4.101 General

Table 1 – Reference table of service conditions relevant to DC GIS

Item	Normal		Special	
	Indoor	Outdoor	Indoor	Outdoor
Ambient air temperature: Minimum (°C) Maximum (°C)	 –5 +40	 –25 +40	 –25 +50	 –50 +50
Solar radiation (W/m^2)	Not applicable	1 000	Not applicable	>1 000
Altitude (m)	1 000	1 000	>1 000	>1 000
RUSCDdc [a]	reference is made to IEC TS 62271-5:2024, Clause B.2	reference is made to IEC TS 62271-5:2024, Clause B.2	Reference is made to IEC TS 62271-5:2024, Clause B.3	Reference is made to IEC TS 62271-5:2024, Clause B.3
Ice coating (mm)	Not applicable	20	Not applicable	>20
Wind (m/s)	Not applicable	34	Not applicable	>34
Average humidity over 24 hours (%)	95	100	98	100
Condensation or precipitation	Occasional	Yes	Yes	Yes
Abnormal vibrations, shock or tilting	Not applicable	Not applicable	Applicable	Applicable

NOTE The user's specification can use any combination of normal or special service conditions above.

[a] Usually DC site severity is covered by a reference d.c. Unified Specific Creepage Distance, and IEC TS 60815-4:2016 gives information on how to determine RUSCD$_{dc}$.

At any altitude the dielectric characteristics of the internal insulation are identical with those measured at sea-level. For this internal insulation no specific requirements concerning the altitude are applicable.

Some items of a DC GIS such as pressure relief devices and pressure and density monitoring devices can be affected by altitude. The manufacturer shall take appropriate measures if necessary.

5 Ratings

5.1 General

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

j) rated values of the components forming part of DC gas-insulated metal-enclosed switchgear, including their operating devices and auxiliary equipment.

5.2 Rated direct voltage (U_{rd})

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

Components forming part of the DC GIS can have individual values of rated voltage for equipment in accordance with the relevant documents.

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:

The DC GIS comprises components having a definite insulation level. Although internal faults can largely be avoided by the choice of a suitable insulation level, measures to limit external overvoltages (e.g. surge arresters,) should be considered.

NOTE 1 Regarding the external parts of bushings (if any), see to IEC/IEEE 65700-19-03:2014.

NOTE 2 The waveforms are standardized lightning impulse and switching impulse shapes, pending the results of studies on the ability of this equipment to withstand other types of impulses.

NOTE 3 The choice between alternative insulation levels for a particular rated voltage for equipment can be based on insulation coordination studies, taking into account also the self-generated transient overvoltages due to switching.

NOTE 4 Annex H provides further information about DC switchgear located on a neutral bus.

5.4 Rated continuous current (I_{rd})

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

Some main circuits of DC GIS (e.g. busbars, feeder circuits, etc.) can have different values of rated continuous current. However, these values should also be selected from R10 series.

5.5 Rated values of short-time withstand current

5.5.1 Typical waveform of short-circuit current

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

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

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

5.5.3 Rated peak withstand current (I_{pd})

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

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

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

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

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 62271-1:2017 is applicable. Annex E provides further information about notes concerning certain countries.

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.

6.3.101 Earthing of the main circuit

To ensure safety during maintenance work, all parts of the main circuit to which access is required or provided shall be capable of being earthed.

Earthing can be made by:

a) earthing switches with a making capacity equal to the rated peak withstand current, if there is still a possibility that the circuit connected is energised;
b) earthing switches without a making capacity or with a making capacity lower than the rated peak withstand current, if there is certainty that the circuit connected is not energised.

Furthermore, it shall be possible, after opening the enclosure, to connect removable earthing devices for the duration of the work on a circuit element previously earthed via an earthing switch. The removable earthing device shall have the relevant short-circuit withstand capability and/or induced current capability.

The earthing circuit can be degraded after being subjected to the short-circuit current. After such event, it can be applicable to replace the earthing circuit.

6.3.102 Earthing of the enclosure

The enclosures shall be connected to earth. All metal parts which do not belong to a main or an auxiliary circuit shall be earthed. For the interconnection of enclosures, frames, etc., fastening (e.g. bolting or welding) is acceptable for providing electrical continuity.

The continuity of the earthing circuits can be ensured taking into account the thermal and electrical stresses caused by the current they have to carry.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC TS 62271-5:2024 is applicable.

6.5 Dependent power operation

Subclause 6.5 of IEC TS 62271-5:2024 is applicable.

6.6 Stored energy operation

Subclause 6.6 of IEC TS 62271-5:2024 is applicable.

6.7 Independent unlatched operation (independent manual or power operation)

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

6.8 Manually operated actuators

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

6.9 Operation of releases

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

6.10 Pressure/level indication

Subclause 6.10 of IEC TS 62271-5:2024 is applicable with the following addition:

The performance of the DC GIS is dependent upon the gas density of the pure gas or the gas mixtures.

For DC GIS it is not sufficient to monitor the gas pressure without temperature compensation.

The gas density or temperature compensated gas pressure in each compartment shall be continuously monitored. The monitoring device shall provide at least two alarm levels for pressure or density (alarm and minimum functional pressure or density). The correct functioning of gas monitoring devices shall be able to be checked with the high-voltage equipment in service.

NOTE 1 When the filling density differs between adjacent compartments, an additional alarm indicating over pressure or density can be used, if the DC GIS design requires it.

NOTE 2 Tolerances of the monitoring device, as well as possible differences in temperature (e.g. inside/outside of a building) between the monitoring device and the volume of gas being monitored, can be considered.

NOTE 3 Checking of gas monitoring can initiate wrong alarms which can initiate or inhibit switching operations.

NOTE 4 It is preferable for gas monitoring devices to be placed as close as possible to the gas compartment which is being monitored to ensure measuring accuracy and minimum leakage, however consideration can be given to safety and accessibility when choosing the location.

NOTE 5 The preferred solution for checking the gas monitoring device is to separate the density monitor from the gas compartment without mechanically removing it from the DC GIS, in order to minimize gas losses.

6.11 Nameplates

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

A common nameplate shall be provided to identify the DC GIS. It shall, as a minimum, detail the ratings listed in Clause 5 of this document. The common nameplate shall be clearly readable from the position of local operation side.

For each individual device a nameplate according to its relevant document is required where ratings are not detailed on the common nameplate.

The nameplates shall be durable and clearly legible for the lifetime of the DC GIS.

The manufacturer shall give information of the type, volume and mass of the gas contained in each gas compartment as well as the total mass for the entire DC GIS installation either on the nameplate or on a label placed in a visible location. If required, more information shall be provided in the instruction manual.

6.12 Locking devices

Subclause 6.12 of IEC TS 62271-5:2024 is applicable with the following addition:

The following provisions are mandatory for apparatus installed in main circuits which are used as isolating distance and earthing:

- apparatus installed in main circuits, which are used for ensuring isolating distances during maintenance work, shall be provided with visible locking devices to prevent closing (e.g. padlock);
- earthing switches shall be provided with locking devices to avoid opening during maintenance work.

6.13 Position indication

Subclause 6.13 of IEC TS 62271-5:2024 is applicable with the following addition:

In case of disconnector switch and earthing switch subclause 6.104.2 of IEC TS 62271-314:2024 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:

This applies to bushings only.

6.16 Gas and vacuum tightness

6.16.1 General

Subclause 6.16.1 of IEC TS 62271-5:2024 is applicable with the following addition:

This applies only to insulating and switching medium, not to operating medium of switchgear and controlgear.

DC GIS shall be a closed pressure system or a sealed pressure system.

Leakage losses and handling releases shall be considered separately. The objective is to minimize the release of gas in the atmosphere due to leakage and handling (see IEC 62271-4).

The cause of any leakage shall be investigated carefully, and corrective actions shall be considered, especially if it is above the specified values.

6.16.2 Controlled pressure systems for gas

Subclause 6.16.2 of IEC TS 62271-5:2024 is applicable.

6.16.3 Closed pressure systems for gas

Subclause 6.16.3 of IEC TS 62271-5:2024 is applicable with the following addition:

The relative leakage rate from any single compartment of DC GIS to atmosphere and between compartments shall not exceed 0,5 % per year for the expected operation duration of the equipment.

NOTE 1 Expected operation duration is typically 40 years under normal service condition as specified in Annex D.

The permissible relative leakage rate F_{rel} for type tests is specified as:

- ≤ 0,1 % per year for SF_6, SF_6 mixtures and for other gas mixtures with GWP > 1 000.
- ≤ 0,5 % per year for other gas mixtures with GWP ≤ 1 000.

NOTE 2 The global warming potential (GWP) of gases in DC GIS is the major reason for requiring low permissible leakage rates. Solutions with alternative gases with GWP lower than 1 000 exist. GWP (100 years) of SF_6 is 24 300 according to the IPCC – AR6 Climate Change 2021 [1] [2].

For small gas compartments containing less than 1 kg gas, the permissible relative leakage rate F_{rel} for type tests is specified as:

- ≤ 0,2 % per year for SF_6, SF_6 mixtures and for other gas mixtures with GWP > 1 000.

6.16.4 Sealed pressure systems

Subclause 6.16.4 of IEC TS 62271-5:2024 is applicable.

6.16.101 Leakage

In accordance with standardized procedure defined in Clause 10 of IEC TR 62271-306:2012 and IEC TR 62271-306:2012/AMD1:2018, the manufacturer shall demonstrate that the relative leakage rate from any compartment of DC GIS or between compartments complies with 6.16.3 or 6.16.4.

6.16.102 Gas handling

The DC GIS shall be designed to minimize life cycle gas-handling losses (including end of life activities). The manufacturer shall specify test and maintenance procedures for minimizing gas-handling releases and shall identify the gas releases associated with each procedure.

Procedures for gas handling according to IEC 62271-4 shall be used.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC TS 62271-5:2024 is not 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.

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

6.21 Corrosion

Subclause 6.21 of IEC TS 62271-5:2024 is applicable with the following addition:

The continuity of the earthing circuits shall be ensured taking into account the corrosion of bolted and screwed assemblies.

6.22 Filling levels for insulation, switching and/or operation

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

6.101 General requirements for DC GIS

DC GIS shall be designed so that normal service, inspection and maintenance operations, earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of dangerous electrostatic charges, can be carried out safely, after installation and extension.

The design of the equipment shall be such that the agreed permitted movement of foundations and mechanical or thermal effects do not impair the assigned performance of the equipment.

All components of the same type (rating, design and construction, etc.) which can be replaced shall be interchangeable.

The various components contained within the enclosure are subject to their relevant documents except were modified by this document.

6.102 Pressure coordination

The pressure inside a DC GIS can vary from the filling pressure p_{re} due to different service conditions.

In service conditions, the mechanical stresses are associated with the internal pressure which depends on the gas temperature. Consequently, the maximum pressure in service corresponds to the filling pressure at the maximum temperature the gas can reach due to continuous current and service conditions (e.g. temperature, solar radiation).

Figure 1 shows the various pressure levels and their relationship.

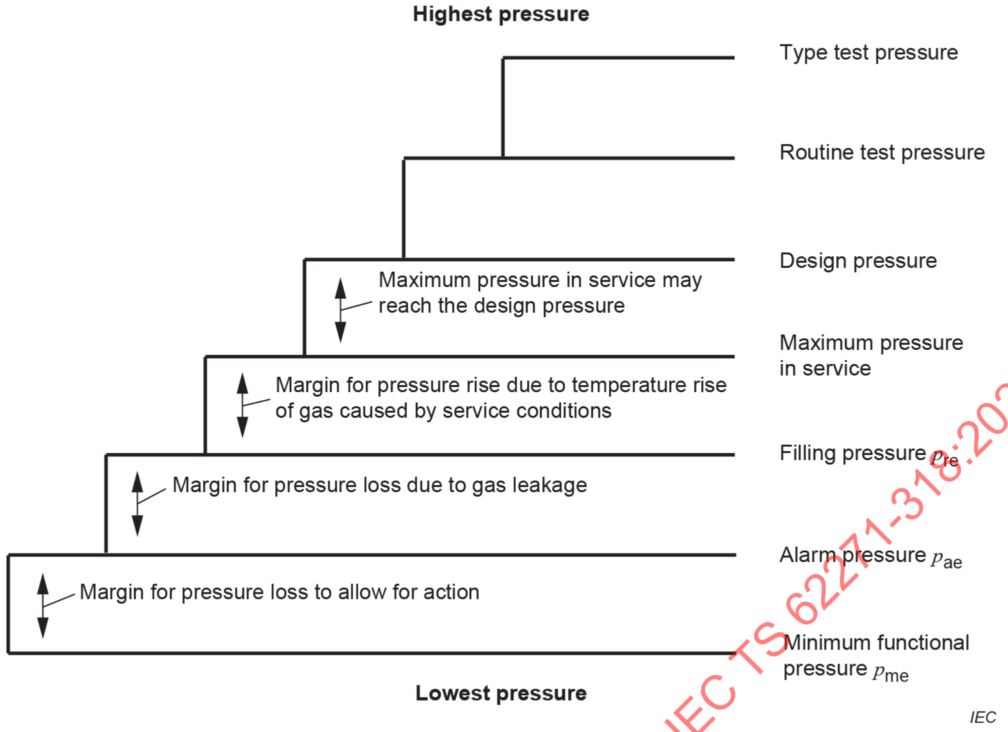

Figure 1 – Pressure coordination

The manufacturer is responsible for choosing the minimum functional pressure for insulation p_{me} and filling pressure p_{re}.

The manufacturer shall propose the alarm pressure p_{ae} which is related to both the filling pressure p_{re} and the minimum functional pressure. The alarm pressure p_{ae} will inform the user of any gas leak. For DC GIS using gas with a GWP > 1000, the filling pressure p_{re} and the alarm pressure p_{ae} shall be as close as possible, considering the tolerances of the density sensors, in order to make the user aware as soon as possible of gas losses.

Installation conditions (indoor, outdoor, direct solar radiations, ...), design and tolerances of the gas monitoring device shall be taken into consideration.

The time between the alarm pressure p_{ae} and the minimum functional pressure p_{me} allows corrective actions to be undertaken by the user and is dependent upon the gas leakage rate. During this period of time, the tolerances of the gas monitoring devices shall be taken into consideration.

6.103 Internal arc fault

6.103.1 General

A fault leading to arcing within DC GIS built according to this document has a very low order of probability. This results from the application of an insulating gas other than air at atmospheric pressure which will not be altered by pollution, humidity or vermin.

DC GIS shall be designed, manufactured and operated in order to prevent the occurrence of internal fault within DC GIS. All possible measures to keep a very low probability of occurrence shall be taken such as:

- insulation co-ordination;
- gas leakage limitation and control;
- control of gas quality;
- high quality of work on-site;
- interlocking of switching device.

The very low probability of such an event shall be considered. Arrangements shall be made to minimize the effects of internal faults on service continuity (e.g. high-speed protection, remote control, additional gas compartments). The internal arc shall not propagate into adjacent gas compartments.

After such an event, an intervention will be necessary in order to isolate the faulty compartment. The general partitioning of DC GIS design shall permit the restoration of the part of DC GIS which is not affected in order to satisfy the service continuity requirements when defined (see IEC 62271-203:2022, Annex F).

6.103.2 External effects of the arc

The effects of an internal arc are:

- pressure increase of gas (see Annex C),
- possible burn-through of enclosure.

The external effects of the arc shall be limited to the appearance of a hole or a tear in the enclosure without any fragmentation (by a suitable protective system). The duration of the arc is related to the performance of the protective system.

Table 2 gives the performance criteria depending on a dedicated Joule integral value of the short-circuit current derived by applying the Joule integral value $E_j = \int i^2 dt$ for both alternating and direct short-circuit current (see IEC TS 62271-5:2024, Clause D.6).

Table 2 – Performance criteria

Joule integral value (E_j)	Explanation	Performance criteria
< 320 (kA)^2·s	This corresponds to the main protection.	No external effect other than the operation of suitable pressure relief devices
< 800 (kA)^2·s	This corresponds to the back-up protection.	No fragmentation (burn-through is acceptable)

NOTE 1 Energy limits have been calculated using the Joule integral according to IEC TS 62271-5:2024, Clause D.6 based on performance criteria of IEC 62271-203:2022, 6.103.2. Value of 320 (kA)^2·s was calculated by $E_j = \int I^2 dt$ for 40 kA RMS and 0,2 s. Value of 800 (kA)^2·s was calculated by $E_j = \int I^2 dt$ for 40 kA RMS and 0,5 s.

NOTE 2 For current and expected near term implementations of HVDC, the short-circuit current is much lower than in AC systems.

The term "no fragmentation of the enclosure" is interpreted as follows:

- no explosion of the compartment;
- no solid parts flying off from the compartment.

Exceptions are:

- parts of the pressure relief device or parts installed in these, if their ejection is directed;
- glowing particles and molten material resulting from burn-through of the enclosure.

Additionally, manufacturer and user can define a time during which an arc due to an internal fault up to a given value of short-circuit current will cause no external effects. The definition of this time shall be based on test results or an acknowledged calculation procedure. See Equation (C.1).

NOTE 3 Using an alternating current for testing, Annex C is applicable. If considering direct current for testing, there is currently insufficient experience to derive a calculation procedure.

The duration of current without burn-through for different values of the short-circuit AC current can be estimated from an acknowledged calculation procedure like CIGRE Technical Brochure 602 [2], CIGRE Session 1998 – WG 21/23/33-03 [3] and RGE: 04/82 [4].

Hence, Annex C is not applicable when using direct current for testing.

6.103.3 Internal fault location

The manufacturer of the DC GIS should propose appropriate methods for the determination of the location of a fault, if required by the user.

6.104 Enclosures

6.104.1 General

The enclosure shall be capable of withstanding the normal and transient pressures to which it is subjected in service.

6.104.2 Design of enclosures

The design of the enclosure shall be made in accordance with established documents for pressurized enclosures of gas-filled, high-voltage switchgear and controlgear with inert, non-corrosive, low pressurized gases. For further information, see EN 50052 [5], EN 50064 [6], EN 50068 [7], EN 50069 [8]. Annex E provides further information about notes concerning certain countries.

Methods for the calculation of the thickness and the construction of enclosures either by welding or casting shall be based on the design pressure (see definition in 3.114).

When designing an enclosure, account shall also be taken of the following:

a) the possible recovery or evacuation gas or air in the enclosure as part of the normal filling process;
b) the full differential pressure possible across the enclosure walls or partitions;
c) the resulting pressure in the event of an accidental leak between the compartments in the case of adjacent compartments having different service pressures if overpressure is not monitored;
d) the possibility of the occurrence of an internal fault (see 6.103);
e) the corrosive impact on enclosures shall be considered by appropriate measures (e.g. filter material to absorb humidity and decomposition products).

In determining the design pressure, the gas temperature shall be taken as the mean of the upper limits of the enclosure temperature and the main circuit conductor temperature with rated continuous current flowing unless the design pressure can be established from existing continuous current test records.

For enclosures and parts thereof, the strength of which has not been fully determined by calculation, proof tests (see 7.103) shall be performed to demonstrate that they fulfil the requirements.

Materials used in the construction of enclosures shall be of known and certified minimum physical properties on which calculations and/or proof tests are based. The manufacturer shall be responsible for the selection of the materials and the maintenance of these minimum properties, based on certification of the material supplier, or tests conducted by the manufacturer, or both.

6.105 Partitions

6.105.1 Design of partitions

Partitions shall be used to separate compartments of the DC GIS and shall be gas tight such that contamination between adjacent compartments cannot occur. Partitions shall be made of material having insulating and mechanical properties so as to ensure proper operation over the lifetime of the DC GIS. Partitions shall maintain their dielectric withstand strength at voltages, which can occur in service (including temporary and transient voltages), when contaminated by by-products of gases and gas mixtures generated from normal load switching.

The design pressure of a partition is defined by the situation where the partition is pressurized on one side and maintenance is being carried out on the other side at atmospheric pressure (e.g. when maintenance is being carried out). In this case the pressure to be considered on the pressurized side of the partition is the pressure at maximum ambient temperature with solar radiation effects (where applicable) and rated continuous current (where applicable and without time limit). The pressure so derived is the design pressure of the partition.

During maintenance activities, the gas pressure can be lowered to a specified and controlled pressure. If this pressure is below the minimum functional pressure the concerned gas compartments shall be switched off. Warning notices and gas handling procedures shall be written in the operating and maintenance manuals.

Beyond the design pressure, account shall be taken of the following, if applicable:

- recovery or evacuation of gas or air in a gas compartment on one side of the partition with service pressure on the other, as part of the filling process; if there is a pressure differential limitation, or a time limitation related to the pressure differential, these shall be clearly stated by the manufacturer in the operating and maintenance manuals;
- for non-symmetrical partitions, as far as the pressure on the partition is concerned, the worst-case pressure direction;
- superimposed loads and vibration;
- the possibility of maintenance being carried out adjacent to a pressurized partition, with special care to avoid rupture of the partition and the risk of injuries for maintenance people.

NOTE Enhanced pressure due to internal fault is not considered to establish the pressure design since in such situation, partition will be closely inspected and replaced if applicable.

6.105.2 Partitioning

The selection of the electrical single-line diagram is the primary consideration to fulfil service continuity requirements. Layout arrangements and introduction of dismantling facilities will influence service continuity during maintenance, repair and extension.

Partitioning of a DC GIS is influenced by the service continuity requirements during maintenance, repair and extension. Local health and safety requirements shall also be considered, see Clause 12.

Annex F of IEC 62271-203:2022 provides guidance for specifying service continuity.

NOTE 1 Annex F of IEC 62271-203:2022 applies to AC GIS. In principle, this guideline can also be applied to DC GIS.

DC GIS shall be divided into compartments in such a manner that:

- during various activities requiring de-energization of parts of the DC GIS, compartments to be taken out of service comply with the user's service continuity requirements. These activities include:
  - maintenance;
  - repair;
  - extension;
  - on-site dielectric test;
- the effects of an arc inside a compartment are limited to that compartment (see 6.103.1);
- duration of unavailability in case of major failure shall be in accordance with the user's service continuity requirements;
- the gas or air of the compartment can be recovered, evacuated and filled in a reasonable time considering the gas handling devices available.

NOTE 2 For on-site dielectric tests (after maintenance, repair or extension), see 11.101.2.

Partitions are generally of insulating material. They are not intended to provide electrical safety of personnel. For this purpose, other means such as separating by an isolating distance and earthing of the equipment can be used.

Partitions provide mechanical safety against the gas pressure still present in the adjacent compartment during maintenance, repair and extension. During such activities, other mechanical stresses than pressure should be considered on partitions, such as shock of any piece, or transient mechanical stresses from conductors in order to define the safety rules and avoid health risk for people.

Where a DC GIS bus-duct pass between indoor and outdoor locations (for example, DC GIS installed within a building with outdoor bushings), the gas compartment can be provided with a partition close to the wall, separating the compartment between the indoor and outdoor environments to prevent problems arising from false alarms of the gas monitoring devices and condensation occurring due to indoor and outdoor temperature differences.

Each compartment shall be equipped with the following accessories:

- filling valve;
- gas monitoring device (see 6.10).

Depending on the DC GIS design or on users request each compartment can be equipped with the following accessories:

- pressure relief device (see 6.106.3);
- desiccant;
- internal arc fault location detector (see 6.103.3).

Figure 2 gives an example of an arrangement of enclosures and partitions for different types of adjacent compartments.

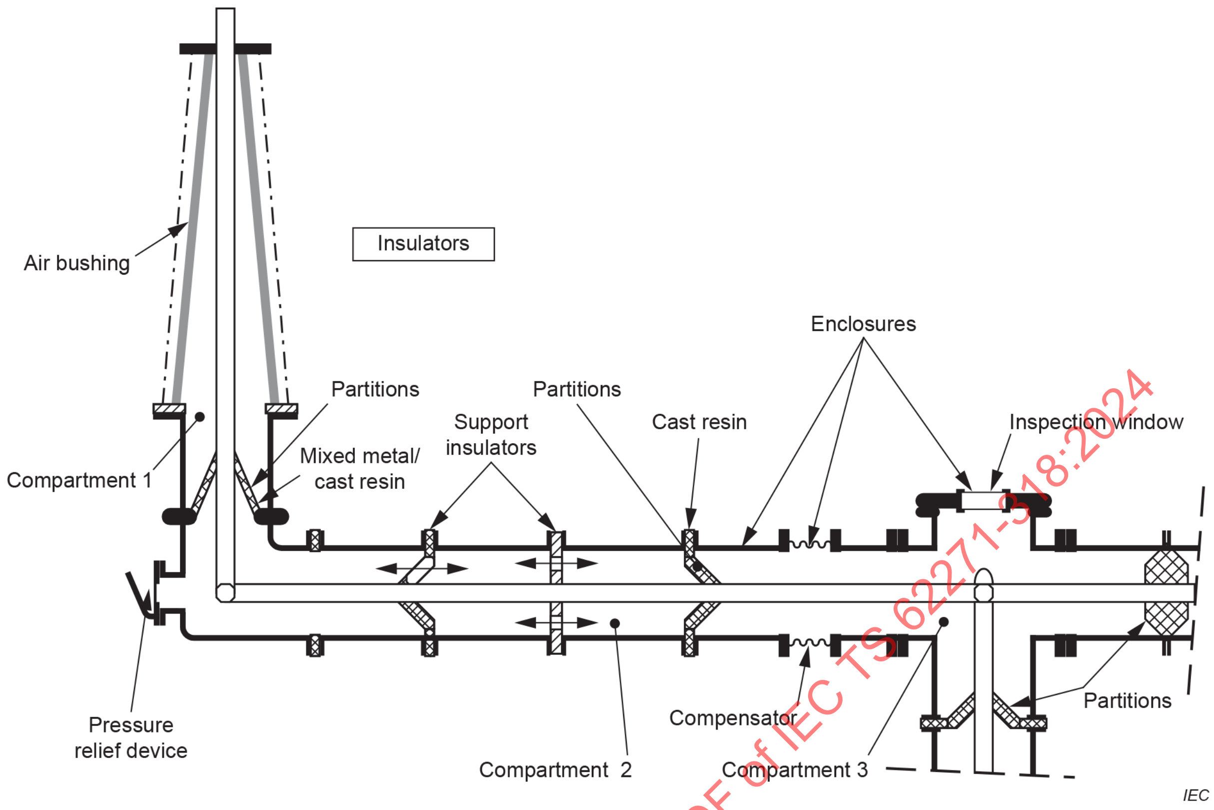

Figure 2 – Example of arrangement of enclosures and gas compartments

6.106 Pressure relief

6.106.1 General

Pressure relief device includes both pressure relief valves, characterized by an opening pressure and a closing pressure; and non-reclosing pressure relief devices, such as diaphragms and bursting disks. Pressure relief devices in accordance with this subclause shall be arranged so as to minimize the danger to an operator performing normal operating duties in the DC gas-insulated substation if gases or vapours are escaping under pressure.

6.106.2 Non-reclosing pressure relief device

Since, after an arc due to an internal fault, the damaged enclosures will be replaced, non-reclosing pressure relief devices shall only be proportioned to limit the external effects of the arc (see 6.103.2).

6.106.3 Pressure relief valve

For filling a gas compartment, a pressure relief valve shall be fitted to the filling pipe to prevent the gas pressure from rising to more than 10 % above the design pressure during the filling of the enclosure.

After an opening operation, a pressure relief valve shall reclose before the pressure has fallen to 75 % of the design pressure.

The filling pressure p_{re} should be corrected to take into account the gas and ambient temperature at the time of filling.

6.106.4 Limitation of pressure rise in the case of an internal fault

Non-reclosing pressure relief devices protect against overpressure in case of internal fault. For safety reasons and in order to limit consequences on DC GIS, it is recommended that each compartment be equipped with a non-reclosing pressure relief device, except for large volumes where the overpressure is self-limited to values which do not exceed the type test pressure.

NOTE 1 Using an alternating current for testing, calculation method of Annex C is applicable. For using a direct current for testing, currently not sufficient experience is available to derive a calculation procedure.

The pressure relief device shall be equipped with a deflector in order to control the direction of emission to secure an operator working in accessible places for normal operation. In order to avoid any pressure relief operation under normal conditions, a sufficient difference is necessary between the operation pressure of the pressure relief device and the design pressure. Moreover, transient pressure occurring during operation (if applicable) shall be taken into account when determining the operating pressure of the pressure relief device.

NOTE 2 In the case of an internal fault which causes yielding of the enclosure, enclosures of adjacent compartments can be checked for absence of distortion.

6.107 Noise

During an operation, the level of noise emitted by the switchgear should not exceed a specified value defined by the user. The procedure of verification should be agreed between manufacturer and user (see IEC 61672-1 [29] and IEC 61672-2 [30]).

6.108 Interfaces

6.108.1 General

In order to facilitate testing of DC GIS, isolating or removable links can be included in the design in each of the components mentioned below. This type of separation is preferable rather than dismantling. For air bushing, the high-voltage connection can be removed, preferably on the air side.

An isolating link shall be designed to withstand the test voltages across isolating distance according to Table 1 of IEC TS 62271-5:2024.

A removable link shall be designed to withstand the phase-to-earth test voltages according to Table 1 of IEC TS 62271-5:2024.

The isolating or removable links shall be designed to withstand the test voltages of the components mentioned below.

Those interfaces connected to the DC GIS shall be capable of withstanding the maximum pressure in service of the DC GIS. Typical maximum pressures in service are up to 1,1 MPa (absolute) for SF_6 and up to 1,5 MPa (absolute) for other gases and gas mixtures.

6.108.2 Cable connections

6.108.2.1 General

See IEC 62271-209.

NOTE A CIGRE Joint working group JWG B1/B3/D1.79 is developing recommendations for dielectric testing of cable connection enclosures. Resulting technical brochure will give more information.

Those parts of the DC GIS, which remain connected to the cable, shall be capable of withstanding the cable test voltages specified in the relevant cable standards for the same rated voltage for equipment.

Parts not capable of withstanding the cable test voltages should be equipped with removable or isolating links.

During dielectric tests on cables in general, the adjacent parts of the DC GIS should be de-energized and earthed, unless special measures are taken to prevent disruptive discharges in the cable affecting the energized parts of the DC GIS.

The location of bushings for cable testing should be provided at the cable connection enclosure or at the DC GIS itself (see IEC 62271-209) or (to reduce handling releases of gas) at the other end of the cable.

6.108.2.2 Extruded insulation cable

According to IEC 62895, the electrical tests after installation are direct voltage tests in such case; part of the DC GIS in the vicinity of the cable termination can be subject to direct test voltage of the cable. If it is not acceptable to apply direct cable test voltages to the DC GIS, special provisions for cable testing shall be made (e.g. disconnecting facilities and/or increasing of the gas density for insulation).

6.108.2.3 Oil-filled cable

According to IEC 60141-1 [9] , CIGRE TB 841 [10], CIGRE TB 852 [11] and CIGRE TB 853 [12] the electrical tests after installation are direct voltage tests, in such case; if it is not acceptable to apply direct cable test voltages to the DC GIS, special provisions for cable testing shall be made (e.g. disconnecting facilities and/or increasing of the gas density for insulation).

6.108.3 Direct transformer connections

In order to facilitate testing of transformers, an earthing switch, which can be insulated from the DC GIS enclosure and ground, can be included in the design of the bushing or the DC GIS.

NOTE 1 Opening of the DC GIS for the testing of the transformer can then be avoided and reduce the gas handling releases and the outage time of the equipment.

NOTE 2 Direct transformer connection is used in case of a bipolar HVDC scheme when DC GIS is applied between line-side of converter transformer and converter. See Annex G.

NOTE 3 For reference, see IEC 62271-211.

6.108.4 Bushings

IEC/IEEE 65700-19-03 and IEC TS 60815-1 shall be used. See also IEC TS 60815-2 [13], IEC TS 60815-3 [14] and IEC TS 60815-4.

6.108.5 Interfaces for future extensions

When an extension is planned, the locations of any possible future extension should be considered and stated by the user in the document.

In the case of later extension with another DC GIS product and if requested by the user, the manufacturer shall supply information preferably in the form of drawings giving sufficient information to enable such an interface to be designed at a later stage. The procedure to ensure confidentiality of the design details shall be agreed between the user and manufacturer. See IEEE C37.122.6 [15].

The interface should concern busbars or busducts only, and not direct connections to "active" devices such as circuit-breakers or disconnectors. If an extension is planned, it is recommended that the interface incorporates facilities for installation and testing of the extension to limit the part of the existing DC GIS to be re-tested and to allow the connection to the existing DC GIS without further dielectric testing (see Clause B.3). It shall be designed to withstand the rated insulation levels across the isolating distance.

6.109 Interlocking

Disconnectors and earthing switches should be interlocked with associated equipment to prevent unintended opening or closing.

7 Type tests

7.1 General

7.1.1 General remarks

Subclause 7.1 of IEC TS 62271-5:2024 is applicable with the following addition:

For type tests, technical grade SF_6 and its mixtures in accordance with IEC 60376 or used SF_6 and its mixtures in accordance with IEC 60480 can be used.

If the DC GIS is designed to use any other gas than SF_6, the necessary technical grade and the characteristics of the gas / gas mixture used for the type testing shall be defined and documented by the manufacturer of the DC GIS and documented in the type test reports.

NOTE A working group of IEC TC 10 is currently working on standardization of technical grade of SF_6 free gas mixtures (IEC 63359 [34] and IEC 63360 [35]).

In regard of gas handling, IEC 62271-4 shall be taken into account.

As a general rule, tests on DC GIS components should be carried out in accordance with their relevant documents, unless a specific test specification or condition is defined in this document. For such cases, the condition given in this document shall be taken into account.

Unless specific testing requirements are defined, type testing shall be carried out on a complete functional unit. When this is impracticable, type tests can be made on representative assemblies or sub-assemblies.

Because of the variety of types, ratings and possible combinations of components, it is impracticable to subject all arrangements of the DC GIS to type tests. The performance of any particular arrangement can be substantiated from test results obtained on representative assemblies or sub-assemblies. The user and the manufacturer shall check that tested sub-assemblies are representative of the users' arrangement.

The type tests and verifications are listed in Table 3.

Table 3 – Type tests

	Mandatory type tests	
		Subclause
a)	Tests to verify the insulation level of the equipment and dielectric tests on auxiliary circuits	7.2
b)	DC insulation system test	7.2.101
c)	Tests to prove the radio interference voltage (RIV) level (if applicable)	7.3
d)	Tests to prove the continuous current of any part of the equipment and measurement of the resistance of the main circuit	7.3 and 7.4
e)	Tests to prove the rated peak and the rated short-time withstand current	7.5
f)	Tests to verify the making and breaking capacity of the included switching devices	7.101
g)	Tests to prove the satisfactory operation of the included switching devices	7.102.1
h)	Tests to prove the satisfactory operation at limit temperatures	7.102.2
i)	Tests to prove the strength of enclosures	7.103
j)	Verification of the degree of protection of the enclosure	7.6
k)	Gas tightness tests	7.7
l)	Electromagnetic compatibility tests (EMC)	7.8
m)	Additional tests on auxiliary and control circuits	7.9
n)	Tests on partitions	7.104
o)	Tests to prove performance under thermal cycling and gas tightness tests on insulators	7.106
p)	Corrosion test on earthing connections (if applicable)	7.107
q)	X-radiation test procedure for vacuum interrupters (if applicable)	7.10
	Type tests, when requested by the user	
		Subclause
r)	Dielectric tests under high-load condition	7.2.7.101
s)	Tests to assess the effects of arcing due to an internal fault	7.105
t)	Corrosion tests on sealing systems of enclosures and auxiliary equipment (if applicable)	7.108
u)	Long-term energized test	7.2.102

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.

7.2 Dielectric tests

7.2.1 General

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

Dielectric tests performed as type tests shall be followed by a partial discharge measurement according to the test procedure described in 7.2.10.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC TS 62271-5:2024 is applicable with the following addition:

No atmospheric correction factors shall be applied for dielectric tests on DC GIS.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC TS 62271-5:2024 is not applicable but the following points shall be noted:

- the wet test is applicable to outdoor bushings only;
- the test voltage and the test procedure shall be those specified in IEC/IEEE 65700-19-03:2014.

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.

g) DC insulation system tests:

   Test procedure A of IEC 60060-1:2010 shall be used. The test procedure is recommended for tests on degradable or non-self-restoring insulation normally, but in the case of a DC insulation system test, if a flashover in the self-restoring insulation (gas) occurs, the electric field distribution could be changed. Therefore, the procedure A is chosen as mandatory procedure. The DC GIS has passed the impulse tests if the following conditions are fulfilled:

   - Each series consists of at least 3 impulses;
   - Three impulses of the specified shape and polarity at the specified withstand voltage level are applied to the test object. The requirements of the test are satisfied if no indication of failure is obtained.
   - A visual inspection of all insulator surfaces is mandatory. Flashover tracks are not allowed.

If any disruptive discharges occur during the type test series, it is recommended to use all possible measures (even opening of the compartment) to find the location of flashover and to analyse the reason for it.

7.2.6 Application of the test voltage and test conditions

7.2.6.1 General

Subclause 7.2.6.1 of IEC TS 62271-5:2024 is applicable with the following addition:

The test voltages are specified in 7.2.7, 7.2.8 and 7.2.9.

Current transducers secondaries shall be short-circuited and earthed during dielectric testing.

Attention shall be given to the possibility that switching devices, in their open position, can result in less favourable field conditions. Under such conditions, the test shall be repeated in the open position. If, in the open position of a disconnector, an earthed metallic screen is interposed between the open contacts, this contact gap is not an isolating distance.

When voltage transducers and/or surge arresters forming an integral part of the DC GIS have a reduced insulation level, they can be replaced during the dielectric tests by replicas reproducing the field configuration of the high-voltage connections. Overvoltage protection devices shall be disconnected or removed during the tests. When this procedure is adopted, the voltage transducers and/or surge arresters shall be separately tested in accordance with the relevant documents.

7.2.6.2 General case

Subclause 7.2.6.2 of IEC TS 62271-5:2024 is applicable.

7.2.6.3 Special case

Subclause 7.2.6.3 of IEC TS 62271-5:2024 is applicable with the following addition:

The test across the isolating distance can be performed with the test voltage applied to one side of the isolating distance and the other side earthed or according to 7.2.6.2 of IEC TS 62271-5:2024.

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 applicable.

7.2.7.2 Direct voltage tests

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

The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The main circuits of the DC GIS shall be subjected to direct voltage tests in dry conditions only.

The bushings shall be subjected to direct voltage tests in dry and wet conditions, as specified in IEC/IEEE 65700-19-03:2014.

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:

The main circuits of the DC GIS shall be subjected to switching impulse voltage tests in dry conditions only.

The bushings shall be subjected to switching impulse voltage tests in dry and wet conditions.

7.2.7.4 Lightning impulse voltage tests

Subclause 7.2.7.4 of IEC TS 62271-5:2024 is applicable.

7.2.7.5 Superimposed impulse voltage tests

Subclause 7.2.7.5 of IEC TS 62271-5:2024 is applicable.

7.2.7.6 Polarity reversal tests

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

7.2.7.101 Dielectric tests under high-load condition

These tests are optional because these tests are covered by superimposed voltage tests along with the DC insulation system test. In case of doubt only, the following dielectric tests under high-load condition shall be carried out at ambient temperature and rated continuous direct current or equivalent alternating current.

- Direct voltage test according to 7.2.7.2. The direct voltage shall be applied for a period of 1 min after thermal stabilisation (duration d_{ϑ}).
- Superimposed impulse voltage test according to 7.2.7.5.
- If specified: polarity reversal test according to 7.2.7.6.

The heating used shall be conductor heating, and the heating shall be generated with direct or alternating current; the results are generating the same heating. The thermal steady state will normally be met after a test duration of five times the thermal time constant of the device under test.

NOTE 1 Duration d_{ϑ} for gas insulated components is typically in the range of some hours.

The time for the whole test can be shortened by preheating the circuit with a higher value of current, provided that sufficient test data is recorded to enable calculation of thermal time constant.

NOTE 2 The electric field strength distribution is influenced by the temperature and the temperature distribution. The DC insulation system test was introduced as a type test under high load conditions (see 7.2.101). The dielectric tests under high-load condition can be used to verify the dielectric withstand behaviour during the transition phases or in case of doubt.

7.2.8 Artificial pollution tests for outdoor insulators

Subclause 7.2.8 of IEC TS 62271-5:2024 is applicable with the following addition:

This test applies only to bushings.

7.2.9 Partial discharge tests

Subclause 7.2.9 of IEC TS 62271-5:2024 is applicable with the following addition:

7.2.9.101 General

The partial discharge test at ambient temperature and under zero load condition shall be performed on those test objects which have successfully passed direct withstand voltage tests, superimposed voltage tests, and the switching and lightning impulse voltage tests.

It is preferred to carry out the test at alternating voltage stress including an alternating voltage pre-stress. If alternating voltage tests are not possible due to laboratory limitations, the partial discharge test may be carried out at direct voltage.

Partial discharge tests shall be performed, and the measurement made in accordance with IEC 60270.

The test can be carried out on assemblies or sub-assemblies of the equipment used for all dielectric type tests.

In case of alternating voltage tests, the frequency shall be within the limits given by IEC 60060-1:2010.

7.2.9.102 Test procedure

The applied direct or alternating voltage is raised to a pre-stress value and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage is decreased to a specific value defined in Table 4.

The extinction voltage shall be recorded.

Table 4 – Test voltage for measuring PD intensity

	PD measurement at alternating voltage (preferred method)		PD measurement at direct voltage	
	Pre-stress voltage $U_{\text{pre-stress AC}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test AC}}$ (>1 min)	Pre-stress voltage $U_{\text{pre-stress DC}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test DC}}$ (>1 min)
Single-phase enclosures design (phase-to-earth voltage)	$\hat{U}_{\text{pre-stressAC}} = 1{,}5\ U_{\text{rd}}$	$\hat{U}_{\text{pd-testAC}} = 1{,}2\ U_{\text{rd}}$	$U_{\text{pre-stressDC}} = 1{,}5\ U_{\text{rd}}$	$U_{\text{pd-testDC}} = 1{,}2 \times U_{\text{rd}}$
$\hat{U}_{\text{pre-stress AC}}$	the peak value of alternating pre-stress voltage $\hat{U}_{\text{pre-stressAC}} = 1{,}5 \times U_{\text{rd}}$ during type tests, routine tests, and on-site tests to pre-stress the equipment before PD measurements are made.			
$\hat{U}_{\text{pd-test AC}}$	is the peak value of alternating test voltage $\hat{U}_{\text{pd-testAC}} = 1{,}2 \times U_{\text{rd}}$ for PD measurement during type tests, routine tests and on-site tests.			
$U_{\text{pre-stress DC}}$	is the direct pre-stress voltage $U_{\text{pre-stressDC}} = 1{,}5 \times U_{\text{rd}}$ during type tests to pre-stress the equipment before PD measurements are made.			
$U_{\text{pd-test DC}}$	is the direct test voltage $U_{\text{pd-testDC}} = 1{,}2 \times U_{\text{rd}}$ for PD measurement during type tests, routine tests and on-site tests.			

In addition, all components shall be tested in accordance with their relevant documents.

7.2.9.103 Maximum permissible partial discharge intensity

The maximum permissible partial discharge level shall not exceed 5 pC at the AC test voltage specified in Table 4.

The values stated above applies to individual components as well as to the sub-assemblies in which they are contained. However, some equipment, such as voltage transducers insulated with liquid, immersed or solid, have an acceptable level of partial discharge in accordance with their relevant document greater than 5 pC. Any sub-assembly containing components with a permitted partial discharge intensity greater than 5 pC shall be considered acceptable if the discharge level does not exceed 10 pC. Components for which higher levels are accepted shall be tested individually and are not integrated to the sub-assembly during test.

The direct voltage test shall be carried out at both positive and negative polarity. The pulse train response defined in IEC 60270 is not appropriate for direct voltage tests. An accepted and agreed-upon method shall be employed in order to clearly differentiate between PD within the DC GIS under test from any external interference during the PD tests. Partial discharge shall be measured and recorded at the test voltages defined in Table 4. The method of interpretation shall be reported along with the measured values. In case of doubt, an AC PD measurement according to the preferred method defined in Table 4 shall be additionally performed.

NOTE The interpretation of PD measurements at direct voltage stress is briefly touched upon in IEC 60270. The two methods shown are pulse counting vs. PD-level and the other is accumulative pulse-count over a given time interval, but at present can only be considered as a rough guide for evaluating DC PD. Much further investigation is applicable for more rigorous clarification of acceptance level, count number (over time), and other acceptance criteria for direct voltage applications. A further method to identify PD under direct voltage stress is the PSA method.

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 condition check

Subclause 7.2.11 of IEC TS 62271-5:2024 is applicable with the following addition.

The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

Annex E provides further information about notes concerning certain countries.

7.2.101 DC insulation system test

7.2.101.1 General

For verification of the insulation system under high-load (HL) condition and DC steady state, a long duration voltage test shall be carried out. Normally, for well-designed systems using typical cone-type or flat disk insulator geometries, the maximum electric field stress occurs on the surface of the insulator under zero-load or high-load condition. This is valid for both insulators with low electrical conductivity (duration d_ϑ < duration d_{DC}) and insulators with high electrical conductivity (duration $d_\vartheta \geq$ duration d_{DC}). The aim of the DC insulation system test is to verify the dielectric performance of DC GIS under high-load conditions. The worst-case load condition shall be defined by simulations using the real insulator geometry.

The duration of the test after reaching the thermal stability can be approximated with the following methods:

1) Worst case approximation of DC steady state time calculated according to the following equation:

$$d_{DC} = 2{,}3\ \tau_m = 2{,}3\ \varepsilon_0 \varepsilon_r / \sigma$$

where

τ_m is the dielectric time constant;

ε_0 is the vacuum permittivity;

ε_r is the relative permittivity of the insulator;

σ is the electrical conductivity of the insulator.

2) Direct electric field simulation: a simulation verified by experiments (at least by means of model arrangements) shall be used. Material and gas characterisations which are relevant for the numerical model shall be provided. The scalability of the model shall be demonstrated. Of importance are the electric field strength, temperatures, and temperature gradients; these parameters shall represent realistic service conditions.

3) Measurement of the direct potential field on the actual insulator surface in energized state at different locations along the insulator radius. The temperature gradient across the insulators shall represent the maximum temperature gradient (worst case) under service conditions with tolerances lower than 20 %. The direct voltage during the measurement on the actual insulator shall be representative for service conditions, which could be considered as proven for a direct voltage higher than 80 % of the rated direct voltage. If the measurements are only possible at lower direct voltages, the independence of the charging duration on the voltage shall be verified by suitable tests.

The requirements are fulfilled by demonstrating method 1), or alternatively by methods 2) or 3).

Also, the surface conductivity of the insulating material shall be measured. If the charge transport in the solid insulation is dominated by the bulk conductivity compared to the charge transport caused by a surface conductivity, only the bulk material shall be taken into account for calculation of the dielectric time constant (in case of dominant bulk conductivity).

It is the responsibility of the manufacturer to supply the relevant data and material properties.

Especially in the case of the third method, the electric field transition time d_{DC} is not directly determined. In those cases, d_{DC} is considered to be fulfilled if the rate of change of the measured potential field is lower than 10 % of the initial rate (initial time delays shall be ignored).

The electrical field transition could lead to long test durations, lasting from hours to months. The insulation system test shall be carried out once only, unless there is a substantial change in the solid insulating system with respect to materials, manufacturing processes, construction, design parameters, or requirements.

For the DC insulation system test, high load conditions shall be applied. The heating method used shall be conductor heating, and the heating shall be generated with equivalent direct or alternating current; the results are equivalent for both heating methods.

The test is valid and the relevant requirements are fulfilled by performing and passing either one of the alternative heating methods. For the insulation system tests, a higher equivalent direct or alternating current (compared to the rated direct current) is allowed because the maximum conductor temperature and maximum temperature drop across the insulation has to be safely achieved.

The thermal steady state will normally be met after a test duration of five times the thermal time constant of the device under test. Duration d_g for gas insulated components is typically in the range of some hours.

The time for the whole test can be shortened by preheating the circuit with a higher value of current, provided that sufficient test data is recorded to enable calculation of thermal time constant.

7.2.101.2 Test object

A minimum of 5 insulators (support and partition) of each type shall be tested.

For other insulators such as disconnector shafts, rods or tubes in minimum 3 samples shall be tested.

For surge arrestors it is only necessary to verify the insulation performance of the interface between surge arrestor and DC GIS, if the design is different from the other insulators.

7.2.101.3 Test sequence

The time span of the long-duration continuous direct voltage test as part of the DC insulation system test (see Table 5) depends on the electric field transition time d_{DC} and shall be calculated before starting the tests. The electric field transition time itself depends on the local temperature distribution and on the lowest temperature of the insulator.

The test can be divided into 2 to 4 test series with different direct voltage polarities (only positive or negative direct voltage for the long duration continuous direct voltage test phase) and with different superimposed impulse voltages (lightning or switching). The test can also be performed using identical test objects.

NOTE 1 The electric field transition time under high load condition (HL) can be reduced by increasing the ambient temperature, e.g. by enclosing the test device within an additional housing and providing means to circulate the air to achieve homogeneous temperature distribution inside the housing.

The electric field transition time d_{DC} is to be defined by simulations and / or measurements before the DC insulation system test.

The test shall be carried out at direct voltage, lightning impulse and switching impulse rated voltages according to sequence in Table 5:

Table 5 – Sequence of DC insulation system test

Test	Conditions	Load conditions	Remark
Thermal pre-test	Heating at defined temperature ±5 K	HL	thermal calibration[a]
Dielectric pre-test	PD test with alternating or direct voltage	ZL	according 7.2.9 [b]
Long-duration continuous direct voltage test	Rated direct voltage U_{rd} (One polarity, positive or negative)	HL	duration d_{DC}
Superimposed lightning impulse voltage test (bipolar and unipolar)	Rated LIWV values, superimposed to the rated direct voltage U_{rd}	HL	3 impulses[c d e g]
Superimposed switching impulse voltage test (bipolar and unipolar)	Rated SIWV values, superimposed to the rated direct voltage U_{rd}	HL	3 impulses[c d e f g]
Long-duration continuous direct voltage test	Rated direct voltage U_{rd} (other polarity)	HL	duration d_{DC}
Superimposed lightning impulse voltage test (bipolar and unipolar)	Rated LIWV values, superimposed to the rated direct voltage U_{rd}	HL	3 impulses[c d e g]
Superimposed switching impulse voltage test (bipolar and unipolar)	Rated SIWV values, superimposed to the rated direct voltage U_{rd}	HL	3 impulses[c d e f g]

[a] During the thermal calibration test, the current has to be determined for the maximum conductor temperature and maximum temperature drop across the solid insulators. This current has to be used for the long duration voltage test. For the DC insulation system test, a higher equivalent direct or alternating current compared to direct rated current is allowed, because the maximum conductor temperature and maximum temperature drop across the insulation shall be safely achieved.

[b] Before starting the DC insulation system test, further pre-testing under the responsibility of the manufacturer is allowed.

[c] Because of laboratory constraints, it can be necessary to interrupt the heating of the test object. The maximum heating interruption time should be less than 60 min. After a heating interruption and before further tests, the steady state temperature shall be reattained.

[d] Due to laboratory constraints, it can be necessary to disconnect the test object from the direct voltage source. The direct voltage drop at the test object shall not exceed 5 % of the test voltage while disconnecting. To verify the voltage on the test object during the disconnect interval, the direct voltage shall be measured using adequate voltage measurement instruments. Alternatively, the electrical time constant of the whole test device (between the disconnecting points) could be measured before starting the test and used to calculate the test voltage drop.

[e] The order of superimposed voltage tests is not of importance. It is possible to start with positive or negative polarity. Moreover, the order of lightning or switching impulses could be chosen according to the laboratory constraints.

[f] The superimposed lightning and switching impulse voltage tests can also be carried out in separate test sequences, if a long interruption time between lightning impulse voltage and switching impulse voltage testing or vice versa becomes necessary. In this case, it shall be ensured that the DC steady state is obtained again before superimposed impulse voltage testing.

[g] If the rated lightning impulse voltage is 1,3 times of the rated switching impulse voltage or larger, superimposed tests with switching impulse voltages are not mandatory.

During the long duration voltage test, partial discharges, temperature (ambient and enclosure), test current and test voltage should be monitored, and the measured data recorded. The measured temperatures should be compared to data obtained from thermal calibration test. It is also an advantage to apply arc detection and gas quality/pressure measurements.

The time between two successive impulses shall be not shorter than 1 min.

Generally, the verification of the dielectric performance under polarity reversals is covered by superimposed voltage tests. Therefore, the time to change the polarity during the insulation system tests could be chosen based on the possibilities and limitations of the laboratories (hours to months).

NOTE 2 The two test parts for the different polarities are independent tests.

If a breakdown or flashover occurs in a test object, the test of the affected direct voltage polarity shall be repeated for this particular test object. If partial discharges higher than 5 pC are detected in the DC GIS during the steady state condition before the application of the impulse test voltage, the location of the partial discharge shall be evaluated.

The insulation system test qualifies the insulators for DC applications provided that the following conditions are fulfilled:

a) The rated direct voltage U_{rd} is not higher than that of the tested system.

b) The maximum conductor temperature is less than or equal to that of the tested system.

c) The maximum temperature drop across the insulator is less than or equal to that of the tested system.

7.2.102 Long-term energized test

This test is an optional test. The testing procedure is described in Annex F. The long-term energized test is intended to indicate the long-term performance of the complete DC GIS and is normally to be completed after the type tests have been carried out.

NOTE The long-term energized test is a long-term test developed in the CIGRE TB 842 [16] and described as a prototype installation test. The naming has been adjusted to make it easier to understand.

The long-term energized test additionally helps to qualify the manufacturer as a supplier of a DC GIS provided that the following conditions are fulfilled:

a) The rated voltage U_{rd} of the DC GIS is not higher than that of the DC GIS tested.

b) The rated current I_{rd} of the DC GIS is not higher than that of the DC GIS tested.

c) The limiting temperature of the various parts in the DC GIS is not higher than that of the DC GIS tested.

7.3 Resistance measurement

7.3.1 Measurement of the resistance of auxiliary contacts class 1 and class 2

Subclause 7.3.1 of IEC TS 62271-5:2024 is applicable

7.3.2 Measurement of the resistance of auxiliary contacts class 3

Subclause 7.3.2 of IEC TS 62271-5:2024 is applicable

7.3.3 Electrical continuity of earthed metallic parts test

Subclause 7.3.3 of IEC TS 62271-5:2024 is applicable

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

7.3.4.1 Resistance measurement test procedure

Subclause 7.3.4.1 of IEC TS 62271-5:2024 is applicable with the following addition:

The current used for the measurement shall be equal to or greater than 100 A direct current to obtain sufficient accuracy of the measurement.

If no-load operations cannot be made, then 3 measurements shall be made without no-load operations of the switching devices.

NOTE It is recognised that for some tests, it is not practical (for example if gas handling is required between the measurements) nor possible (for example during continuous current test because of the presence of temperature sensors within the contact system) to make any no-load operations between each of the three resistances measurements.

7.3.4.2 Making and breaking tests

Subclause 7.3.4.2 of IEC TS 62271-5:2024 is applicable.

7.3.4.3 Other tests

Subclause 7.3.4.3 of IEC TS 62271-5:2024 is applicable.

NOTE Switching of small DC currents are covered by IEC TS 62271-314.

7.4 Continuous current tests

7.4.1 Conditions of the test object

Subclause 7.4.1 of IEC TS 62271-5:2024 is applicable.

7.4.2 Arrangement of the equipment

Subclause 7.4.2 of IEC TS 62271-5:2024 is applicable with the following addition:

DC GIS with single-pole enclosures shall be single-pole tested with the test current flowing through the main conductor. The test current shall not return through the enclosure.

When testing individual sub-assemblies, the neighbouring sub-assemblies should carry the currents which produce the power loss corresponding to the operating conditions. It is admissible to simulate equivalent conditions by means of heaters or heat insulation if the test cannot be made under actual conditions.

7.4.3 Test current and duration

7.4.3.1 Test on main circuit

Subclause 7.4.3.1 of IEC TS 62271-5:2024 is applicable.

7.4.3.2 Test on the auxiliary and control equipment

Subclause 7.4.3.2 of IEC TS 62271-5: 2024 is applicable.

7.4.4 Temperature measurement during test

Subclause 7.4.4 of IEC TS 62271-5:2024 is applicable.

7.4.5 Resistance of the main circuit

Subclause 7.4.5 of IEC TS 62271-5:2024 is applicable.

7.4.6 Criteria to pass test

Subclause 7.4.6 of IEC TS 62271-5:2024 is applicable with the following addition:

Insulators for DC GIS are considered electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC TS 62271-5 shall therefore be applicable for the EIS and not for the electrical insulation material (EIM).

For outdoor application, the manufacturer shall demonstrate that the temperature rise of the equipment will not exceed the limit acceptable under the service condition chosen in Clause 4.

NOTE 1 The effect of solar radiation can be taken into account. See IEEE C37.24 [17].

The temperature rise of components contained in the DC GIS which are subject to documents not covered by the scope of IEC TS 62271-5:2024 shall not exceed the temperature-rise limits permitted in the relevant document for those components.

NOTE 2 When applying a temperature rise equal to or higher than 65 K for parts of the enclosure not accessible to the operator, every precaution can be taken to ensure that no damage is caused to the surrounding insulating materials.

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 additions.

DC GIS with single-pole enclosures shall be tested in a single-pole circuit with return current or without return current in the enclosure.

The tests shall be made on a representative assembly which should include all types of connections of bolted, welded, plug-in or otherwise jointed sections to verify the integrity of DC GIS components are joined together. Assemblies shall be tested such that specimens of all components and sub-assemblies of the design are subjected to the test. Tests shall be made using configurations that provide the most severe conditions.

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.

7.5.101 Tests on the main circuits

After the tests, the resistance measurement shall not increase more than 20 % with respect to its pre-test resistance measurement. Neither the components nor conductors within the enclosure shall show any deformation or damage, which can impair the intended operation.

Short connections to voltage measurement devices shall be considered as part of the main circuit, except for parts included in the voltage measurement device compartment.

7.5.102 Tests on earthing circuits

The manufacturer shall demonstrate by tests or calculations the capability of earthing circuits to withstand the rated short-time and peak withstand current of the system.

When verification tests are required by the user, earthing circuits of DC GIS which are factory assembled and comprise earthing conductors, earthing connections and earthing devices shall be tested as installed in the DC GIS with all associated components which can influence the performance or modify the short-circuit current.

After the test, the components or conductors within the enclosure shall not show deformation or damages, which can impair the intended operation of the main circuit. Some deformation and degradation of the earthing conductor, earthing connections or earthing devices is permissible, but the continuity of the earthing circuit shall be preserved.

7.6 Verification of the protection

7.6.1 General

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

7.6.2 Verification of the IP coding

Subclause 7.6.1 of IEC TS 62271-5:2024 is applicable with the following addition.

Verification of IP coding is not applicable to pressurized DC GIS enclosures.

Where supplementary letter W is specified, it shall be checked by inspection, that the design does not contain places where significant accumulation of water can be retained (to minimize corrosion).

7.6.3 Verification of the IK coding

Subclause 7.6.2 of IEC TS 62271-5:2024 is applicable with the following addition:

Verification of IK coding is not applicable to pressurized DC GIS enclosures.

7.7 Tightness tests

7.7.1 General

Subclause 7.7.1 of IEC TS 62271-5:2024 is applicable with the following addition:

The measurement of gas tightness shall be performed as a type test to show that the relative leakage rate complies with 6.16.101. The tightness test shall be performed at filling pressure p_{re}.

The type test shall be performed with representative types of DC GIS compartments comprising sealings and accessories (e.g. gas filling valves, density monitors, bursting discs, UHF monitors, viewing ports, etc.)

For switching devices and insulators the measurement of gas tightness shall be performed together with the tests of 7.102 and 7.106.

7.7.2 Controlled pressure systems for gas

Subclause 7.7.2 of IEC TS 62271-5:2024 is applicable.

7.7.3 Closed pressure systems for gas

Subclause 7.7.3 of IEC TS 62271-5:2024 is applicable with following addition.

The measurement of gas tightness shall be performed by cumulative method (Q_m described in IEC 60068-2-17, test method 1).

7.7.4 Sealed pressure systems

Subclause 7.7.4 of IEC TS 62271-5:2024 is applicable.

7.7.5 Liquid tightness tests

Subclause 7.7.5 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 addition:

Subclause 7.8.1.1 of IEC TS 62271-5:2024 applies only to bushings.

7.9 Additional tests on auxiliary and control circuits

Subclause 7.9 of IEC TS 62271-5:2024 is applicable.

7.10 X-radiation test for vacuum interrupters

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

7.101 Verification of making and breaking capacities

Switching devices forming part of the main circuit of DC GIS shall be tested to verify their rated making and breaking capacities according to the relevant documents (IEC TS 62271-313, IEC TS 62271-314, IEC TS 62271-315) and under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the DC GIS with all associated components, the arrangement of which can influence the performance, such as connections, supports, etc.

NOTE In determining which associated components are likely to influence the performance, special attention can be given to mechanical forces due to short-circuiting, to the possibility of disruptive discharges, etc. It is recognized that, in some cases, such influences can be quite negligible.

7.102 Mechanical and environmental tests

7.102.1 General

Switching devices of DC GIS shall be submitted to mechanical operation and environmental tests in accordance with their relevant documents (IEC TS 62271-313, IEC TS 62271-314, IEC TS 62271-315) and shall be tested in a representative assembly of all associated components, which can influence the performance, including auxiliary devices. All equipment shall withstand the stresses caused by the operation of switching devices.

7.102.2 Mechanical operation test at ambient temperature

Before and after the mechanical operation tests, the measurement of gas tightness according to 7.7 shall be performed to show that the leakage rate is not changed by influences caused by the mechanical type tests.

All switching devices fitted with interlocks shall be submitted to 5 operating cycles in order to check the operation of the associated interlocks. Before each operation the interlocks shall be set in the position intended to prevent the operation of the switching devices and one attempt shall then be made to operate each switching device. During these tests only normal operating forces shall be employed and no adjustment shall be made to the switching devices or interlocks.

7.102.3 Low- and high-temperature test

Operation tests at minimum and maximum temperature shall be performed in accordance with the relevant apparatus documents.

7.103 Proof tests for enclosures

7.103.1 General

Proof tests are made when the strength of the enclosure or parts thereof is not calculated. They are performed on individual enclosures before the internal parts are added with testing conditions based on the design pressure stresses.

Proof tests can take the form of either a destructive or a non-destructive pressure test, as appropriate to the material employed. For further information, see EN 50052 [5], EN 50064 [6], EN 50068 [7], EN 50069 [8].

7.103.2 Burst test procedure

The pressure rise shall not be greater than 400 kPa/min.

The pressure test requirements shall be at least as follows:

Cast aluminium and composite aluminium enclosures

- type test pressure = [3,5 / 0,7] × design pressure

NOTE The value 0,7 has been included to cover the possible variability of production castings. This factor can be increased to 1,0 if it can be justified by special material tests.

Welded aluminium and welded steel enclosures

- type test pressure = [(2,3 / ν) × (σ_t / σ_a)] × design pressure

  where

  ν is the welding coefficient (1 for ultrasonic or radiography inspection of 10 % of welded section and 0,75 for visual inspection);

  σ_t is the permissible design stress at test temperature;

  σ_a is the permissible design stress at design temperature.

These factors are based on the minimum certified properties of the material used.

Additional factors can be used taking into account the methods of construction.

Any enclosure remaining intact after these pressures have been reached shall not be used for normal operation.

7.103.3 Strain measurement test

In the case of a non-destructive pressure test using a strain indication technique, the following procedure shall be applied:

Before the test, strain gauges capable of indicating strains to 5×10^{-5} mm/mm shall be affixed to the surface of the enclosure. The number of gauges, their position and their direction shall be chosen so that principal strains and stresses can be determined at all points of importance to the integrity of the enclosure.

Hydrostatic pressure shall be applied gradually in steps of approximately 10 % until the routine test pressure for the expected design pressure (see 8.101) is reached or significant yielding of any part of the enclosure occurs.

When either of these points is reached, the pressure shall not be increased further.

Strain readings shall be taken during the increase of pressure and repeated during pressure decrease.

Indication of localized permanent set can be disregarded provided there is no evidence of general distortion of the enclosure.

If the curve of the strain/pressure relationship show a non-linearity, the pressure can be re-applied not more than five times until the loading and unloading curves corresponding to two successive cycles substantially coincide. If coincidence is not attained, the design pressure and the test pressure shall be taken from the pressure range corresponding to the linear portion of the curve obtained during the final unloading.

If the routine test pressure is reached within the linear portion of the strain/pressure relationship, the expected design pressure shall be considered to be confirmed.

If the final test pressure or the pressure range corresponding to the linear portion of the strain/pressure relationship (see above) is less than the routine test pressure, the design pressure shall be calculated from the following equation:

$$p = \frac{1}{1{,}1\,k}\left(p_{\mathrm{y}}\,\frac{\sigma_{\mathrm{a}}}{\sigma_{\mathrm{t}}}\right)$$

where

p is the design pressure;

p_{y} is the pressure at which significant yielding occurs or the pressure range corresponding to the linear portion of the strain/pressure relationship of the most highly strained part of the enclosure during final unloading (see above);

k is the routine test pressure factor (see 8.101);

σ_{t} is the permissible design stress at test temperature;

σ_{a} is the permissible design stress at design temperature.

7.104 Pressure test on partitions

The purpose of this test is to demonstrate the safety margin of the partition submitted to pressure in service condition. For further information see EN 50089 [18].

The partitions shall be installed as for the maintenance condition. The pressure shall rise at a rate of not more than 400 kPa/min.

The bursting pressure shall be three times the design pressure.

7.105 Test under conditions of arcing due to an internal fault

Evidence of performance according to 6.103.2 shall be demonstrated by the manufacturer when required by the user.

Evidence can consist of a test or calculations based on test results performed on a similar arrangement or a combination of both.

If such a test is required, the procedure shall be in accordance with the methods described in Annex A.

NOTE Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [2], CIGRE Session 1998 – WG 21/23/33-03 [3] and RGE: 04/82 [4].

For the convenience of testing, alternating test current can be used alternatively. In such a case, the RMS value of the alternating current shall be not less than the rated short-time withstand direct current as defined in IEC TS 62271-5. The test duration can be one of the preferred values of short-circuit duration given in IEC TS 62271-5:2024, 5.5. The test duration can be reduced to 0,3 s by increasing the test current to reach the equivalent Joule integral value according to Table 2.

7.106 Insulator tests

7.106.1 General

Tests on insulators (partitions and support insulators) shall be performed as in 7.106.2 and 7.106.3.

7.106.2 Thermal performance

The thermal performance of each insulator design shall be verified by subjecting five insulators to ten thermal cycles each. Temperature values should be chosen according to Table 1.

The thermal cycle shall be as follows:

a) 4 h at minimum ambient air temperature (for example –40 °C);

b) 2 h at room temperature;

c) 4 h at limit of temperature according to Table 10 row 7 of IEC TS 62271-5:2024 (for example +105 °C);

d) 2 h at room temperature.

Insulators for DC GIS are considered electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC TS 62271-5 are therefore applicable for the EIS and not for the electrical insulation material (EIM).

The given thermal cycle times do not include the necessary transition times to reach the stable end temperatures of steps a), b), c) and d).

After the test sequence, all insulators shall be tested in accordance with routine tests 8.2, 8.6 and 8.104.

7.106.3 Tightness test for partitions

An overpressure withstand test shall be performed as described:

The design pressure of the partition shall be applied on one side of the partition while the adjacent compartment is under vacuum to verify the tightness of a partition. Alternatively, the pressure on one side of the partition shall be the design pressure of the partition plus 1 bar while the adjacent compartment is at 1 bar. The pressure in both compartments shall be measured over a period of 24 h.

Precautions shall be taken during test, as the test pressure across the partition is higher than the design pressure of the partition.

At the end of the test, no damage shall be observed on the partition. A gas tightness test shall be performed in accordance with 7.7. The relative leakage rate shall not be greater than the defined value prescribed in 6.16.

7.107 Corrosion test on earthing connections

7.107.1 General

For outdoor application, or on user's request, a corrosion proof test shall be performed in accordance with this subclause.

The tested sub-assemblies shall be representative of a DC GIS arrangement, including the devices providing electrical continuity and earthing of the enclosure, flanges of enclosures which can be part of the earthing system, the accessories (pressure monitoring device) and the secondary system as described in 15.7 of IEC TR 62271-306:2012 and IEC TR 62271-306:2012/AMD1:2018.

Testing of one representative earthing connection is considered to be sufficient.

7.107.2 Test procedure

The tested sub-assembly shall be submitted to environmental testing Ka (salt mist) according to IEC 60068-2-11. The duration of the test is 168 h.

In addition, for painted surfaces, the resistance to humid atmospheres containing sulphur dioxide shall be tested according to ISO 22479.

NOTE The CIGRE working group WG B3.57 is working on lifetime management of outdoor DC GIS [19]. The recommendations of this CIGRE guide can be considered.

7.107.3 Criteria to pass the test

The resistance of the earthing of the enclosure, measured according to 7.3.1, shall not increase more than 20 % after this test.

After the test, the dismantling of the assemblies shall not be affected. The degree of corrosion, if any, should be indicated in the test report. If the surfaces are painted, no trace of degradation shall be noticed.

7.108 Corrosion tests on sealing systems of enclosures and auxiliary equipment

7.108.1 General

On user's request, a corrosion proof test shall be performed in accordance with this subclause.

The tested sub-assemblies shall be representative of a DC GIS arrangement, including the enclosures, auxiliary equipment (gas filling valves, viewports, pressure monitoring device, pressure relief device, UHF sensor, etc.) and sealing systems (including dynamic sealings of switching devices) as described in 15.7 of IEC TR 62271-306:2012 and IEC TR 62271-306:2012/AMD1:2018.

7.108.2 Test procedure

The tested sub-assembly shall be submitted to environmental testing Ka (salt mist) according to IEC 60068-2-11. The duration of the test is 168 h.

After the corrosion tests a gas tightness test shall be performed in accordance with 7.7.

7.108.3 Criteria to pass the test

- The relative leakage rate in the gas tightness test shall not be greater than the defined value prescribed in 6.16.
- Visual inspection of flanges and sealing systems. If corrosion is observed, it shall be documented in the test report.
- The degree of corrosion, if any, should be indicated in the test report.

NOTE The CIGRE working group WG B3.57 is working on lifetime management of outdoor DC GIS [19]. The recommendations of this CIGRE guide can be considered.

8 Routine tests

8.1 General

Subclause 8.1 of IEC TS 62271-5:2024 is applicable with the following addition:

For routine tests technical grade SF_6 and its mixtures in accordance with IEC 60376 or used SF_6 and its mixtures in accordance with IEC 60480, can be used. See 6.2.

If the DC GIS is designed to use any other gas than SF_6, the necessary technical grade and the characteristics of the gas / gas mixture used for the routine testing shall be defined and documented by the manufacturer of the DC GIS and documented in the routine test reports.

The routine tests shall be performed on all components of a DC gas-insulated metal-enclosed switchgear and its controlgear. Depending on the nature of tests, some tests can be performed on components, transport units or on the complete installation.

The following routine tests shall be carried out:

		Subclause
a)	Dielectric test on the main circuit	8.2
b)	Tests on auxiliary and control circuits	8.3
c)	Measurement of the resistance of the main circuit	8.4
d)	Tightness test	8.5
e)	Design and visual checks	8.6
f)	Pressure tests of enclosures	8.101
g)	Mechanical operation tests	8.102
h)	Tests on auxiliary circuits, equipment and interlocks in the control mechanism	8.103
i)	Pressure test on partitions	8.104

8.2 Dielectric test on the main circuit

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

The tests shall be performed at the minimum functional pressure for insulation p_{me}.

8.2.101 Alternating or direct voltage tests on the main circuit

The alternating or direct voltage test of DC GIS shall be performed according to the requirements in 7.2.6.1 or 7.2.7.1 to earth, between poles (if applicable) and across the open switching devices. The voltage test across the open switching device can be carried out from one side of the switching device.

The test voltage shall be the rated direct withstand voltage divided by √2 for alternating voltage test or the rated direct withstand voltage for direct voltage test. The rated direct withstand voltages are specified in column 3 of Table 1 in IEC TS 62271-5:2024.

The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

8.2.102 Partial discharge measurement

The measurement of partial discharges shall be performed to detect possible material and manufacturing defects.

Partial discharge tests shall be performed in accordance with 7.2.10.

The measurement of partial discharges shall be performed with dielectric tests after mechanical routine tests.

The test shall be carried out on all components of a switchgear and controlgear. It can be performed on the complete switchgear and controlgear, if applicable, or on transport units or on individual components. Tests on simple components containing no solid insulation can be excepted.

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 with the following addition:

Overall measurements are made on sub-assemblies or, on transport units in the factory. Overall measurements shall be made in such a way that comparison with measurement taken on-site after installation, during maintenance or repair of the installation is possible.

8.5 Tightness test

Subclause 8.5 of IEC TS 62271-5:2024 is applicable with the following addition:

The tightness test shall be performed at filling pressure for insulation p_{re}, when the detection method is by sniffing device.

The maximum relative leakage rate F_{rel} of each compartment under the standardized ambient temperature of 20 °C shall be 0,5 % per year (independent on type of gas and size of gas compartment).

NOTE The commonly used test method for gas-filled systems tested in factory and on-site is the probing test using a sniffing device with the minimum sensitivity mentioned in IEC TS 62271-5:2024, 8.5.3. If a leak is detected, the test is considered failed, and the test object will be repaired, or the leak will be quantified by using a cumulative method. Leakage rate below 0,5 % per year per gas compartment are not always easily possible to verify using the probing test method.

8.6 Design and visual checks

Subclause 8.6 of IEC TS 62271-5:2024 is applicable.

8.101 Pressure tests of enclosures

Pressure tests shall be made on enclosures after complete machining.

The standard test pressure shall be k times the design pressure, where the factor k

- is 1,3 for welded aluminium and welded steel enclosure,
- is 2 for cast aluminium and composite aluminium enclosures.

The test pressure shall be maintained for at least 1 min.

No rupture or permanent deformation should occur during this test.

8.102 Mechanical operation tests

Operation tests are made to ensure that the switching devices comply with the prescribed operating conditions and that the mechanical interlocks work properly.

Switching devices of DC GIS shall be submitted to a mechanical routine test in accordance with their relevant documents. The mechanical routine tests can be made before or after assembly of transport units.

In addition, all switching devices fitted with mechanical interlocks shall be submitted to five operating cycles in order to check the operation of the associated interlocks. Before each operation one attempt shall be made to operate each switching device as specified in 7.102.

NOTE Mechanical interlocks can be checked on-site depending on the size of delivered transport components.

During these tests, which are performed without voltage on, or current in, the main circuits, it shall be verified in particular that the switching devices open and close correctly within the specified limits of the supply voltage and pressure of their operating devices.

8.103 Tests on auxiliary circuits, equipment and interlocks in the control mechanism

All auxiliary equipment shall be tested either by a functional operation or by verification of the continuity of wiring. Settings relays or sensors shall be checked.

The electrical, pneumatic and other interlocks, together with control devices having a predetermined sequence of operations, shall be tested five times in succession in the intended conditions of use and operation and with the most unfavourable limit values of auxiliary supply. During the test, no adjustment shall be made.

The tests are considered to be satisfactory if the auxiliary devices have operated properly, if no effect on the entire operating unit can be visually determined after the tests and if the force to operate the switching device is practically the same before and after the tests.

8.104 Pressure test on partitions

Each partition shall be subjected to a pressure test at twice the design pressure for 1 min.

For the pressure test the partition shall be secured in exactly the same manner as in service.

The partition shall not show any sign of overstress or leakage.

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

9.1 General

Subclause 9.1 of IEC TS 62271-5:2024 is applicable with the following addition:

Annex D provides a summary of the considerations for specifying ratings of switchgear and controlgear.

NOTE IEEE C37.122.1 [20] and CIGRE Technical Brochure 125 [21] describe the general guideline for the selection of a AC gas-insulated metal-enclosed switchgear above 52 kV and of 72,5 kV and above, respectively. Some of them can also be referred to a DC GIS.

9.2 Selection of rated values

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

The rated values should be chosen in accordance with Clause 5 of this document.

9.3 Cable-interface considerations

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 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 with the following addition:

Annex D defines, in tabular format, technical information to be exchanged between user and supplier.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC TS 62271-5:2024 is applicable.

10.3 Information with tenders

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

f) list of recommended tools that should be procured by the user.

11 Transport, storage, installation, operating 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.

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 case of leakage which cannot be easily repaired, temporary solutions for limiting or stopping this leakage and allowing continuity of service should be recommended by the manufacturer and agreed by the user until a repair is scheduled.

NOTE The direct voltage stress can cause charge accumulation on the surface of the insulating material of the bushings. This can lead to increased dirt accumulation. The maintenance of bushings is described in IEC/IEEE 65700-19-03:2014, 11.6. The subclause shows special precautions which need to be observed related to cleanliness of the surface.

11.101 Tests after installation on-site

11.101.1 General

After installation, and before being put into service, the DC GIS shall be tested in order to check the correct operation and the dielectric integrity of the equipment.

These tests and verifications comprise:

		Subclause
a)	dielectric tests on the main circuits	11.101.2
b)	dielectric tests on auxiliary circuits	11.101.3
c)	measurement of the resistance of the main circuit	11.101.4
d)	gas tightness tests	11.101.5
e)	checks and verifications	11.101.6
f)	gas quality verifications	11.101.7

To ensure minimum disturbance, and to reduce the risk of humidity and dust entering enclosures and thus preventing correct operation of the switchgear, no obligatory periodic inspections or pressure tests concerning the enclosures are specified or recommended when the DC GIS is in service. Reference shall be made, in any case, to the manufacturer's installation, operation and maintenance manuals.

The manufacturer and user should agree on a commissioning test plan for tests on-site.

11.101.2 Dielectric tests on the main circuits

11.101.2.1 General

Since it is especially important for DC GIS, the dielectric integrity shall be checked in order to eliminate fortuitous causes (wrong fastening, damage during handling, transportation, storage and installation, presence of foreign bodies, etc.) which might in the future give rise to an internal fault.

Because of their different purpose, these tests shall not replace the type tests or the routine tests carried out on the transport units and, as far as possible, in the factory. They are supplementary to the dielectric routine tests with the aim of checking the dielectric integrity of the completed installation and of detecting irregularities as mentioned above. Normally the dielectric test shall be made after the DC GIS has been fully installed and gas-filled at the filling density preferably at the end of all site tests, when newly installed. Such a dielectric test is also recommended to be performed after major dismantling for maintenance or reconditioning of compartments. These tests shall be distinguished by their progressive voltage increase, performed in order to achieve some form of electrical conditioning of the equipment before commissioning.

The execution of such site tests is not always practicable and deviations from the standard tests can be accepted. The aim of these tests is to offer a final check before energizing. It is very important that the chosen test procedure does not jeopardize sound parts of the DC GIS, see Clause B.3.

In choosing an appropriate test method for each individual case, a special agreement can be made in the interest of practicability and economy, considering the electrical power requirements and the dimensions and weight of the test equipment.

A detailed test programme for the dielectric tests on-site shall be agreed between manufacturer and user.

11.101.2.2 Test procedure

The DC GIS shall be installed completely and gas-filled at its filling density.

Some parts can be disconnected for the test, either because of their high charging current or because of their effect on voltage limitation, such as

- high voltage cables and overhead lines;
- main transformer,
- voltage transducers, and
- surge arresters.

NOTE In determining the parts which can be disconnected, attention is drawn to the fact that the reconnection can introduce faults after the tests are completed.

Every newly installed part of a DC GIS shall be subjected to a dielectric test on-site.

In the case of extensions, in general, the adjacent existing part of the DC GIS shall be de-energized and earthed during the dielectric test, unless special measures are taken to prevent disruptive discharges in the extension affecting the energized part of the existing DC GIS.

Application of the test voltage may be necessary after repair or maintenance of major parts or after installation of extensions. The test voltage can then be applied to existing parts in order to test all sections involved. In those cases, the same procedure should be followed as for newly installed DC GIS.

One of the following test procedures shall be chosen:

a) **Procedure A (recommended for all voltage levels):**
   - Alternating voltage test for a duration of 1 min at the value of $\hat{U}_{\text{pre-stress AC}} = 1{,}5 \times U_{\text{rd}}$; and
   - partial discharge measurements according to Table 4, however with $\hat{U}_{\text{pd-test AC}} = 1{,}2 \times U_{\text{rd}}$.

In addition to the before mentioned tests, a direct voltage test at $1{,}2 \times U_{\text{rd}}$ (column 2 in Table 6) for 1 h in the same polarity as used in service is recommended. If both polarities can occur in service, each polarity shall be tested for 1 h.

A PD measurement at U_{rd} is also recommended since this measurement can be helpful in determining the need for maintenance of the equipment after a period of service. For practical application of PD measurements, see Annex B.

b) **Procedure B (alternative to procedure A):**
   - Alternating voltage test for a duration of 1 min at the value of $\hat{U}_{\text{pre-stress AC}} = 1{,}5 \times U_{\text{rd}}$; and
   - Partial discharge measurements according to Table 4, however with $\hat{U}_{\text{pd-test AC}} = 1{,}2 \times U_{\text{rd}}$
   - Lightning impulse tests with three impulses of each polarity and with the value specified in Table 6, column (4).

In addition to the before mentioned tests, a direct voltage test at $1{,}2 \times U_{\text{dds}}$ (Column (2) in Table 6) for 1 h in the same polarity as used in service is recommended. If both polarities can occur in service, each polarity shall be tested for 1 h.

A PD measurement at U_{rd} is also recommended since this measurement can be helpful in determining the need for maintenance of the equipment after a period of service. For practical application of PD measurements, see Annex B.

11.101.2.3 Test voltages

Considering that

- transport units have normally been subjected to routine test,
- the probability of disruptive discharges is higher for the complete installation than for individual functional units,
- disruptive discharges in correctly installed equipment shall be avoided,

the test voltage for dielectric tests on-site shall be as shown in Table 6.

Table 6 – On-site test voltages

Rated voltage for equipment U_{rd} kV	On-site short-duration direct withstand voltage U_{dds} kV	On-site short-duration alternating withstand voltage U_{ds} kV (RMS value)	On-site lightning impulse withstand voltage U_{ps} kV (peak value)
(1)	**(2)**	**(3)**	**(4)**
105	130	115	305
160	195	170	360
210	255	225	440
265	320	285	600
340	410	365	760
420	505	450	940
525[a]	635	560	1 140
630	760	670	1 240
840	1 010	895	1 560

NOTE 1 The on-site test voltages have been calculated as follows:

U_{dds} (on-site test value) = $U_{dd} \times 0{,}8$ (column (2))

U_{ds} (on-site test value) = $U_{dd} / \sqrt{2}$ (column (3))

U_{ps} (on-site test value) = $U_p \times 0{,}8$ (column (4))

All values have been rounded up to the next higher modus 5 kV.

NOTE 2 If other insulation levels than the rated values of Table 1 in IEC TS 62271-5:2024 are specified, then the on-site test voltage is calculated according to Note 1.

[a] Instead of U_{rd} = 525 kV rated direct voltage, U_{rd} = 550 kV can also be applicable.

In certain circumstances, for technical or practical reasons, dielectric tests on-site can be carried out with reduced voltage values. Details are given in B.3.

11.101.2.4 Voltage waveforms

For the choice of an appropriate voltage waveform, IEC 60060-1 should be taken into consideration; however, similar waveforms are also permissible. An ideal voltage waveform covering all requirements does not exist. Permissible deviations are indicated below. Information concerning the generation of test voltages is given in B.1.

a) **Alternating voltage tests**

Alternating voltage tests are especially sensitive in detecting contaminations (e.g. free moving conducting particles), and are, in most cases, also sufficient in detecting abnormal field configurations.

The existing experience refers to test frequencies from 10 Hz to 300 Hz.

b) **Impulse voltage tests**

Tests with lightning impulse voltages are especially sensitive in detecting abnormal field configurations (e.g. damaged electrodes).

Based on the existing experience, lightning impulse voltages with a front time extended up to 8 µs are acceptable. When using oscillating lightning impulse voltages, the front time can be extended to approximately 15 µs.

NOTE Reflections due to steep front waves in large installations can be taken into account.

c) **Direct voltage tests**

Direct voltage tests are less sensitive in detecting. Nevertheless, to minimize the risk of a dielectric breakdown after applying DC system voltage (at service), beforehand a test with direct voltage stress is also required.

The existing experience refers to ripple factor lower than or equal to 3 %.

11.101.2.5 Voltage application

The test voltage source can be connected to any convenient point of the conductor under test.

It is often convenient to divide the whole installation of DC GIS into sections by opening disconnectors for at least one of the following reasons:

- to limit the capacitive load on the test voltage source;
- to facilitate the location of disruptive discharges;
- to limit the discharged energy if a disruptive discharge occurs.

The sections which, in such cases, are not being tested, and which are isolated by a disconnector from the section under test, shall be earthed. Unless dismantled after routine test or during maintenance, no dielectric test across the open switching devices shall be carried out on-site.

11.101.2.6 Assessment of the test

The switchgear shall be considered to have passed the test if each section has withstood the specified test voltage without any disruptive discharge.

In the event of a disruptive discharge occurring during dielectric tests on-site, the tests shall be repeated.

Guidelines on repetition tests are given in B.6.

If partial discharges are measured with the conventional method according to IEC 60270, the maximum permissible intensity of partial discharge shall be 10 pC. The limit of 10 pC only applies when the test is carried out with alternating voltage.

NOTE 1 It can be difficult to have noise level below 5 pC on-site. Special care with the test circuit is needed to achieve a good measurement. If the noise level is higher than 5 pC, the test is still valid for detecting major defects but not suitable for detection of fixed conducting particles since this kind of defect will cause a very low level of partial discharges and they will be completely masked by the noise. In such circumstances, the test is acceptable if no discharges are detected above the noise level.

NOTE 2 It can also be possible to isolate the component that is causing the noise level higher than 5 pC. Test procedure considers this possibility in the test sequence and is agreed between user and manufacturer.

NOTE 3 If VHF/UHF or acoustic partial discharge measuring methods are used, a calibration is not possible. Instead, a sensitivity check according to B.7.5, IEC TS 62478 [33] and CIGRE Technical Brochure 654 [22] can be performed.

11.101.3 Dielectric tests on auxiliary circuits

Subclause 8.3 of IEC TS 62271-5:2024 is applicable with the following addition:

Dielectric tests should be carried out on new wiring. If wiring shall be taken off or if electronic devices are in circuits, these circuits shall not be tested.

11.101.4 Measurement of the resistance of the main circuit

Overall measurements shall be made on the complete installation, under conditions as similar as possible to those of the routine test on transport units.

The resistance measured shall not exceed the maximum values permitted for the routine tests on transport units (see 8.4), taking into account the differences of the two test arrangements (number of devices, contacts and connections, length of conductors, etc.).

Resistance values between earthing switches shall be verified during on-site assembly and documented in the project documentation.

11.101.5 Gas tightness tests

Subclause 8.5 of IEC TS 62271-5:2024 is also applicable for on-site gas tightness tests. A qualitative gas tightness test shall be carried out on all field assembled connections.

A leakage detector can be used. See appendixes of IEC 62271-4.

11.101.6 Checks and verifications

The following shall be verified:

a) conformity of the assembly with the manufacturer's drawings and instructions;
b) sealing of all pipe junctions, and the tightness of bolts and connections;
c) conformity of the wiring with the diagrams;
d) proper function of the electrical, pneumatic and other interlocks;
e) proper function of the control, measuring, protective and regulating equipment including heating and lighting.

The mechanical operation checks and tests shall be carried out according to the relevant documents. If verification is not specified, the manufacturer shall specify them in the commissioning test plan.

11.101.7 Gas quality verifications

In order to get a reliable measurement, the humidity content shall be checked at least 5 days after final filling of gas. The humidity content shall not exceed the limit defined in 6.2 of IEC TS 62271-5:2024.

For checking the condition of the gas during service, reference is made to IEC 60480 for SF_6 and its mixtures and to manufacturer recommendations and IEC 62271-4 for other gases.

For handling precautions, reference is made to IEC 62271-4 for SF_6 and manufacturer recommendations for other gases.

12 Safety

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

Working on gas compartments with adjacent compartments under full pressure according to manufacturer safety procedures can require applying safety measures for workers. Local regulations can apply.

13 Influence of the product on the environment

Clause 13 of IEC TS 62271-5:2024 is applicable with following addition:

Local regulations can apply for handling releases during manufacturing, installation, on-site tests, repair, maintenance and end-of-life, see IEC 62271-4.

For environmental aspects of gases and gas mixtures see CIGRE Technical Brochure 802 [13].

Annex A
(normative)

Methods for alternating current testing of DC gas-insulated metal-enclosed switchgear under conditions of arcing due to an internal fault

A.1 General

The occurrence of an arc inside DC GIS due to an internal fault is accompanied by various physical phenomena.

For example, the energy resulting from an arc developing in the enclosure will cause internal overpressure and local overheating, which will result in mechanical and thermal stressing of the switchgear. Moreover, the materials involved can produce hot decomposition products which can be discharged into the atmosphere.

This annex takes into account the internal overpressure acting on the enclosure and the thermal effects of the arc or its root on the enclosure. It does not cover all the effects which can constitute a risk, such as toxic gases and their by-products (see annexes of IEC 62271-4 for further information).

A.2 Short-circuit current arcing test

A.2.1 Test arrangements

When choosing the object to be tested, reference shall be made to the design documents for the DC GIS. The compartments which appear to have the least likelihood of withstanding the pressure and temperature rise in the event of arcing shall be selected.

In any case, the following points shall be observed:

a) each test can be carried out on a test object not previously subjected to arcing tests. Test objects that have already undergone arcing tests shall be restored so that the conditions for further arcing tests are neither aggravated nor eased;
b) the test object shall be fully equipped and arranged to include any protection device, such as pressure reliefs, short-circuiting devices, etc. provided by the manufacturer for the limitation of the effects of the arc.
c) the test object shall be filled with normal insulating gas at filling pressure p_{re}.

A.2.2 Current and voltage applied

A.2.2.1 General

Single-pole enclosures shall be tested single-pole.

A.2.2.2 Voltage

The test can be made with an applied voltage lower than the rated voltage for equipment of the test object if the following conditions are met:

a) the arc current shall be practically sinusoidal;
b) the arc shall not extinguish prematurely.

A.2.2.3 Current

a) **AC component**

The AC component at the beginning of the test shall lie within a +10 %, -0 % tolerance. The current shall not fall below 80 % of the specified value, provided that the average AC component is not less than the stated short-circuit current.

NOTE If the test plant does not permit this, the test duration can be extended by not more than 20 % with an appropriate adjustment to the times at which assessments are made.

b) **DC component**

The instant of short-circuit making shall be chosen to ensure that the first loop of the arc-current has a peak value according to IEC TS 62271-5.

A.2.2.4 Duration of the test

The current duration shall be such as to cover the back-up protection chosen on the basis of the expected duration as determined by the protection devices. See 6.103.2.

A.2.3 Test procedure

A.2.3.1 Test connections

The point of current infeed to be chosen is the one likely to result in the most onerous condition.

Care shall be taken to ensure that the connections do not ease the test conditions. Generally, the enclosure is earthed on the same side of the test object into which the current is fed.

A.2.3.2 Arc initiation

The arc shall be initiated by means of a metal wire of suitable diameter.

The point of initiation to be chosen is where the arc is likely to set up the rated stresses in the test object. Generally, this will be achieved when the arc is initiated in the vicinity of a partition furthest from the point of infeed and furthest from the pressure relief device, if fitted.

NOTE The arc cannot be initiated by perforating the solid insulation.

A.2.3.3 Measurement and recording of the test performance

The following parameters shall be plotted and recorded

- the current and its duration
- the arc voltage;
- the pressure on one or more points of the test object and in each compartment, if the test object comprises more than one;

and, when applicable

- the instant of pressure relief (either by operation of the pressure relief device or perforation of the enclosure).

Phenomena such as pressure relief, enclosure perforation and external effects shall be observed and recorded by appropriate means, e.g. cameras, luminosity detectors.

A.2.4 Criteria to pass the test

The switchgear is considered adequate if, during the test, no external effect other than the operation of suitable pressure relief devices occurs within the Joule integral value specified in 6.103.2, and if gases or vapours escaping under pressure are directed so as to minimize the danger to an operator performing his normal operating duties.

Projections of small parts, up to an individual mass of 60 g are accepted.

No fragmentation of the enclosure shall occur.

A.2.5 Test report

The following information shall be given in the test report:

- rating and description of the test object, the materials of the enclosure and the conductors, together with a drawing showing the main dimensions and the arrangement of pressure relief devices;
- arrangement of the test connections, the point of initiation of the arc and the position of the transducers for pressure measurements;
- current, voltage, energy, pressure and times derived from the oscillograms;
- precise description of the test results and observations;
- other relevant remarks;
- photographs of the conditions before and after the test.

A.2.6 Extension of the test results

The test results can be extended to other enclosures of similar design but of different size and shape and/or to other test parameters by calculations.

A.3 Composite verification by calculation and separate tests

The manufacturer is responsible for demonstrating the validity of extrapolation of test results for other currents and other sizes of enclosures. The manufacturer shall provide all necessary information with the calculation.

NOTE Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [2], CIGRE Session 1998 – WG 21/23/33-03 [3] and RGE: 04/82 [4].

Annex B
(informative)

Technical and practical considerations of site testing

B.1 Test voltage generators

DC GIS installations have a relatively high load capacitance. This means that:

- alternating voltage tests, especially at higher U_{rd}, require a high reactive power,
- impulse testing with standardized double exponential waveforms can be inefficient due to the poor voltage utilization of the impulse generator.

The following voltage-generating equipment can be used:

a) **Alternating voltage sources**

   The alternating voltage can be produced by:

   - test sets with a test transformer,
   - test sets with a variable resonant reactor for constant frequency,
   - test sets with a constant resonant reactor for variable frequency,
   - power or voltage transformers by energization from the low-voltage side (entails no dismantling after testing).

NOTE The thermal stresses of the voltage source can be taken into account especially when using voltage transformers

b) **Impulse voltage sources**

   For large installations and especially for high voltages for equipment, impulse generators for double exponential waves are unwieldy. Oscillating impulses can be produced with an impulse generator and a high-voltage coil connected to the switchgear to be tested to form a damped series resonant circuit. Oscillating switching impulses can be produced by discharging a capacitor into the low-voltage side of a power, voltage or test transformer.

c) **Direct voltage sources**

   A direct voltage test generator should be used. Discharging current should be limited by protecting elements to avoid damages of the test object and test equipment.

B.2 Locating discharges

There are different phenomena caused by discharges which can be helpful in locating them. Some of the possible means which can be tried are as follows:

- detection of light emission;
- measurement of audible noise and vibrations;
- recording and evaluation of electromagnetic transients following discharge;
- detection of decomposition products of the gas.

B.3 Special test procedures

B.3.1 General

In general, it is recommended that all testing should be performed at the specified test voltage and filling density. However, in certain circumstances special test procedures have been established which are not in general use but are worth mentioning for technical and/or practical reasons.

For extensions the user should be responsible for any flashovers in the existing DC GIS and the manufacturer of the extension equipment should be responsible for any flashovers in the extension equipment.

B.3.2 Testing at reduced voltage

In accordance with the practice in some countries, DC gas-insulated metal-enclosed switchgear, or at least one bay or an equivalent part of the DC GIS installation, can be assembled completely at the factory and tested there at its full rated withstand voltages. If the tested units are transported without dismantling or if dismantling is limited to very simple connections, and subject to agreement between manufacturer and user, the site test can be carried out with reduced voltages.

Direct voltage test with 1,1 × U_{rd}; with a 10 min voltage application.

B.3.3 Testing at reduced gas density

Tests with reduced gas density are not generally advisable.

B.4 Partial discharge measurements

Partial discharge measurements can be helpful in detecting certain kinds of faults during site tests and in determining the need for maintenance of the equipment after a period in service. They are therefore a useful complement to dielectric tests on-site but are often difficult to perform because of ambient disturbances.

If such a test is possible and agreed upon, then the requirements given in 11.101.2.6 should be applied as far as possible.

If VHF/UHF partial discharge measuring methods are specified by the user, internal PD sensors are recommended.

B.5 Electrical conditioning

The term "electrical conditioning" means a progressive application of an alternating or direct voltage either by steps or continuously. It can be performed by the manufacturer as part of the gas-filling process on-site in order to move possible particles towards areas with a low field strength, where they become harmless.

Electrical conditioning is not a requirement and does not replace the alternating or direct voltage test, unless the test voltage is increased up to the specified value. Nevertheless, a disruptive discharge should be reported to the user as it can result in a weakening of the insulation.

B.6 Repetition tests

B.6.1 General

The procedure to be implemented following a disruptive discharge during dielectric tests on-site can depend on several factors which include:

- the type of disruptive discharge (breakdown in self-restoring or non-self-restoring insulation) if it can be identified (see Clause B.2);
- magnitude of the arc energy dissipated during the discharge;
- shape and material of the solid insulation;
- strategic importance of the installation.

Consideration of these and any other relevant factors should allow a procedure to be established and agreed between the manufacturer and user. A recommended procedure is given below but should be treated only as a guide. Variations can be acceptable, depending on the significance of the factors involved.

B.6.2 Recommended procedure

B.6.2.1 Procedure a)

If the disruptive discharge occurs along the surface of a solid insulation, it is recommended that the compartment should be opened and the insulation carefully inspected for impairments. After taking any necessary remedial action, the compartment should then be subjected to the complete specified dielectric test once more.

B.6.2.2 Procedure b)

A disruptive discharge in the gas can be due to contamination or a surface imperfection which can be burned away during the discharge. It can be acceptable, therefore, that the test can be repeated at the specified test voltage. Another test voltage can be agreed between manufacturer and user before the site tests have been started.

NOTE 1 It is assumed that the manufacturer can satisfy the user that the gaseous insulation can be regarded as self-restoring for the arc energy dissipated in the discharge.

NOTE 2 In the event of a disruptive discharge occurring during dielectric tests on-site, secondary discharges can occur in other parts of the test section.

If the repetition test fails, again Procedure a) should be followed.

B.7 Partial discharge detection method

B.7.1 General

For partial discharge detection on-site, the electrical VHF/UHF and the acoustic method can be used in DC GIS in addition to the conventional method, according to IEC 60270. These two methods are less sensitive to noise than the conventional measurement and can also be used for partial discharge monitoring in service. However, for these new methods the sensitivity depends on the distance between the defect (signal source) and the sensor. Suitable procedures for using the VHF/UHF and acoustic method are available. They ensure that defects causing an apparent charge of around a few pC can be found by such equipment. The proposed sensitivity verification can be easily performed on-site. The advantage of the two additional methods is that the location of the defects can be detected. The methods and the interpretation of the results can only be used by experienced personnel. The methods are still under investigation and are not yet standardized.

B.7.2 Conventional method according to IEC 60270

Electromagnetic interference from radio transmitters and other sources is picked up by open-air bushings and lead to a PD measurement sensitivity of some tens of pC. For noise rejection, analogue and digital filtering methods are available. Nevertheless, the use of such filtering tools requires trained personnel and is a limitation in this procedure. In actual site conditions, a noise level below 5 pC is hard to achieve. Therefore, a totally encapsulated test circuit with a shielded coupling capacitor directly connected to the DC GIS is preferable. In such a case, a sensitivity below 5 pC is achievable for DC GIS with cable terminations and for DC GIS sections which are separated by an open disconnector from open-air bushings.

B.7.3 VHF/UHF method

The discharge currents at the defects of DC GIS have rise times that can be less than 100 ps. These defects cause electromagnetic transients with frequency content to above 2 GHz. The resulting signals propagate within a DC GIS with the speed of light as electromagnetic waves.

Reflections occur at the numerous discontinuities in the arrangement. Due to the finite conductivity of the metallic conductors and losses at the dielectric surfaces, the propagating signals are damped. The result is a complex resonance pattern of electromagnetic waves within each compartment.

The partial discharge signals in the VHF/UHF range (e.g. 100 MHz to 2 GHz) can be detected in the time domain or the frequency domain by means of couplers, which are usually of similar design to capacitive couplers. As consequence of VHF/UHF signal attenuation, many couplers can need to be installed in a DC GIS. The maximum distance between two adjacent couplers is approximately some tens of metres. The VHF/UHF signal is best taken from internal couplers, but when these are not available, it is sometimes possible to use external couplers on windows or partition and support insulator.

Due to the complexity of the resonance patterns, the magnitude of the detected PD signal depends strongly on the location and, to a minor degree, on the orientation of the defect and the coupler. The VHF/UHF method can therefore not be calibrated as in, for example, the measuring circuit of IEC 60270. Instead, the sensitivity check in B.7.5 can be performed.

The signal-to-noise-ratio and therefore, the sensitivity of the VHF/UHF measuring device can be improved by using suitable couplers, amplifiers and filters. The VHF/UHF method has proved to be at least as sensitive in detecting defects as the conventional method, and this is mainly due to the low external noise level. Tests in laboratories and on-site have shown that small critical defects and even non-critical defects can be detected.

An accurate location of the defect can be obtained by using a broadband oscilloscope to measure the time interval between the signals arriving at adjacent couplers.

B.7.4 Acoustic method

Acoustic signals (mechanical waves) are emitted from defects in a DC GIS mainly in two primary mechanisms: moving particles excite a mechanical wave in the enclosure when they impinge on it, whereas discharges from fixed defects create a pressure wave in the gas, which is then transferred to the enclosure. The resulting signal will depend on the source and on the propagating path. As the enclosures normally are made of aluminium or steel, the damping of the signals is quite small. However, there is a loss of energy when the signals are transmitted from one part to another across a flange. Acoustic signals can be picked up by means of externally mounted sensors. Normally, either accelerometers or acoustic emission sensors are used and the test procedure consists of measuring between all flanges.

The location of a defect can be found by searching for the acoustic signal with the highest amplitude or by time travel measurements with two sensors. Separation between different kinds of defects is possible by analysing the shape of the acoustic signal.

The signal from a bouncing particle is broadband (i.e. >1 MHz) and has a high amplitude compared with signals emitted from pre-discharges at fixed defects. The particle type signal will be spatially attenuated as it moves away from the source point. In general, two parameters of the acoustic signal are important for this type of defect: amplitude and flight time (this being the time between two consecutive impacts of the particle). These parameters are essential not only for recognition of defect type but also for risk assessment.

Predischarge type signals from protrusions will be very wideband close to the source, but because the gas acts as a low pass filter, the high frequencies are attenuated as the signal propagates away from the source towards the enclosure. Normally, detected signals from predischarge sources are limited to the frequency range below 100 kHz. The signal level is found to be fairly constant within the same sections, and to drop some 8 dB once a flange is crossed.

Bouncing particles producing apparent discharges in the 5 pC range can be detected with a high signal-to-noise ratio. The detection limit for corona discharges is in the 2 pC range.

Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the DC GIS. However, no direct correspondence between apparent PD-level and acoustic signal level has been established. Acoustic measurement is immune to electromagnetic noise in the substation. The acoustic sensitivity to bouncing particles is usually much higher than the sensitivity of any other diagnostic method, when the sensor is placed close to the defect. The acoustic method is therefore good for detecting the location of such defects.

B.7.5 Sensitivity verification of acoustic and UHF method

For the acoustic and the UHF method, the same technical principle is applied for the sensitivity verification of partial discharge detection. First, an artificial acoustic or electrical pulse is determined which emits a signal similar to that from a real defect that causes a defined level of apparent charge (e.g. 5 pC or more) according to IEC 60270. Secondly, this artificial pulse is injected during the commissioning test or operating conditions into the DC GIS in order to verify the detection sensitivity for the DC GIS and the associated measuring equipment. If the stimulated signal can be measured at the adjacent sensor, the sensitivity verification has been successful for the DC GIS section between these sensors.

For further information, see IEC TS 62478 [33] and CIGRE Technical Brochure 654 [22].

Annex C
(informative)

Calculation of pressure rise due to an internal fault

The pressure rise in a closed compartment filled with gas due to an internal fault can be calculated according to (C.1):

$$\Delta p = C_{\text{equipment}} \times \frac{I_{\text{arc}} \times t_{\text{arc}}}{V_{\text{compartment}}} \qquad \text{(C.1)}$$

where

Δp	is the pressure rise (MPa);
I_{arc}	is the arc fault current (kA_{RMS});
$V_{\text{compartment}}$	is the volume of the compartment (l);
t_{arc}	is the arc duration (ms);
$C_{\text{equipment}}$	is the equipment factor.

The value of the equipment factor $C_{\text{equipment}}$ shall be demonstrated by the manufacturer by tests on similar equipment.

Formula (C.1) can be used to verify that the pressure will not exceed the type test pressure of the enclosures in case of an internal fault in a gas compartment without a pressure relief device. This is verified if the maximum arc current and arc duration (based on the performance of the protective system) does not cause a pressure rise which exceeds the type test pressure of the enclosures.

NOTE For direct currents, the equivalent current according to the value of Joule integral is used.

Annex D
(informative)

Information to be given with enquiries, tenders and orders

D.1 General

This annex defines, in tabular format, the technical information to be exchanged between user and supplier.

Reference to “supplier information” means that only the supplier provides this information.

D.2 Normal and special service conditions

See Clause 4. Table D.1 shows the technical information to be given regarding normal and service conditions.

Table D.1 – Normal and special service conditions

		User requirements (see Table 1)	**Supplier proposals**
Service condition	Indoor or outdoor		
Ambient air temperature: Minimum Maximum	 °C °C		
Solar radiation	W/m^2		
Altitude	m		
Pollution (RUSCDdc)	mm/kV		
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in secondary system	kV		