

INTERNATIONAL STANDARD



High-voltage switchgear and controlgear –
Part 203: **AC** gas-insulated metal-enclosed switchgear for rated voltages above
52 kV

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INTERNATIONAL STANDARD



High-voltage switchgear and controlgear –
Part 203: **AC** gas-insulated metal-enclosed switchgear for rated voltages above
52 kV

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 203: **AC** gas-insulated metal-enclosed switchgear
for rated voltages above 52 kV

FOREWORD

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This commented version (CMV) of the official standard IEC 62271-203:2022 edition 3.0 allows the user to identify the changes made to the previous IEC 62271-203:2011 edition 2.0. Furthermore, comments from IEC SC 17C experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 62271-203 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: **2**

- a) the document has been aligned with IEC 62271-1:2017;
- b) beside SF₆ also alternative gases have been implemented where needed;
- c) the terms and definitions have been updated and terms not used have been removed;
- d) Subclause 6.16 “Gas and vacuum tightness” has been updated;
- e) Subclause 6.16.3 “Closed pressure systems”: Two classes of gas has been introduced:
 - 1) GWP ≤ 1 000
 - 2) GWP > 1 000
 and the tightness requirements for type tests for gasses with GWP > 1 000 has been reduced from 0,5 % to 0,1 % per year per gas compartment;
- f) Subclause 6.108 “Interfaces”: Typical maximum pressures in service for interfaces connected to GIS have been defined;
- g) Subclauses 7.2 through 7.8 have been restructured;
- h) Subclause 7.107 “Corrosion test on earthing connections” has been updated;
- i) Subclause 7.108 “Corrosion tests on sealing systems of enclosures and auxiliary equipment” has been updated;
- j) Annex F ‘Service Continuity’ has been modified and aligned with the recommendations of CIGRE WG B3.51.

The text of this International Standard is based on the following documents:

Draft	Report on voting
17C/835/FDIS	17C/844/RVD

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 International Standard 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 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,
- replaced by a revised edition, or
- amended.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 203: **AC** gas-insulated metal-enclosed switchgear for rated voltages above 52 kV **3**

~~1~~ **General**

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 **4** other than air at atmospheric pressure, for alternating current of rated voltages above 52 kV, for indoor and outdoor installation, and for service frequencies up to and including 60 Hz.

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

The 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 ~~necessary~~ applicable, the various relevant standards applying to the individual components constituting GIS.

2 Normative references **5**

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 60044-1:1996, Instrument transformers – Part 1: Current transformers~~

~~IEC 60044-2:1997, Instrument transformers – Part 2: Inductive voltage transformers~~

IEC 60068-2-11, ~~Basic environmental testing procedures~~ *Environmental testing – Part 2-11: Tests – Test Ka: Salt mist*

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

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

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

IEC 60137:2008/2017, ~~Insulating~~ *Insulated bushings for alternating voltages above 1 000 V*

IEC 60141-1, *Tests on oil-filled and gas-pressure cables and their accessories – Part 1: Oil-filled, paper or polypropylene paper laminate insulated, metal-sheathed cables and accessories for alternating voltages up to and including ~~400~~ 500 kV*

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

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

IEC 60480, ~~Guidelines for the checking and treatment of sulfur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use~~ *Specifications for the re-use of sulphur hexafluoride (SF₆) and its mixtures in electrical equipment*

IEC 60840, *Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV) – Test methods and requirements*

~~IEC/TR 61639:1996, Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above~~

IEC 61869-1, *Instrument transformers – Part 1: General requirements*

IEC 61869-2, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

IEC 62067, *Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m = 170 kV) up to 500 kV (U_m = 550 kV) – Test methods and requirements*

IEC 62271-1:2007:2017, *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 sulphur hexafluoride (SF₆) and its mixtures*

IEC 62271-100:2008:2021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102:2004:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-209:2007:2019, *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 62271-211:2014, *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 62271-303, High-voltage switchgear and controlgear – Part 303: Use and handling of sulphur hexafluoride (SF₆)~~

~~ISO 3231, Paints and varnishes – Determination of resistance to humid atmospheres containing sulfur dioxide~~

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

3 Terms and definitions **6**

For the purposes of this document, the terms and definitions given in IEC 62271-1:2017 and the following, apply.

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

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

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

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

Note 2 to entry: Three-phase enclosed gas-insulated switchgear applies to switchgear with the three phases enclosed in a common enclosure.

Note 3 to entry: Single-phase enclosed gas-insulated switchgear applies to switchgear with each phase enclosed in a single independent enclosure.

[SOURCE: IEC 60050-441:1984, 441-12-05, modified – "or gas mixture" has been added in the definition, and Note 2 and 3 to entry have been added.]

3.103

gas-insulated switchgear enclosure

part of 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

Note 1 to entry: The enclosure can be single-phase or three-phase.

3.104

isolating link **7**

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 Table 2 and Table 3.

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.

3.105

removable link **8**

part of the conductor which can easily be opened or removed in order to ~~isolate~~ separate 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 Table 2 and Table 3.

Note 2 to entry: The purpose of a removable link is to ensure electrical separation between sections of a GIS, where the equipment is separated from the rest of the GIS, e.g. in front of voltage transformers, surge arresters, cable connections and transformer connections during high voltage testing of GIS or testing of the components.

3.106 compartment

part of gas-insulated metal-enclosed switchgear, ~~totally enclosed except for openings necessary for interconnection and control~~ which is gastight and enclosed

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

3.107 component

essential part of the main or earthing circuits of gas-insulated metal-enclosed switchgear which serves a specific function (for example circuit-breaker, disconnecter, switch, fuse, instrument transformer, bushing, busbar, etc.)

3.108 support insulator

internal insulator supporting one or more conductors

3.109 partition

gas tight support insulator of gas-insulated metal-enclosed switchgear separating ~~one compartment from other compartments~~ two adjacent compartments

3.110 bushing

a device that enables one or several conductors to pass through ~~a partition such as a wall or a tank,~~ an enclosure and insulate the conductors from it

~~NOTE The means of attachment (flange or fixing device) to the partition form part of the bushing.~~

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – “an enclosure” inserted after “pass through” and “a partition such as a wall or a tank” deleted. Notes 1 and 2 were deleted.]

3.111 main circuit

all the conductive parts of 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 – “gas-insulated metal-enclosed switchgear” inserted after “parts of” and “an assembly” deleted]

3.112 auxiliary circuit

all the conductive parts of gas-insulated metal-enclosed switchgear included in a circuit ~~(other than the main circuit)~~ intended to control, measure, signal and regulate

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

3.113 enclosure design temperature ~~of enclosures~~

maximum temperature that the enclosures can reach under specified maximum service conditions

3.114**enclosure design pressure** ~~of enclosures~~

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.

Note 2 to entry: The transient pressure occurring during and after a breaking operation (e.g. circuit-breaker) is not ~~to be~~ considered in the determination of the design pressure.

3.115**partition design pressure** ~~of partitions~~

relative pressure across the partition **used to determine the design of the partition**

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

Note 2 to entry: The transient pressure occurring during and after a breaking operation (e.g. circuit-breaker) is not ~~to be~~ considered in the determination of the design pressure.

3.116**operating pressure**

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

3.117**routine test pressure**

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

3.118**type test pressure**

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

3.119**fragmentation**

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

~~NOTE 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, if their ejection is directed;~~

~~— glowing particles and molten material resulting from burn-through of the enclosure.~~ **9**

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

3.120**service period**

~~time until a maintenance, including opening of the gas compartments, is required~~

3.121**transport unit**

part of gas-insulated metal-enclosed switchgear suitable for shipment without being dismantled

3.122**functional unit 10**

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 can be distinguished according to the function for which they are intended, for example complete single-phase or three-phase bay or functional parts of a bay like complete circuit-breaker, disconnector, earthing switch, voltage transformer, current transformer, operating mechanism, enclosure, etc.

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

4 Normal and special service conditions

~~Clause 2 of IEC 62271-1 is applicable with the following additions:~~

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

~~Some items of a GIS such as pressure relief devices and pressure and density monitoring devices may be affected by altitude. The manufacturer shall take appropriate measures if necessary.~~ **11**

4.1 Normal service conditions

Subclause 4.1 of IEC 62271-1:2017 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 62271-1:2017 is applicable, taking into account the recommended values presented in Table 1 of this document.

In the cases where higher than (>) is used in Table 1, the values shall be specified by the user as described in IEC 62271-1:2017.

4.101 General

Table 1 – Reference table of service conditions relevant to GIS

Item	Normal		Special	
	Indoor	Outdoor	Indoor	Outdoor
Ambient air temperature:				
Minimum (°C)	~~–5 or –25~~	~~–25 or –40~~	–25	–50
Maximum (°C)	+40	+40	+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
Site pollution severity ^a	Not applicable	c	c, d or e	d or e
Ice coating (mm)	Not applicable	~~1, 10 or 20~~	Not applicable	>20
Wind (m/s)	Not applicable	34	Not applicable	>34
Average humidity over 24 h (%)	95	100	98	100
Condensation or precipitation	Occasional	Yes	Yes	Yes
~~Vibration class~~	~~Not applicable~~	~~Not applicable~~	~~IEC 62271-207 IEC/TR 62271-300~~	~~IEC 62271-207 IEC/TR 62271-300~~
Abnormal vibrations, shock or tilting	Not applicable	Not applicable	Applicable	Applicable
NOTE The user's specification ~~may~~ can use any combination of normal or special service conditions above.				
^a Site pollution severity c, d or e according to IEC TS 60815-1:2008, 8.3 [5] ¹				

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 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. **12**

5 Ratings

5.1 General

Subclause 5.1 of IEC 62271-1:2017 is applicable with the following modifications:

- e) rated short-time withstand current (I_k) (for main and earthing circuits);
- f) rated peak withstand current (I_p) (for main and earthing circuits);

and with the following addition:

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

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 is applicable with the following addition:

¹ Numbers in square brackets refer to the Bibliography.

~~NOTE~~ Components forming part of the GIS ~~may~~ can have individual values of rated ~~voltage~~ for equipment in accordance with the relevant standards.

5.3 Rated insulation level (U_d , U_p , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition:

Tables 1, 2, 3 and 4 in Subclause 5.3 of IEC 62271-1:2017 are replaced with Table 2 and Table 3 below.

~~For rated voltages above 800 kV, see Annex G.~~

NOTE 1 The higher values for GIS in IEC 62271-203 compared to the values in IEC 62271-1 were introduced with revision 1 in 2003. They have now been established as standard values.

The 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 According to CIGRE studies the natural ratio between the withstand voltages under standard tests, for SF₆ gas insulation is $U_d/U_p = 0,45$ and $U_s/U_p = 0,75$. The values U_d shown in Table 3 are calculated with these factors.~~ **13**

NOTE 2 Regarding the external parts of bushings (if any), see to IEC 60137:2017.

NOTE 3 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 4 The choice between alternative insulation levels for a particular rated voltage for equipment ~~should~~ can be based on insulation coordination studies, taking into account also the self-generated transient overvoltages due to switching.

**Table 2 – Rated insulation levels for rated voltages
for equipment of range I (245 kV and below)**

Rated voltage for equipment U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth, across open switching device and between phases	Across the isolating distance	Phase-to-earth, across open switching device and between phases	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
72,5	140	160	325	375
100	185	210	450	520
123	230	265	550	630
145	275	315	650	750
170	325	375	750	860
245	460	530	1 050	1 200

NOTE Values in column (2) are applicable:

a) for type tests, phase-to-earth and between phases;

b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

Values in columns (3), (4) and (5) are applicable for type tests only.

**Table 3 – Rated insulation levels for rated voltages for equipment of range II
(above 245 kV)**

Rated voltage for equipment U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases (Notes 3 and 5)	Across open switching device and/or isolating distance (Note 3)	Phase-to-earth and across open switching device (Note 5)	Between phases (Notes 3 and 4)	Across isolating distance (Notes 1, 2 and 3)	Phase-to-earth and between phases (Note 5)	Across open switching device and/or isolating distance (Notes 2 and 3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	460	595	850	1 275	700 (+245)	1 050	1 050 (+170)
362	520	675	950	1 425	800 (+295)	1 175	1 175 (+205)
420	650	815	1 050	1 575	900 (+345)	1 425	1 425 (+240)
550	710	925	1 175	1 760	900 (+450)	1 550	1 550 (+315)
800	960	1 270	1 425	2 420	1 100 (+650)	2 100	2 100 (+455)
1 100 14	1 100	1 100	1 550	2 635	1 550 +(900)	2 250	2 250 + (630)
		1 100 +(635)	1 800	2 880	1 675 +(900)	2 400	2 400 + (630)
1 200	1 200	1 200	1 800	2 970	1 675 +(980)	2 400	2 400 + (685)
		1 200 +(695)	1 950	3 120		2 550	2 550 + (685)

NOTE 1 Column (6) is also applicable to some circuit-breakers, see IEC 62271-100:2021.

NOTE 2 In column (6), values in brackets are the peak values of the power-frequency voltage $U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

In column (8), values in brackets are the peak values of the power-frequency voltage $0,7 U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

NOTE 3 Values in column (2) are applicable:

- for type tests, phase-to-earth and between phases;
- for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

Values in columns (3), (4), (5), (6), (7) and (8) are applicable for type tests only.

NOTE 4 These values are derived using the multiplying factors stated in Table 3 of IEC 60071-1:2006/2019 [4].

NOTE 5 For earthing switches only phase-to-earth tests according column (2), (4) and (7) are applicable.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 is applicable.

~~4.4 Rated normal current and temperature rise~~

5.5 Rated ~~normal~~ continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 is applicable with the following addition:

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

~~4.4.2 Temperature rise~~

~~Subclause 4.4.2 of IEC 62271-1 is applicable with the following addition:~~

~~The temperature rise of components contained in the GIS which are subject to standards not covered by the scope of IEC 62271-1 shall not exceed the temperature rise limits permitted in the relevant standard for those components.~~

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

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable ~~with the following addition.~~

~~NOTE In principle, the rated short time withstand current and the rated peak withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components.~~

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable.

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

Subclause 5.9 of IEC 62271-1:2017 is applicable.

5.10 Rated supply frequency ~~of closing and opening devices and~~ of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable.

~~4.11 Rated filling levels for insulation and/or operation~~

~~Subclause 4.11 of IEC 62271-1 is applicable.~~

6 Design and construction

~~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, including the checking of phase sequence 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 rating and construction which may need to be replaced shall be interchangeable.~~

~~The various components contained within the enclosure are subject to their relevant standards except where modified by this standard.~~ 15

6.1 Requirements for liquids in switchgear and controlgear

Subclause 6.1 of IEC 62271-1:2017 is ~~not~~ applicable.

6.2 Requirements for gases in switchgear and controlgear

Subclause 6.2 of IEC 62271-1:2017 is applicable ~~with the following addition.~~

~~Recommendation for dew point measurements and adequate corrections shall be supplied by the manufacturer. Refer to E.4~~

6.3 Earthing of switchgear and controlgear

Subclause 6.3 of IEC 62271-1:2017 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 ~~may~~ 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 ~~live~~ 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 ~~live~~ 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 withstand capability.~~

The earthing circuit ~~may~~ can be degraded after being subjected to the ~~rated~~ short-circuit current. After such event, earthing circuit ~~may~~ can need to be replaced.

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 shall be ensured taking into account the thermal and electrical stresses caused by the current they ~~may~~ can have to carry.

If using single-phase enclosed switchgear, a looping circuit, i.e. an interconnection between the enclosures of the three phases, should be installed for the induced current. Each of these looping circuits should be linked as directly as possible to the general earthing grid by a conductor capable to carry the short-circuit current.

NOTE The looping circuits are intended to avoid induced currents in the enclosures from flowing in the earthing circuits and earthing grid. They are usually dimensioned for the rated continuous current and located at the appropriate location according to the layout of the GIS installation.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 and IEC 62271-1:2017/AMD1:2021 is applicable.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is applicable.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable.

6.7 ~~Independent manual or power operation (independent unlatched operation)~~ Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is applicable.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is applicable.

6.10 ~~Low and high pressure interlocking and monitoring devices~~ Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable with the following addition:

~~For GIS only gas density is of importance.~~

The performance of the GIS is depending on the gas density of the pure gas or the gas mixtures.

For 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 ~~sets of~~ alarm levels for pressure or density (alarm and minimum functional pressure or density). The correct functioning of gas monitoring devices shall be ~~capable of being able to be~~ checked with the high-voltage equipment in service.

NOTE 1 When the ~~rated~~ filling density differs between adjacent compartments, an additional alarm indicating over pressure or density ~~may~~ can be used, if it is applicable for the GIS design.

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, ~~should~~ can be considered.

NOTE 3 Checking of gas monitoring ~~may~~ can initiate wrong alarms which ~~may~~ 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 ~~should~~ can be given to safety and accessibility when choosing the location.

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

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following addition:

A common nameplate shall be provided to identify the 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 standard is required where ratings are not detailed on the common nameplate.

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

The manufacturer shall give information of the ~~total amount of SF₆~~ type, volume and mass of the gas contained in each gas compartment as well as the total mass for the entire GIS installation either on the nameplate or on a label placed in a visible location. If required, more information ~~regarding the SF₆ amount~~ shall be provided in the instruction manual.

6.12 ~~Interlocking~~ Locking devices

Subclause 6.12 of IEC 62271-1:2017 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.

~~Earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit should be interlocked with the associated disconnectors.~~

~~Earthing switches having a short-circuit making capacity less than the rated peak withstand current, or a breaking capacity less than the rated normal current, and disconnectors should be interlocked with the associated circuit breaker to prevent opening or closing of the switch or disconnector unless the associated circuit breaker is open. However, on-load bus-transfer switching operations at multiple busbar substations shall be possible.~~ 16

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable with the following addition:

~~Subclause 5.104.3.1 of IEC 62271-102:2001 is applicable.~~

In case of disconnector switch and earthing switch 6.104.3.2 of IEC 62271-102:2018 is applicable.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is applicable with the following addition:

This applies to bushings only.

6.16 Gas and vacuum tightness 17

6.16.1 General

Subclause 6.16.1 of IEC 62271-1:2017 is applicable with the following addition:

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

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

Leakage losses and handling ~~losses~~ 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 limits specified in this document.

~~NOTE 1 The objective is to achieve a total loss (leakage and handling) as low as possible. A value of less than 15 % averaged over all gas compartments and for the service period of minimum 25 years should be achieved.~~

~~NOTE 2 The cause of abnormal leakage in service should be investigated carefully and corrective actions should be considered.~~

6.16.2 Controlled pressure systems for gas

Subclause 6.16.2 of IEC 62271-1:2017 is ~~not~~ applicable.

6.16.3 Closed pressure systems for gas

Subclause 6.16.3 of IEC 62271-1:2017 is applicable with the following addition:

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

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

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

- $\leq 0,1$ % per year for SF₆, SF₆ mixtures and for other gas mixtures with GWP > 1 000;
- $\leq 0,5$ % per year for other gas mixtures with GWP ≤ 1 000.

NOTE 2 The global warming potential (GWP) of gases in 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 SF₆ is 23 500 according the IPCC – AR5 Climate Change 2013 [31].

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

- $\leq 0,2$ % per year for SF₆, SF₆ mixtures and for other gas mixtures with GWP > 1 000. 18

6.16.4 Sealed pressure systems

Subclause 6.16.4 of IEC 62271-1:2017 is applicable.

6.16.101 Leakage

In accordance with standardized procedure defined in ~~Annex E of IEC 62271-4~~ Clause 10 of IEC TR 62271-306:2012 and IEC TR 62271-306:2012/AMD1:2018 [12], the manufacturer shall demonstrate that the relative leakage rate from any compartment of GIS or between compartments complies with 6.16.3 or 6.16.4.

6.16.102 Gas handling

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

The manufacturer shall recommend procedures for ~~SF₆~~ gas handling according to ~~IEC 60480 and IEC/TR 62271-303~~ IEC 62271-4.

6.17 ~~Liquid tightness~~ Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is ~~not~~ applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-Ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable with the following addition:

This applies only to ~~circuit breakers with~~ GIS components which use vacuum interrupters.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 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.~~

The corrosion of bolted and screwed assemblies shall be taken into account when ensuring the continuity of the earthing circuits

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable.

6.101 General requirements for GIS

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, including the checking of phase sequence 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 standards except where modified by this document. 19

6.102 Pressure coordination

The pressure inside a GIS ~~may~~ can vary from the ~~rated~~ filling pressure ~~level~~ p_{re} due to different service conditions. ~~Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due to leakage may reduce the insulation properties.~~

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

Figure 1 shows the various pressure levels and their relationship.

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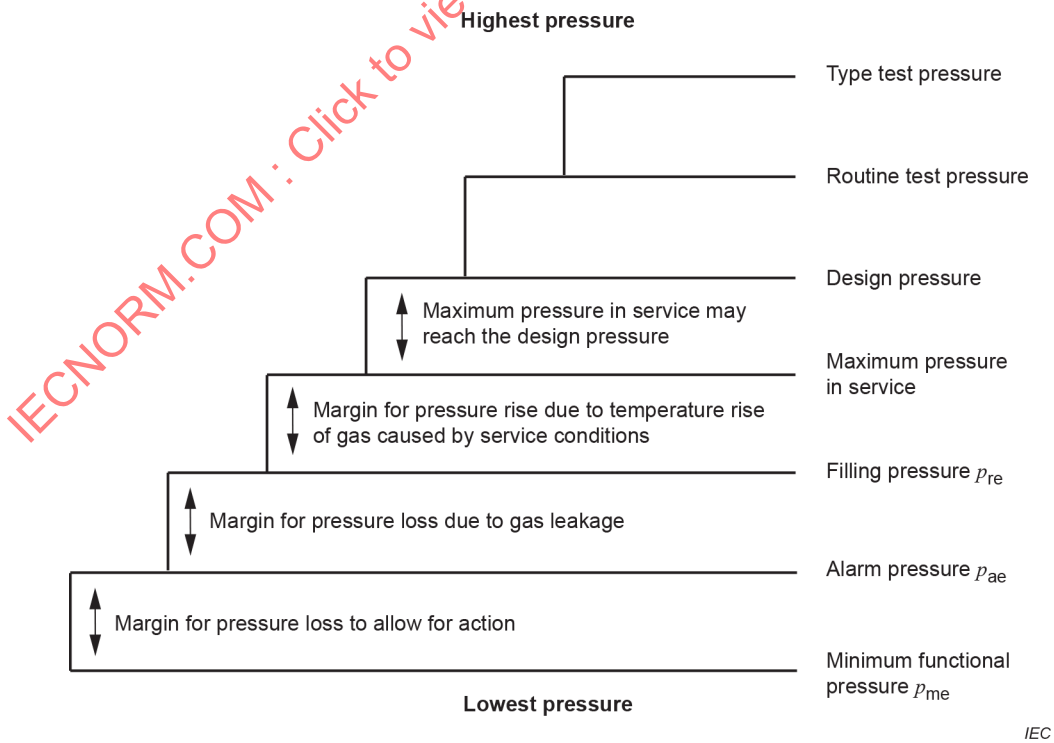
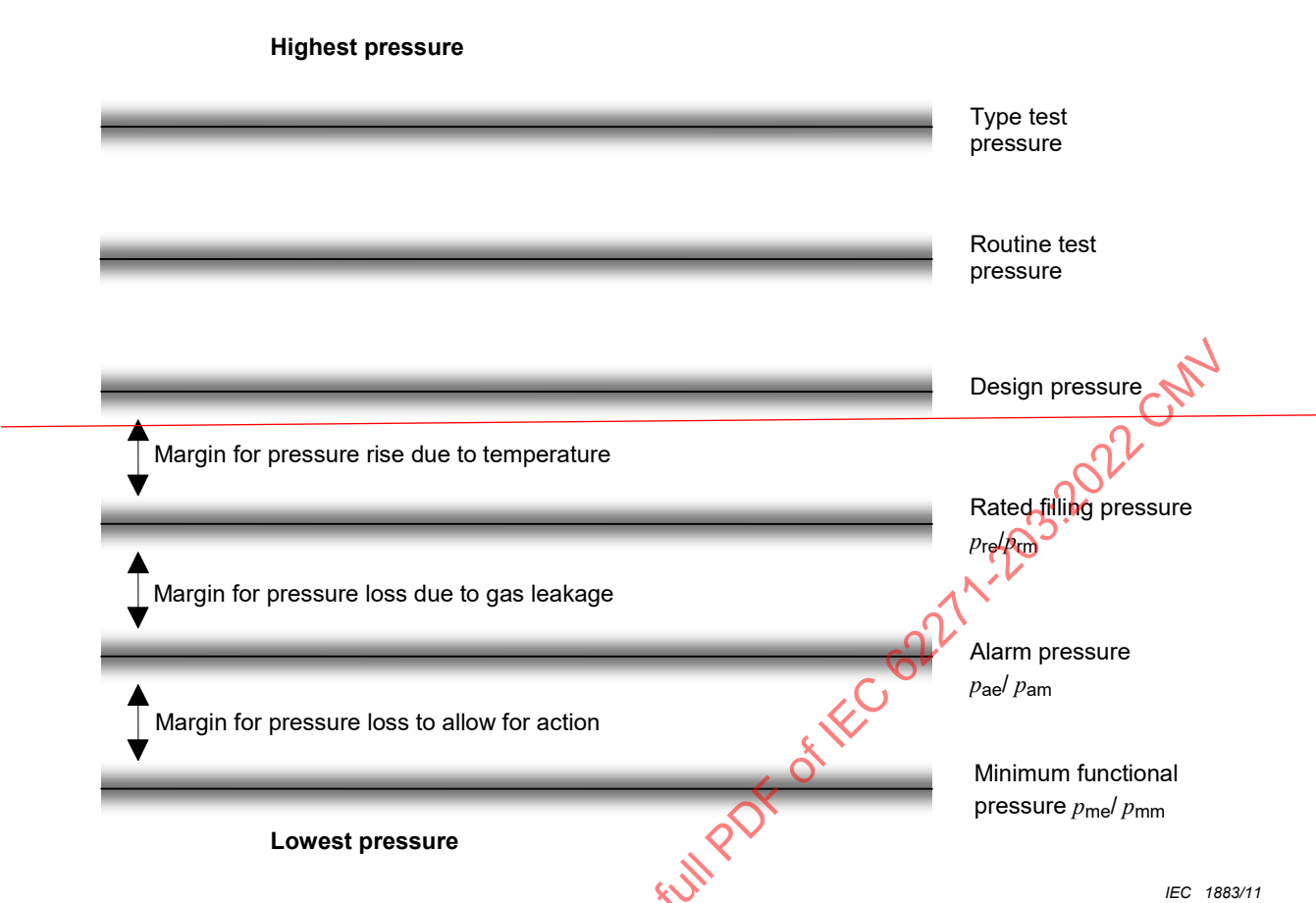


Figure 1 – Pressure coordination

The manufacturer is responsible for choosing the minimum functional pressure for insulation p_{me} and ~~operation~~ p_{mm} filling pressure p_{re} . ~~The alarm pressures p_{ae} / p_{am} are related to the rated filling pressures p_{re} / p_{mm} by the specified leakage rate in order to achieve the minimum requirements for the re-filling period specified in IEC 62271-1 and by the user.~~

~~Routine test pressure and type test pressure are based on design pressure taking into account material and manufacturing process factors.~~

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 GIS using gas with a GWP > 1 000, 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 aware the user as soon as possible of gas losses. **20**

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. ~~When considering the duration of~~ During this time period 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 GIS built to this document has a very low order of probability of occurrence. 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.

GIS shall be designed, manufactured and operated in order to prevent the occurrence of internal fault within 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 ~~should~~ will be necessary in order to isolate the faulty compartment. The general partitioning of GIS design shall permit the restoration of the part of GIS which is not affected in order to satisfy the service ~~operation~~ continuity requirements when defined (see Annex F).

6.103.2 External effects of the arc

The effects of an internal arc are:

- pressure increase of gas (see Annex D);

- possible burn-through of enclosure.

The external effects of the arc shall be limited by a suitable protective system to the appearance of a hole or a tear in the enclosure without any fragmentation. The duration of the arc is related to the performance of the protective system determined by the first stage (main protection) and second stage (back-up protection).

Table 4 gives the performance criteria for the duration of the arc according to the performance of the protective system.

Table 4 – Performance criteria

Rated short-circuit current	Protection stage	Duration of short-circuit current	Performance criteria
<40 kA RMS	1	$\leq 0,2$ s	No external effect other than the operation of suitable pressure relief devices
	2	$\leq 0,5$ s	No fragmentation (burn-through is acceptable)
≥ 40 kA RMS	1	$\leq 0,1$ s	No external effect other than the operation of suitable pressure relief devices
	2	$\leq 0,3$ s	No fragmentation (burn-through is acceptable)

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. **21**

Additionally, manufacturer and user ~~may~~ 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 (D.1).

The duration of current without burn-through for different values of the short-circuit current ~~may~~ can be estimated from an acknowledged calculation procedure like CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

6.103.3 Internal fault location

The manufacturer of the 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 standards for pressurized enclosures of gas-filled high-voltage switchgear and controlgear with inert, non-corrosive, low pressurized gases. For further information, see EN 50052 [15], EN 50064 [16], EN 50068 [17], EN 50069 [18].

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).

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

- a) the possible ~~recovery~~ or evacuation of ~~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 adsorb 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 ~~normal~~ continuous current flowing unless the design pressure can be established from existing ~~temperature-rise~~ 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 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 GIS. Partitions shall maintain their dielectric withstand strength at ~~voltages, which can occur in service (including temporary and transient voltages), when contaminated by SF₆ by-products of gases and gas mixtures generated from normal load switching or short-circuit fault breaking.~~

The design pressure of a partition is defined by ~~maintenance~~ the situation where the partition is pressurized on one side and the other side is at atmospheric pressure (e.g. when maintenance is being carried out). ~~During maintenance activities, the partition is normally pressurized on one side and maintenance is being carried out on the other side at atmospheric pressure.~~ 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.

~~For safety reasons, During maintenance activities, the gas pressure may can be lowered to a specified and controlled pressure below the rated pressure. In such cases this reduced pressure on one side of the partition can be used when determining the design 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. **22**

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;
- ~~— a controlled enhanced pressure, in excess of the maximum gas pressure, on one side of the partition with service pressure on the other side during electrical testing of the equipment and associated circuits;~~
- 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 ~~necessary~~ 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 GIS is influenced by the service continuity requirements during maintenance, repair and extension. Local health and safety requirements shall also ~~have to~~ be considered, see Clause 12.

Annex F provides guidance for specifying service continuity.

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

- during various activities requiring de-energization of parts of the 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 is 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 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 ~~may~~ can be ~~necessary~~ 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 GIS bus-duct pass between indoor and outdoor locations (for example, GIS installed within a building with outdoor bushings), the gas compartment ~~may~~ 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.

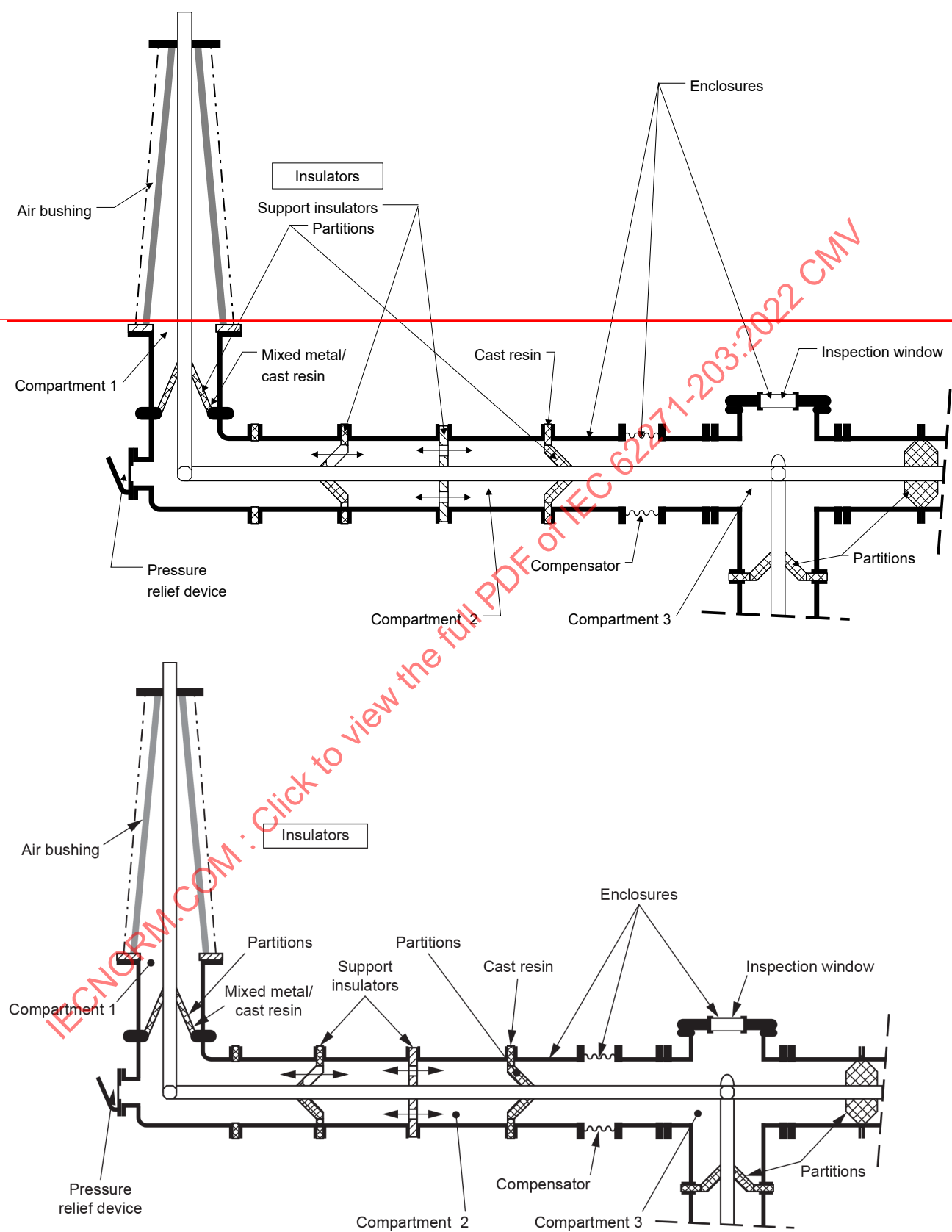
Each compartment shall be equipped with the following accessories:

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

Depending on the GIS design or on users request each compartment ~~may~~ 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.



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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 ~~during the time he is~~ performing ~~his~~ normal operating duties in the 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 ~~need~~ **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 ~~of~~, a pressure relief valve, ~~it~~ 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 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. For the calculation method, see Annex D.

The pressure relief device shall be equipped with a deflector in order to control the direction of emission ~~in such a way so as to minimize the danger~~ 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 e.g. circuit-breaker) shall be taken into account when determining the operating pressure of the pressure relief device.

NOTE In the case of an internal fault which causes yielding of the enclosure, enclosures of adjacent compartments ~~should~~ **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 [9] and IEC 61672-2 [10]).

6.108 Interfaces

6.108.1 General

In order to facilitate testing of GIS, isolating ~~facilities may~~ or **removable links can** be included in the design in each of the components mentioned below. This type of separation is preferable

to 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 Table 2 and Table 3.

A removable link shall be designed to withstand the phase-to-earth test voltages according Table 2 and Table 3. **23**

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

Those interfaces connected to the GIS shall be capable of withstanding the maximum pressure in service of the GIS. Typical maximum pressures in service are up to 1,1 MPa (absolute) for SF₆ and up to 1,5 MPa (absolute) for other gases and gas mixtures. **24**

6.108.2 Cable connections

6.108.2.1 General

See IEC 62271-209.

Those parts of the 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.

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

During dielectric tests on cables in general, the adjacent parts of the 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 GIS.

The location of bushings for cable testing should be provided at the cable connection enclosure or at the GIS itself (see IEC 62271-209) or (to reduce handling ~~losses of SF₆~~ releases of gas) at the other end of the cable.

6.108.2.2 Extruded insulation cable

According to IEC 60840 and IEC 62067 the electrical tests after installation are AC voltage tests in such case; part of the GIS in the vicinity of the cable termination can be subject to AC test voltage of the cable.

6.108.2.3 Oil-filled cable

According to IEC 60141-1 the electrical tests after installation are DC voltage tests, in such case; if it is not acceptable to apply DC cable test voltages to the 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

~~Refer to IEC/TR 61639.~~ See IEC 62271-211.

In order to facilitate testing of transformers, an ~~isolated~~ earthing switch, which can be insulated from the GIS enclosure and ground, ~~may~~ can be included in the design of the bushing or the GIS. ~~It should be considered that any opening of the GIS for the testing of the transformer should be avoided to reduce the handling losses of SF₆ and to reduce the outage time of the equipment.~~

NOTE Opening of the GIS for the testing of the transformer can then be avoided and reduce the gas handling releases and the outage time of the equipment. **25**

6.108.4 Bushings

See IEC 60137:2017, IEC TS 60815-1 [5], IEC TS 60815-2 [6], IEC TS 60815-3 [7], IEC 61462 [8] and IEC 62155 [11].

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 technical specification.

In the case of later extension with another 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 [20].

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 limit the part of the existing GIS to be re-tested and allow the connection to the existing GIS without further dielectric testing (see Clause C.3). It shall be designed to withstand the rated insulation levels across the isolating distance.

6.109 Interlocking

Disconnectors should be interlocked with the associated circuit-breaker to prevent opening or closing of the disconnector unless the associated circuit-breaker is open. However, on-load bus-transfer switching operations at multiple busbar substations shall be possible.

Earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit should be interlocked with the associated circuit-breaker and/or disconnectors to prevent opening or closing of the earthing switch unless the associated circuit-breaker and/or disconnector is open. Similar interlocking can be applied for earthing switches with making capability. **26**

7 Type tests

7.1 General

Subclause 7.1 of IEC 62271-1:2017 is applicable with the following addition:

For type tests, technical grade SF₆ and its mixtures in accordance with IEC 60376 or used SF₆ and its mixtures in accordance with IEC 60480 can be used.

If the GIS is designed to use any other gas than SF₆, 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 GIS and documented in the type test reports.

NOTE A working group of IEC TC10 is currently working on standardisation of technical grade of SF₆ free gas mixtures (IEC 63359 and IEC 63360). **27**

In regard of gas handling ~~IEC/TR 62271-303~~ IEC 62271-4 shall be taken into account.

7.1.1 ~~Grouping of tests~~ Basics

Subclause 7.1.1 of IEC 62271-1:2017 is applicable with the following addition:

As a general rule, tests on GIS components should be carried out in accordance with their relevant standards, 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 ~~prescriptions~~ requirements are defined, type testing shall be carried out on a complete functional unit ~~(single phase or three phase)~~. When this is impracticable, type tests ~~can~~ may 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 GIS to type tests. The performance of any particular arrangement ~~may~~ 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 5 below. ~~As proposed in IEC 62271-1, some tests can be grouped. An example of a possible grouping is also shown in Table 5.~~

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Table 5 — ~~Example of grouping of~~ Type tests 28

Mandatory type tests		
Group		Subclause
4	a) Tests to verify the insulation level of the equipment and dielectric tests on auxiliary circuits	7.2
-	b) Tests to prove the radio interference voltage (RIV) level (if applicable)	7.3
2	c) Tests to prove the ~~temperature rise~~ continuous current of any part of the equipment and measurement of the resistance of the main circuit	7.4 and 7.5
3	d) Tests to prove the rated peak and the rated short-time withstand current	7.6
3	e) Tests to verify the making and breaking capacity of the included switching devices	7.101
4	f) Tests to prove the satisfactory operation of the included switching devices	7.102.1
*	g) Tests to prove the strength of enclosures	7.103
4	h) Verification of the degree of protection of the enclosure	7.7
4	i) Gas tightness tests	7.8
*	j) Electromagnetic compatibility tests (EMC)	7.9
4	k) Additional tests on auxiliary and control circuits	7.10
*	l) Tests on partitions	7.104
4	m) Tests to prove the satisfactory operation at limit temperatures	7.102.2
*	n) Tests to prove performance under thermal cycling and gas tightness tests on insulators	7.106
*	o) Corrosion test on earthing connections (if applicable)	7.107
*	p) X-radiation test procedure for vacuum interrupters (if applicable)	7.11
NOTE — All type tests should be carried out using the number of test samples specified in 6.1.1 of IEC 62271-1:2007 and in the relevant apparatus standards. Where the test is marked by * an additional test sample is allowed for the marked test.		
Type tests, when requested by the user ~~(additional test samples may be used)~~		
Group		Subclause
*	q) Tests to assess the effects of arcing due to an internal fault	7.105
*	r) Corrosion tests on sealing systems of enclosures and auxiliary equipment (if applicable)	7.108

7.1.2 Information for identification of ~~specimens~~ test objects

Subclause 7.1.2 of IEC 62271-1:2017 is applicable.

7.1.3 Information to be included in type-tests reports

Subclause 7.1.3 of IEC 62271-1:2017 is applicable.

7.2 Dielectric tests **29**

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

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

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is not applicable but the following points ~~need to~~ 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 60137:2017.

~~6.2.3 Conditions of switchgear and controlgear during dielectric tests~~

~~Subclause 6.2.3 of IEC 62271-1 is applicable.~~

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable with the following addition:

~~NOTE—It is especially important for GIS to check the dielectric strength in order to eliminate all possible reasons for an internal fault in service. Therefore,~~ If any disruptive discharges occur during the type test series, it is ~~highly~~ 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 62271-1:2017 is applicable with the following addition:

The test voltages are specified in 7.2.7 and 7.2.8.

When each phase is individually enclosed in a metallic enclosure (single-phase design), only tests to earth, and no test between phases, shall be carried out. Bushings, used for external connections, shall be tested according to the relevant standards.

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

Attention shall be given to the possibility that switching devices, in their open position, ~~may~~ 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 transformers and/or surge arresters forming an integral part of the GIS have a reduced insulation level, they ~~may~~ 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 transformers and/or surge arresters shall be separately tested in accordance with the relevant standards.

Special requirements are prescribed in detail in Annex A.

7.2.6.2 General case

Subclause 7.2.6.2 of IEC 62271-1:2017 is applicable.

7.2.6.3 Special cases

Subclause 7.2.6.3 of IEC 62271-1:2017 is applicable with the following addition:

When the test voltage across the open switching device or across the isolating distance is higher than the phase-to-earth withstand level, but equal to the phase-to-phase withstand level, the test voltage shall be applied according to 7.2.6.3 of IEC 62271-1:2017.

For switchgear and controlgear of $U_r \leq 245$ kV, 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 grounded or according to 7.2.6.3 of IEC 62271-1:2017.

When the phase-to-phase withstand level is higher than the phase-to-earth withstand level, the test voltage shall be applied according to Annex A.

7.2.7 Tests of switchgear and controlgear of $U_r \leq 245$ kV

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-1:2017 is applicable with the following addition:

The rated withstand voltages shall be those specified in Table 2.

7.2.7.2 Power-frequency voltage tests

Subclause 7.2.7.2 of IEC 62271-1:2017 is applicable with the following addition:

The main circuits of the GIS shall be subjected to power-frequency voltage tests in dry conditions only.

7.2.7.3 Lightning impulse voltage tests

Subclause 7.2.7.3 of IEC 62271-1:2017 is applicable with the following addition:

If the alternative method described in 7.2.6.3 of IEC 62271-1:2017 is used, the test voltage is defined in column (5) of Table 2.

7.2.8 Tests of switchgear and controlgear of ~~rated voltage~~ $U_r > 245$ kV

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-1:2017 is applicable with the following addition:

The rated withstand voltages shall be those specified in Table 3.

7.2.8.2 Power-frequency voltage tests

Subclause 7.2.8.2 of IEC 62271-1:2017 is applicable.

7.2.8.3 Switching impulse voltage tests

Subclause 7.2.8.3 of IEC 62271-1:2017 is applicable with the following addition:

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

Special test requirements shall be used for the phase-to-phase switching test for a three-phase design. They are defined in detail in Annex A.

7.2.8.4 Lightning impulse voltage tests

Subclause 7.2.8.4 of IEC 62271-1:2017 is applicable.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is ~~not~~ applicable with the following addition:

This test applies only to bushings.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition:

7.2.10.1 General

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

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

NOTE Power-frequency voltage tests and partial discharge tests can be performed at the same time.

7.2.10.2 Test procedure

The applied power-frequency voltage is raised to a pre-stress value which is identical to the power-frequency withstand voltage test 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 6 depending on the configuration of equipment and system neutral.

The extinction voltage shall be recorded.

Table 6 – Test voltage for measuring PD intensity

	System with ~~solidly~~ effectively earthed neutral		System without ~~solidly~~ effectively earthed neutral	
	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test}}$ (>1 min)	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test}}$ (>1 min)
Single-phase enclosures design (phase-to-earth voltage)	$U_{\text{pre-stress}} = U_{\text{d}}$	$U_{\text{pd-test}} = 1,2 U_{\text{r}} / \sqrt{3}$	$U_{\text{pre-stress}} = U_{\text{d}}$	$U_{\text{pd-test}} = 1,2 U_{\text{r}}$
Three-phase enclosures design	$U_{\text{pre-stress}} = U_{\text{d}}$	$U_{\text{pd-test, ph-ea}} = 1,2 U_{\text{r}} / \sqrt{3}$ $U_{\text{pd-test, ph-ph}} = 1,2 U_{\text{r}}$	$U_{\text{pre-stress}} = U_{\text{d}}$	$U_{\text{pd-test, ph-ea}} = 1,2 U_{\text{r}}$
U_{r} : rated voltage for equipment. U_{d} : power-frequency withstand test voltage as per Table 2 and Table 3. $U_{\text{pre-stress}}$: pre-stress voltage. $U_{\text{pd-test}}$: test voltage for PD measurement. $U_{\text{pd-test, ph-ea}}$: test voltage for PD measurement, phase-to-earth. $U_{\text{pd-test, ph-ph}}$: test voltage for PD measurement, phase-to-phase.				

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

7.2.10.3 Maximum permissible partial discharge intensity

The maximum permissible partial discharge level shall not exceed 5 pC at the test voltage specified in Table 6.

The values stated above apply to individual components as well as to the sub-assemblies in which they are contained. However, some equipment, such as voltage transformers ~~isolated~~ insulated with liquid, immersed or solid, have an acceptable level of partial discharge in accordance with their relevant standard 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.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 is applicable with the following addition:

The test voltage shall be 80 % of the value in Table 2 and Table 3, columns (2) and (3).

In the case of three-phase enclosed designs, this test shall be performed across open switching devices, isolating distances, phase-to-earth and phase-to-phase.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 and 7.9.1 of IEC 62271-1:2017 are applicable with the following addition:

This test applies only to bushings.

7.4 Resistance measurement ~~of the resistance of circuits~~ 30

~~6.4.1 Main circuit~~

~~Subclause 6.4.1 of IEC 62271-1 is applicable with the following addition:~~

~~The resistance measurement applies to all GIS components before and after the temperature rise tests and short circuit tests.~~

~~6.4.2 Auxiliary circuits~~

~~Subclause 6.4.2 of IEC 62271-1 is applicable.~~

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

Subclause 7.4.1 of IEC 62271-1:2017 is applicable.

7.4.2 Measurement of the resistance of auxiliary contacts class 3

Subclause 7.4.2 of IEC 62271-1:2017 is applicable.

7.4.3 Electrical continuity of earthed metallic parts test

Subclause 7.4.3 of IEC 62271-1:2017 is applicable.

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

7.4.4.1 Resistance measurement test procedure

Subclause 7.4.4.1 of IEC 62271-1:2017 is applicable with the following addition:

The current used for the measurement shall be equal or greater than 100 A DC 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.

7.4.4.2 Making and breaking tests

Subclause 7.4.4.2 of IEC 62271-1:2017 is applicable.

7.4.4.3 Other tests

Subclause 7.4.4.3 of IEC 62271-1:2017 is applicable.

6.5 — Temperature-rise tests

6.5.1 — Conditions of the switchgear and controlgear to be tested

~~Subclause 6.5.1 of IEC 62271-1 is applicable.~~

6.5.2 — Arrangement of the equipment

~~Subclause 6.5.2 of IEC 62271-1 is applicable with the following addition:~~

~~Except in the case when each phase is enclosed individually in a metallic enclosure, the tests shall be made with the rated number of phases and the rated normal current flowing from one end of the busbars to the terminals provided for the connection of cables.~~

~~When a single phase test is permitted and carried out, the current in the enclosure shall be the rated current.~~

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

6.5.3 — Measurement of the temperature and the temperature rise

~~Subclause 6.5.3 of IEC 62271-1 is applicable.~~

6.5.4 — Ambient air temperature

~~Subclause 6.5.4 of IEC 62271-1 is applicable.~~

6.5.5 — Temperature-rise test of the auxiliary and control equipment

~~Subclause 6.5.5 of IEC 62271-1 is applicable.~~

6.5.6 — Interpretation of the temperature-rise tests

~~Subclause 6.5.6 of IEC 62271-1 is applicable with the following addition:~~

~~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 2.~~

~~NOTE The effect of solar radiation should be taken into account.~~

7.5 — Continuous current tests 31

7.5.1 — Conditions of the test object

Subclause 7.5.1 of IEC 62271-1:2017 is applicable.

7.5.2 — Arrangement of the equipment

Subclause 7.5.2 of IEC 62271-1:2017 is applicable with the following addition:

GIS with three-phase enclosures shall be subject to three-phase testing.

GIS with single-phase enclosures shall be single-phase tested with the test current flowing through the main conductor and back 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.

7.5.3 Test current and duration

7.5.3.1 Test on main circuit

Subclause 7.5.3.1 of IEC 62271-1:2017 is applicable.

7.5.3.2 Test on the auxiliary and control equipment

Subclause 7.5.3.2 of IEC 62271-1:2017 is applicable.

7.5.4 Temperature measurement during test

Subclause 7.5.4 of IEC 62271-1:2017 is applicable.

7.5.5 Resistance of the main circuit

Subclause 7.5.5 of IEC 62271-1:2017 is applicable.

7.5.6 Criteria to pass test

Subclause 7.5.6 of IEC 62271-1:2017 is applicable with the following addition:

Insulators for GIS are electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC 62271-1 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 [21].

The temperature rise of components contained in the GIS which are subject to standards not covered by the scope of IEC 62271-1:2017 shall not exceed the temperature-rise limits permitted in the relevant standard 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, precaution can be taken to ensure that no damage is caused to the surrounding insulating materials.

7.6 Short-time withstand current and peak withstand current tests 32

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the ~~switchgear and controlgear~~ equipment and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is ~~not~~ applicable with the following additions.

GIS with three-phase enclosures shall be subject to three-phase testing. GIS with single-phase enclosures shall be tested ~~using~~ in a single-phase circuit with the full 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 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.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

~~6.6.3 Behaviour of switchgear and controlgear during test~~

~~Subclause 6.6.3 of IEC 62271-1 is applicable.~~

7.6.4 Conditions of ~~switchgear and controlgear~~ the test object after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable.

7.6.101 Tests on the main circuits

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

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

7.6.102 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 ~~earthing~~ system.

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

After the test, ~~no deformation or damage to~~ the components or conductors within the enclosure shall not show deformation or damages, which ~~may~~ can impair ~~good~~ the intended operation of the main circuit ~~shall have been sustained~~. 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.

7.7 Verification of the protection 33

Subclause 7.7 of IEC 62271-1 is applicable.

7.7.1 Verification of the IP coding

Subclause 7.7.1 of IEC 62271-1:2017 is applicable with the following addition.

Verification of IP coding is not applicable to pressurized 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).

7.7.2 Verification of the IK coding

Subclause 7.7.2 of IEC 62271-1:2017 is applicable with the following addition:

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

7.8 Tightness tests 34

7.8.1 General

Subclause 7.8.1. of IEC 62271-1:2017 is applicable with the following addition:

~~The measurement of gas tightness shall be performed together with the tests of 6.102 and 6.106 with each type of compartment comprising characteristic sealings of GIS as a type test to show that the leakage rate complies with 5.15.101 and will not be changed by influences caused by the mechanical and limit temperature type tests.~~

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 GIS compartments comprising sealings and accessories (e.g. gas filling valves, gas monitoring and control devices, 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.

7.8.2 Controlled pressure systems for gas

Subclause 7.8.2 of IEC 62271-1:2017 is ~~not~~ applicable.

7.8.3 Closed pressure systems for gas

Subclause 7.8.3 of IEC 62271-1:2017 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).

7.8.4 Sealed pressure systems

Subclause 7.8.4 of IEC 62271-1:2017 is applicable.

7.8.5 Liquid tightness tests

Subclause 7.8.5 of IEC 62271-1:2017 is ~~not~~ applicable.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is applicable.

7.11 X-radiation test ~~procedure~~ for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Verification of making and breaking capacities

Switching devices forming part of the main circuit of GIS shall be tested to verify their rated making and breaking capacities according to the relevant standards and under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the GIS with all associated components, the arrangement of which ~~may~~ can influence the performance, such as connections, supports, etc.

NOTE In determining which associated components are likely to influence the performance, special attention ~~should~~ 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 ~~may~~ can be quite negligible.

7.102 Mechanical and environmental tests

7.102.1 General

Switching devices of GIS shall be submitted to mechanical operation and environmental tests in accordance with their relevant standards and shall be tested in a representative assembly of all associated components, which ~~may~~ 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 7.8 shall be performed to show that the leakage rate is not changed by influences caused by the mechanical type tests.

~~In addition to Annex E of IEC 62271-102:2001,~~ All switching devices fitted with interlocks shall be submitted to ~~50~~ 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 standards ~~with the following additions.~~

~~After the test cycles, the following shall be noted:~~

- ~~— the pressure of the gases contained in the enclosure;~~
- ~~— the gas leakage over a period of 24 h.~~

7.103 Proof tests for enclosures 35

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 ~~may~~ 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 [15], EN 50064 [16], EN 50068 [17], EN 50069 [18].

7.103.2 ~~Destructive pressure test~~ 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 = $[3,5 / 0,7] \times \text{design pressure}$

NOTE The value 0,7 has been included to cover the possible variability of production castings. ~~It is permitted to increase~~ 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 = $[(2,3 / \nu) \times (\sigma_t / \sigma_a)] \times \text{design pressure}$

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 ~~may~~ can be ~~required~~ 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 ~~Non-destructive pressure test~~ 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 ~~standard~~ 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 ~~unloading~~ pressure decrease.

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

If the curve of the strain/pressure relationship show a nonlinearity, the pressure ~~may~~ 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 ~~standard~~ 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 ~~standard~~ routine test pressure, the design pressure shall be calculated from the following equation:

$$p = \frac{1}{1,1k} \left(p_y \frac{\sigma_a}{\sigma_t} \right)$$

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 ~~standard~~ 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 [19].

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

The type test pressure shall be ~~greater than~~ 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 B.

NOTE Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

The short-circuit current applied during the arcing should correspond to the rated short-time withstand current or, in some applications of the switchgear in isolated neutral systems, it ~~may~~ can be the earth fault current occurring in such a system.

Two assessments are made. The first concerns the performance of the equipment during the operation of the first stage (main) protection and the second concerns the case when the fault is cleared by the operation of the second stage (back-up) protection.

In order to verify both assessments, the duration of the test shall be at least equal to the time delay of operation for the second stage of protection. The maximum time setting for the operation of the second stage is defined in Table 4. A shorter test duration can be used if it is not shorter than the operation of the second stage of protection defined by the user.

The switchgear shall be considered adequate if the performance criteria defined in Clause 6.103 and in Table 4 are met.

7.106 Insulator tests

7.106.1 General

Tests on insulators (partitions and support insulators) shall be performed as follows:

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 (e.g. $-40\text{ }^{\circ}\text{C}$);
- b) 2 h at room temperature;
- c) 4 h at limit of temperature according to ~~Table 3~~ Table 14 row 7 of IEC 62271-1:2017 (e.g. $+105\text{ }^{\circ}\text{C}$);
- d) 2 h at room temperature.

NOTE Insulators for GIS are electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC 62271-1 are therefore applicable for the EIS and not for the electrical insulation material (EIM). **36**

The given thermal cycle times are minimum times and shall be prolonged in case stable end temperatures are not reached.

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. ~~The leakage rate in the compartment under vacuum is measured over a period of 24 h.~~ 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.

Precaution 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 7.8. The relative leakage rate shall not be greater than the defined value prescribed in 6.16.

7.107 Corrosion test on earthing connections **37**

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 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, ~~pressure relief device~~) and the secondary system as described in ~~5.20 of IEC 62271-1~~ 15.7 of IEC TR 62271-306:2012 and IEC TR 62271-306:2012/AMD1:2018 [12].

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 3234~~ ISO 22479.

NOTE The Cigre working group WG B3.57 is working on life time management of outdoor HV GIS [30]. 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 7.4.4, shall not ~~differ by~~ ~~increase~~ more than 20 % ~~before and~~ 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 38

~~For information regarding service conditions and recommended test requirements refer to Annex H of IEC 62271-1.~~

7.108.1 General

On user's request, a corrosion proof test shall be performed in accordance with 7.108.

The tested sub-assemblies shall be representative of a 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 [12].

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 7.8.

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 life time management of outdoor HV GIS [30]. The recommendations of this Cigre guide can be considered.

8 Routine tests

8.1 General

Subclause 8.1 of IEC 62271-1:2017 is applicable with the following addition:

For routine tests technical grade SF₆ and its mixtures in accordance with IEC 60376, or used SF₆ and its mixtures in accordance with IEC 60480, can be used. See 6.2.

If the GIS is designed to use any other gas than SF₆, 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 GIS and documented in the routine test reports. **39**

The routine tests shall be performed on all components of a ~~substation~~ gas-insulated metal-enclosed switchgear and its controlgear. Depending on the nature of tests, some tests ~~may~~ can be performed on components, transport units or on the complete installation. ~~The routine tests ensure that the product is in accordance with the equipment on which the type tests have been carried out.~~

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 62271-1:2017 is applicable with the following additions:

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

8.2.101 Power-frequency voltage tests on the main circuit

The power-frequency voltage test of GIS shall be performed according to the requirements in 7.2.6.1 or 7.2.7.1 to earth, between phases (if applicable) and across the open switching devices. The voltage test across the open switching device ~~may~~ can be carried out at one side of the switching device. The withstand voltages for routine tests shall be those specified in column (2) of Table 2 and Table 3.

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 ~~may~~ 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 ~~may~~ can be excepted.

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

The tightness test shall preferably be performed at filling pressure 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 62271-1:2017, 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. 40

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 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

- 1,3 for welded aluminium and welded steel enclosure;
- 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 GIS shall be submitted to a mechanical routine test in accordance with their relevant standards. 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 they are in good no effect on the entire operating condition 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) 41

9.1 General

Subclause 9.1 of IEC 62271-1:2017 is applicable with the following addition:

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

NOTE IEEE C37.122.1 [22] and CIGRE Technical Brochure 125 [23] describe the general guideline for the selection of a gas-insulated switchgear.

9.2 Selection of rated values

Subclause 9.2 of IEC 62271-1:2017 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 62271-1:2017 is applicable.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC 62271-1:2017 is applicable.

9.5 Environmental aspects

Subclause 9.5 of IEC 62271-1:2017 is applicable.

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

10.1 General

Subclause 10.1 of IEC 62271-1:2017 is applicable with the following addition:

Annex E 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 62271-1:2017 is applicable.

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 is applicable with the following addition:

e) List of recommended tools that should be procured by the user.

11 Transport, storage, installation, ~~operation~~ operating instructions and maintenance

11.1 General

Subclause 11.1 of IEC 62271-1:2017 is applicable.

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC 62271-1:2017 is applicable.

11.3 Installation

~~Subclause 10.2 of IEC 62271-1 is applicable with the following addition:~~

~~Subclause 10.2.1 of IEC 62271-1 is not applicable.~~

Subclause 11.3 of IEC 62271-1:2017 is applicable.

11.4 ~~Operation~~ Operating instructions

Subclause 11.4 of IEC 62271-1:2017 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC 62271-1:2017 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.

11.101 Tests after installation on-site

11.101.1 General

After installation, and before being put into service, the 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 ~~moisture~~ 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 gas-insulated substation is in service. Reference shall be made, in any case, to the manufacturer's ~~instruction book~~ 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 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 GIS has been fully installed and gas-filled at the ~~rated~~ 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 ~~may~~ 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 GIS, see Clause C.3.

In choosing an appropriate test method for each individual case, a special agreement ~~may~~ can be ~~necessary~~ made in the interest of practicability and economy, e.g. the electrical power requirements and the dimensions and weight of the test equipment ~~may~~ can need to be considered.

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

11.101.2.2 Test procedure

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

Some parts ~~may~~ ~~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 line;
- power transformers and, occasionally, voltage transformers;
- surge arresters and protective spark gaps.

NOTE 1 In determining the parts which ~~could~~ ~~can~~ be disconnected, attention is drawn to the fact that the reconnection ~~may~~ ~~can~~ introduce faults after the tests are completed.

NOTE 2 Voltage transformers can remain connected for the test when saturation of the voltage transformer is prevented, e.g. by using voltage transformers which are designed for the test voltage or by performing the power-frequency testing at a frequency, where saturation does not occur.

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

In the case of extensions, in general, the adjacent existing part of the 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 GIS.

Application of the test voltage ~~may~~ ~~can~~ be necessary after repair or maintenance of major parts or after installation of extensions. The test voltage ~~may~~ ~~can~~ then ~~have to~~ 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 GIS.

10.2.101.2.3 Dielectric test procedures

One of the following test procedures shall be chosen:

a) Procedure A (recommended for 170 kV and below):

Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2).

b) Procedure B (recommended for 245 kV and above):

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2); and
- partial discharge measurements according to Table 6, however with $U_{\text{pre-stress}} = U_{\text{ds}}$ of Table 7, column (2).

In the few cases, where $U_{\text{pd-test}}$ is higher than $U_{\text{pre-stress}}$ the $U_{\text{pd-test}}$ shall be reduced to $U_{\text{pre-stress}}$.

A PD measurement at $U_r / \sqrt{3}$ is also recommended since this measurement ~~may~~ ~~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 C.

c) Procedure C (recommended for 245 kV and above, alternative to procedure B):

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2); and
- lightning impulse tests with three impulses of each polarity and with the value specified in Table 7, column (3).

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 7.

Table 7 – On-site test voltages

Rated voltage for equipment	On-site short-duration power-frequency withstand voltage	On-site switching impulse withstand voltage 42	On-site lightning impulse withstand voltage	
U_r kV (RMS value)	U_{ds} kV (RMS value)	U_{ss} kV (peak value)	U_{ps} kV (peak value)	
(1)	(2) ~~(see Note 1)~~		(3)	(4)
72,5	120	-	260	
100	165	-	360	
123	200	-	440	
145	235	-	520	
170	270	-	600	
245	380	-	840	
300	380	680	840	
362	425	760	940	
420	515	840	1 140	
550	560	940	1 240	
800	760	1 140	1 680	
1 100	865		1 920	
1 200	865		1 920	

NOTE 1 ~~Values of column (2) are only applicable for SF₆ insulation or when SF₆ is a major part of the gas mixture. For other insulation refer to Tables 1 and 2 of IEC 62271-1, applying a factor 0,8 on column (2).~~

NOTE 2 1 The on-site test voltages have been calculated as follows:

$$U_{ds} \text{ (on-site test value)} = U_p \times 0,45 \times 0,8 \quad (\text{column (2)})$$
~~$$U_{ss} \text{ (on-site test value)} = U_s \times 0,8 \quad (\text{column (3)})$$~~

$$U_{ps} \text{ (on-site test value)} = U_p \times 0,8 \quad (\text{column (3)})$$

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

NOTE 3 2 If other insulation levels than the preferred values of Table 2 and Table 3 (e.g. the lower insulation levels of Tables 1 and 2 in IEC 62271-1:2017) are specified, then the on-site test voltage ~~should~~ can be calculated according to Note 2 1.

NOTE 3 The UHV on-site test voltages for $U_r = 1\,100$ kV and $1\,200$ kV are according to IEC TS 63042-301 [14].

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

11.101.2.4 Voltage waveforms

For the choice of an appropriate voltage waveform, IEC 60060-1 [3] 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 Clause C.1.

a) Power-frequency voltage tests

Power-frequency 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

~~1) 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 μ s are acceptable. When using oscillating lightning impulse voltages, the front time ~~may~~ can be extended to approximately 15 μ s.

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

~~2) Tests with switching impulse voltages can be used especially for higher U_r to detect the presence of contaminations as well as abnormal field configurations with relatively simple test equipment.~~

~~Based on existing experience, switching impulses with either aperiodic or oscillating waveforms and with a time to crest in the range of 150 μ s to 10 ms are suitable.~~ 43

c) DC voltage tests

A DC voltage test is not recommended. The existing test specifications for cables are not applicable to GIS (see 6.108.1).

11.101.2.5 Voltage application

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

It is often convenient to divide the whole installation of GIS into sections by opening circuit-breakers and/or 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 circuit-breaker or 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 ~~need~~ ~~to~~ shall be carried out on-site.

For 3-phase enclosed GIS, the specified test voltage shall be applied between each phase conductor, one at a time, and the enclosure, the other phase conductors being connected to the earthed enclosure. The insulation between phase conductors shall not be subjected to any other separate dielectric test 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 Clause C.6.

If Procedure B is used and if the partial discharges are measured with the conventional method according to IEC 60270, the maximum permissible intensity of partial discharge shall be 10 pC.

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 can consider this possibility in the test sequence, and can be agreed between user and manufacturer.

NOTE 23 If VHF/UHF or acoustic partial discharge measuring methods are used, a calibration is not possible. Instead, a sensitivity check according to C.7.5, IEC TS 62478 [13] and CIGRE Technical Brochure 654 [25] can be performed.

11.101.3 Dielectric tests on auxiliary circuits

Subclause 8.3 of IEC 62271-1:2017 is applicable with the following addition:

Dielectric tests should be carried out on new wiring. If wiring ~~has to~~ 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. 44

11.101.5 Gas tightness tests

Subclause 8.5 of IEC 62271-1:2017 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 ~~may~~ 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 standards. 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 ~~moisture~~ humidity content shall be checked at least 5 days after final filling of gas. ~~For SF₆ the moisture~~ The humidity content shall not exceed the limit defined in 6.2 of IEC 62271-1:2017.

For checking the condition of the gas during service, reference is made to IEC 60480 for SF₆ and its mixtures and to manufacturer recommendations and IEC 62271-4 for other gases.

For handling precautions, reference is made to ~~IEC/TR 62271-303~~ IEC 62271-4 for SF₆ and manufacturer recommendations for other gases.

~~NOTE—Care should be taken to minimize the release of gas into the atmosphere during sampling and/or checking operations (e.g. by providing a collecting bag or receiver installed on the outlet valve of the checking device when determining moisture content).~~ 45

12 Safety

Clause 12 of IEC 62271-1:2017 is applicable with the following addition:

~~NOTE—Working on gas compartments with adjacent compartments under full pressure may~~ can according to local regulations and manufacturer safety procedures require to apply safety measures for workers ~~according to local regulations~~.

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:2017 is applicable with following addition:

Handling ~~losses~~ releases during manufacturing, installation, on-site tests, repair and maintenance shall be ~~recorded~~ be accounted according local regulation, see IEC 62271-4.

~~Each refilling shall be recorded with indication of additional SF₆ mass filled in the compartment.~~

For environmental aspects of gases and gas mixtures see CIGRE Technical Brochure 802 [26].

Annex A (normative)

Test procedure for dielectric test on three-phase encapsulated GIS, range II (above 245 kV)

A.1 Dielectric procedures for three phases in one GIS enclosure

If the requirements for phase-to-earth and phase-to-phase insulation levels are different, the test requirements following IEC 62271-1:2017 shall be reconsidered. This is applicable only for switching impulse tests of range II.

A.2 Application of test requirements

In order to fully cover the tests to be carried out, Table A.1 lists the test conditions in relation to the enclosure, open switching device and phase-to-phase. The table symbols are the same as in IEC 62271-1:2017 (Figure 2).

The preferred method is the use of combined voltage test. The voltage levels required ~~may~~ can be delivered by two different voltage sources in ~~phase opposition connected to the same voltage controller~~ opposite polarity.

Table A.1 – Switching impulse test conditions above 245 kV

Test condition	Connecting device	Switching impulse	Alternating voltage at power-frequency	Earth connected to
Phase-to-phase test		Main part of U_s between phases (Table 3, column (5)) applied to	Complementary part to obtain U_s between phases (Table 3, column (5)) applied to	
1	Closed	Aa	BbCc	F
2	Closed	Bb	AaCc	F
3	Closed	Cc	AaBb	F
4	Open	A	BC	abcF
5	Open	B	AC	abcF
6	Open	C	AB	abcF
7	Open	a	bc	ABCF
8	Open	b	ac	ABCF
9	Open	c	ab	ABCF

NOTE 1 Test conditions 3, 6 and 9 ~~may~~ can be omitted if the arrangement of the outer phases is symmetrical with respect to the centre phase and the enclosure.

NOTE 2 Test conditions 2, 3, 5, 6, 8, 9 can be omitted if the arrangement of the phases is fully symmetrical with respect to each other and to the enclosure.

NOTE 3 Test conditions 7, 8 and 9 can be omitted if the arrangement of the terminals of each phase is symmetrical with respect to the enclosure.

For switching functions and disconnecting functions, respective values ~~have to~~ shall be taken in Table 3 for open conditions.

Annex B (normative)

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

B.1 General

The occurrence of an arc inside 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 ~~may~~ can produce hot decomposition products which ~~may~~ 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 ~~may~~ can constitute a risk, such as toxic gases and their by-products (see annexes of IEC 62271-4 for further information).

B.2 Short-circuit current arcing test

B.2.1 Test arrangements

When choosing the object to be tested, reference shall be made to the design documents for the 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:

- each test ~~may~~ 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;
- 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.

~~“Mock-ups” are permitted provided they have the same volume and external material and would react in the same way as the original parts with respect to withstanding arcing;~~

- the test object shall be filled with normal insulating gas at ~~rated filling density~~ filling pressure p_{re} .

B.2.2 Current and voltage applied

B.2.2.1 General

Single-phase enclosures shall be tested single-phase, and three-phase enclosures shall be tested three-phase.

B.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:

- the arc current shall be practically sinusoidal;

b) the arc shall not extinguish prematurely.

B.2.2.3 Current

a) AC component

The AC component at the beginning of the test shall lie within a tolerance of $^{+10}_0$ %. Within the duration of the first stage protection, the tolerance shall be ± 10 % and within the duration of the second stage protection 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 ~~may~~ 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 of at least 1,7 times the RMS value of the stated short-circuit current AC component. For three-phase tests, this applies to the current in at least one phase.

B.2.2.4 Frequency

For rated frequencies of 50 Hz or 60 Hz, the frequency at the beginning of the test shall lie within the limits of 48 Hz and 62 Hz.

B.2.2.5 Duration of the test

The current duration shall be such as to cover the second stage protection chosen on the basis of the expected duration as determined by the protection devices. See Table 4.

B.2.3 Test procedure

B.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.

B.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 ~~should not~~ cannot be initiated by perforating the solid insulation.

B.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.

B.2.4 Assessment of 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 times 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. 46

No fragmentation of the enclosure shall ~~result~~ occur from a fault ~~cleared within~~ in the stage 2 protection according to Table 4.

B.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;
- currents, voltages, energies, pressures 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.

B.2.6 Extension of the test results

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

B.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.

Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

Annex C (informative)

Technical and practical considerations of site testing

C.1 Test voltage generators

~~Load capacitances of GIS installations are relatively high.~~ GIS installations have a relatively high load capacitance. This means that:

- power-frequency voltage tests, especially at higher U_r , require a high reactive power;
- impulse testing with standardized double exponential waveforms ~~may~~ can be inefficient due to the poor voltage utilization of the impulse generator.

The following voltage-generating equipment ~~may~~ can be used:

a) power-frequency voltage sources

The power-frequency voltage ~~may~~ 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;
- ~~energizing~~ power or voltage transformers ~~by energization~~ from the low-voltage side ~~which~~ (entails no dismantling after testing).

NOTE The thermal stresses of the voltage source ~~should~~ 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 ~~may~~ 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 ~~may~~ can be produced by discharging a capacitor into the low-voltage side of a power, voltage or test transformer.

C.2 Locating discharges

There are different phenomena caused by discharges which ~~may~~ can be helpful in locating them. Some of the possible means which ~~may~~ 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.

C.3 Special test procedures

C.3.1 General

In general, it is recommended that all testing should be performed at the specified test voltage and ~~rated~~ 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 (6.108.4) the user shall be responsible for any flashovers in the existing GIS and the manufacturer of the extension equipment shall be responsible for any flashovers in the extension equipment.

C.3.2 Testing at reduced voltage

C.3.2.1 Simplified method for units transported without dismantling

In accordance with the practice in some countries, gas-insulated metal-enclosed switchgear, or at least one bay or an equivalent part of the GIS installation, ~~may~~ 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 ~~may~~ can be reduced to the following:

AC voltage test with $1,1 \times U_r / \sqrt{3}$ for earthed neutral systems or $1,9 \times U_r / \sqrt{3}$ for isolated neutral or resonant earthed systems; with a 10 min voltage application.

C.3.2.2 Deviations due to practical needs

In certain circumstances due to technical or practical reasons, an AC voltage test ~~may~~ can be performed at reduced voltage for an extended duration. Additionally, partial discharge detection ~~may~~ can be applied in accordance with Clause C.7. The procedure is subject to agreement between the manufacturer and the user.

C.3.2.3 Application of service voltage

In some cases, it is impracticable to perform a dielectric test on-site. In such a case, special care should be taken for shipment, transportation and storage and particular attention should be given to the workmanship on-site. The GIS to be tested should be energized by the service voltage through the largest possible impedance in order to reduce damage caused by a possible disruptive discharge. The test period should be at least 30 min.

C.3.3 Testing at reduced gas density

Tests with reduced gas density are not generally advisable.

C.4 Partial discharge measurements

Partial discharge measurements ~~may~~ 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.

C.5 Electrical conditioning

The term “electrical conditioning” means a progressive application of an AC voltage either by steps or continuously. It ~~may~~ 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 AC 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 ~~may~~ can result in a weakening of the insulation.

C.6 Repetition tests

C.6.1 General

The procedure to be implemented following a disruptive discharge during dielectric tests on-site ~~may~~ 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 C.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 ~~may~~ can be acceptable, depending on the significance of the factors involved.

C.6.2 Recommended procedure

C.6.2.1 Procedure a)

If the disruptive discharge occurs along the surface of a solid insulation it is recommended that ~~wherever practicable~~ 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 specified dielectric test once more.

C.6.2.2 Procedure b)

A disruptive discharge in the gas ~~may~~ can be due to contamination or a surface imperfection which ~~may~~ can be burned away during the discharge. It ~~may~~ can be acceptable, therefore, that the test ~~may~~ can be repeated at the specified test voltage. Another test voltage ~~may~~ 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 ~~may~~ 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.

C.7 Partial discharge detection method

C.7.1 General

For partial discharge detection on-site, the electrical VHF/UHF and the acoustic method can be used in 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.

C.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 GIS is preferable. In such a case, a sensitivity below 5 pC is achievable for GIS with cable terminations and for GIS sections which are separated by an open disconnector from open-air bushings.

C.7.3 VHF/UHF method

The discharge currents at the defects of 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 GIS with the speed of light as ~~TEM, TE and TM~~ 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 ~~have~~ can need to be installed in a 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 spacers.

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 C.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 ~~may~~ can be detected.

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

C.7.4 Acoustic method

Acoustic signals (mechanical waves) are emitted from defects in a 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.

Predischage 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 predischage 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 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.

C.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 GIS in order to verify the detection sensitivity for the 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 GIS section between these sensors.

For further information see IEC TS 62478 [13] and CIGRE Technical Brochure 654 [25]. **47**

Annex D (informative)

Calculation of pressure rise due to an internal fault

The pressure rise in a closed compartment filled with SF_6 gas due to an internal fault can be calculated according to Formula (D.1):

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

where

- Δp is the pressure rise (MPa);
- I_{arc} is the fault arc 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 (D.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.

Annex E (informative)

Information to be given with enquiries, tenders and orders

E.1 General

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

NOTE—Reference to “supplier information” means that only the supplier ~~needs to provide~~ provides this information.

E.2 Normal and special service conditions

See Clause 4.

Table E.1 – Normal and special service conditions

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

E.3 Ratings

See Clause 5.

Table E.2 – Ratings

		User requirements	Supplier proposals
Nominal voltage of system	kV		
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase-to-earth and between phases	kV		
Rated short-duration power-frequency withstand voltage (U_d)			
Rated switching impulse withstand voltage (U_s)			
Phase-to-earth			
Between phases			
Rated lightning impulse withstand voltage (U_{lp})	kV		
Rated frequency (f_r)	Hz		
Rated ~~normal~~ continuous current (I_r)	A	According single-line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short-circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 Hz or 60 Hz	
Neutral earthing		~~Solidly~~ Effectively or not ~~solidly~~ effectively	

E.4 Design and construction

See Clause 6.

Table E.3 – Design and construction

		User requirements	Supplier proposals
Number of phases			
Single- or three-phase design			
Maximum ~~SF₆~~ relative gas leakage rate	% / year		
~~Rated filling pressures $p_{re} + p_{rm}$~~ Filling pressure p_{re}	MPa	Supplier information	
Circuit-breaker	MPa	Supplier information	
Other compartments			
Alarm pressure $p_{ae} + p_{am}$			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Minimum functional pressure $p_{me} + p_{mm}$			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Design pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Type test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Routine test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Operating pressure of pressure relief device			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Internal fault			
Short-circuit current	kA		
Duration of current (as per Table 4)	s		
Quantity of ~~SF₆~~ gas of complete GIS at filling pressure p_{re}	kg	Supplier information	
Quantity of ~~SF₆~~ gas of the largest compartment at filling pressure p_{re}	kg	Supplier information	
Maximum permissible gas dew point	°C	Supplier information	
Recommendation for dew point measurement and adequate correction			
Number of gas compartments		Supplier information	
Length of longest section for transportation	m		
Weight of the heaviest piece of equipment to be handled during installation on-site	kg		
Noise			

E.5 Bus ducts

Table E.4 – Bus ducts

		User requirements	Supplier proposals
Inductance	H/m	Supplier information	
Capacitance	pF/m	Supplier information	
Resistance of enclosure at f_r	Ω /m	Supplier information	
Resistance of conductor at f_r	Ω /m	Supplier information	
Surge impedance	Ω	Supplier information	

E.6 Circuit-breaker

Clause 10 of IEC 62271-100:20082021 is applicable.

E.7 Disconnecter and earthing switch

Clause 10 of IEC 62271-102:20042018 is applicable.

E.8 Bushing

Clause 6 of IEC 60137:20082017 is applicable with the following additions:

Table E.5 – Bushing

Outdoor-immersed bushing (see IEC 60137:20082017, 3.20)		User requirements	Supplier proposals
Type of internal insulation		Gas-insulated or resin-impregnated paper	
Type of external insulation		Porcelain or composite	
Nominal specific creepage distance	mm/kV		
Shed profile		Normal or alternating	
Rated short-duration, power-frequency withstand voltage (U_d)	kV	As GIS or special	
Rated switching impulse withstand voltage (U_s)	kV	As GIS or special	
Rated lightning impulse withstand voltage (U_p)	kV	As GIS or special	
Cantilever test load	N		
Cantilever operation load	N		
Type of line termination		According drawing	

E.9 Cable connection

Clause 10 of IEC 62271-209:20072019 is applicable with the following additions:

Table E.6 – Cable connection

		User requirements	Supplier proposals
Type of cable termination		Fluid-filled or dry type	
Supplier of cable insulator		GIS or cable supplier	

E.10 Transformer connection

Clause 9 of ~~IEC/TR 61639:1996~~ IEC 62271-211:2014 is applicable with the following additions:

Table E.7 – Transformer connection

		User requirements	Supplier proposals
Insulated junction between transformer tank and GIS enclosure		Yes or no	

E.11 Current transformer

~~Clause 11 of IEC 60044-1:1996 is~~ Markings which are listed in IEC 61869-1 and IEC 61869-2 are applicable with the following additions:

Table E.8 – Current transformer

		User requirements	Supplier proposals
Position of current transformer		According single-line	
Number ~~and type~~ of cores		According single-line	
Burdens and accuracy classes	VA / -	According single-line	

E.12 Inductive voltage transformer

~~Clause 11 of IEC 60044-2:1997 is~~ Markings which are listed in IEC 61869-1 and IEC 61869-3 are applicable with the following additions:

Table E.9 – Inductive voltage transformer

		User requirements	Supplier proposals
Position of voltage transformer		According single-line	
Number ~~and type~~ of secondary windings		According single-line	
Burdens and accuracy classes	VA / -	According single-line	
On-site test voltage	kV/Hz	Supplier information	

E.13 Metal-oxide surge arrester

Annex D of IEC 60099-4:2014 is applicable for GIS arresters.

E.14 Documentation for enquiries and tenders

Table E.10 – Documentation for enquiries and tenders

		User requirements	Supplier proposals
Single-line diagram			
Requirements for service continuity during maintenance, repair, extension and on-site testing			
General arrangement drawings of substation layout			
Foundation loading		Supplier information	
Gas schematic diagrams		Supplier information	
List of type test reports		Supplier information	
List of recommended spare parts		Supplier information	
GIS interface drawings (in case of later extension)			

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Annex F (informative)

Service continuity 48

F.1 General

This annex gives information concerning GIS service continuity or availability in relation to substation design. The system requirements for service continuity are fulfilled not only by choice of single line diagram but also by sequence of feeders and physical arrangement of components. The loss of substation (complete or partially) due to maintenance, repair after failure or extension should be the prime concern. The availability of a substation needs to take into account the reliability and performance of assets and the frequency and duration of outages.

In the case of GIS, the way in which the equipment is divided into gas compartments is an additional factor that affects the service continuity.

This annex proposes service continuity requirements, considering the particularity of a GIS substation design and how the availability of this substation is strategic for the network. This is illustrated by a case study with a double busbar system used as example. A summary of the study is provided in Table F.1.

Some arrangements allow the availability of the substation to be increased by reducing the time between fault occurrence and repair or by reducing the parts of the substation out of service during repair.

The selected design should achieve an appropriate balance between equipment cost and the criticality of the substation in the user's network.

Maintenance policy considerations are not discussed in the annex, even though availability of spare parts and skilled staff also have an effect on the substation availability.

F.2 Service continuity requirement

The single line diagram reflects the necessary functions and rating needed for the system planning network. Since the single line diagram has a major influence on GIS design, the aspects of maintenance, repair or extension and their impact on service continuity can be considered during the process of single line diagram optimization.

Depending on the specific purpose of the new substation (generation, transmission or power delivery) and its strategic location in the network, the impact of outage can be different. For this reason, in addition to basic information that user and manufacturer should exchange during tenders (see Clause 9), the user may provide service continuity requirements during maintenance, repair or extension. Type of availability might be specific and different for each part of a substation. As an example, a non-restricted list of availability requirement is given below:

- A) No outage permitted: This is normally only applicable for minor maintenance like visual inspections.
- B) Loss of operational flexibility permitted: This means loss of busbar, loss of busbar separation or bus coupler without loss of a feeder.
- C) Loss of feeders permitted: This means loss of one or more feeders.
- D) Loss of complete substation: This means that network is such that load supply or power transit can be achieved temporarily without this substation.

Acceptable duration for the loss of flexibility, feeder or substation should be specified.

An example of service continuity requirement is given with the case study.

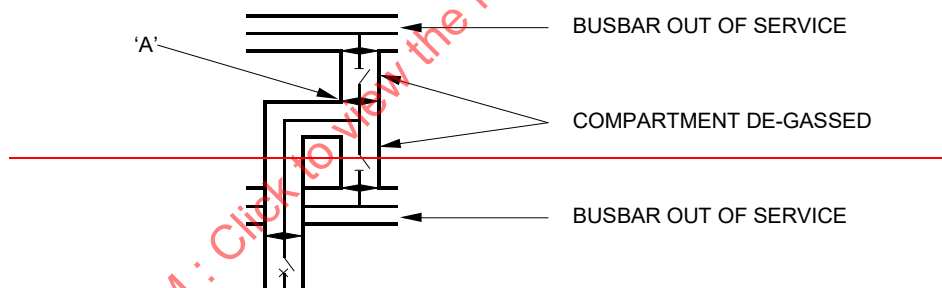
NOTE A feeder is a connection between the GIS and the network, such as overhead lines, cables, transformers, reactors, capacitor banks, etc.

F.3 — Impact of partitioning on service continuity

For GIS and a given switching arrangement, the way in which the equipment is divided into gas compartments affect the service continuity. It is clear that, in order to de-gas a compartment, that compartment with all its components shall be isolated from the system. Occasionally, work such as a fault repair might require the removal of a gas compartment partition and more than one compartment must be de-gassed. Furthermore, in some cases, it may be prohibited to work adjacent to a gas compartment partition while it is pressurised on the other side. In such cases, the gas pressure in the adjacent compartments must be reduced or other safety measures must be taken. Wherever a gas compartment containing a disconnector is reduced in pressure, isolation must be provided by disconnectors or other devices having isolating distance withstand level elsewhere in the substation.

Examples of how partitioning of GIS may affect service continuity are given below.

In some arrangements the two busbar disconnectors are separated by only one partition. In Figure F.1, the removal of the gas compartment partition at 'A' may require both busbars of a double busbar substation to be de-energized, with the loss of all feeders on that section of busbar for the duration of the repair.



IEC 1885/11

Figure F.1 — Impact due to the removal of common partition between busbar-disconnector

In Figure F.2 the removal of the disconnector, including its partitions, at 'B' requires the compartments of the adjacent disconnectors to be de-gassed. This causes the loss of the associated feeders for the duration of the repair.

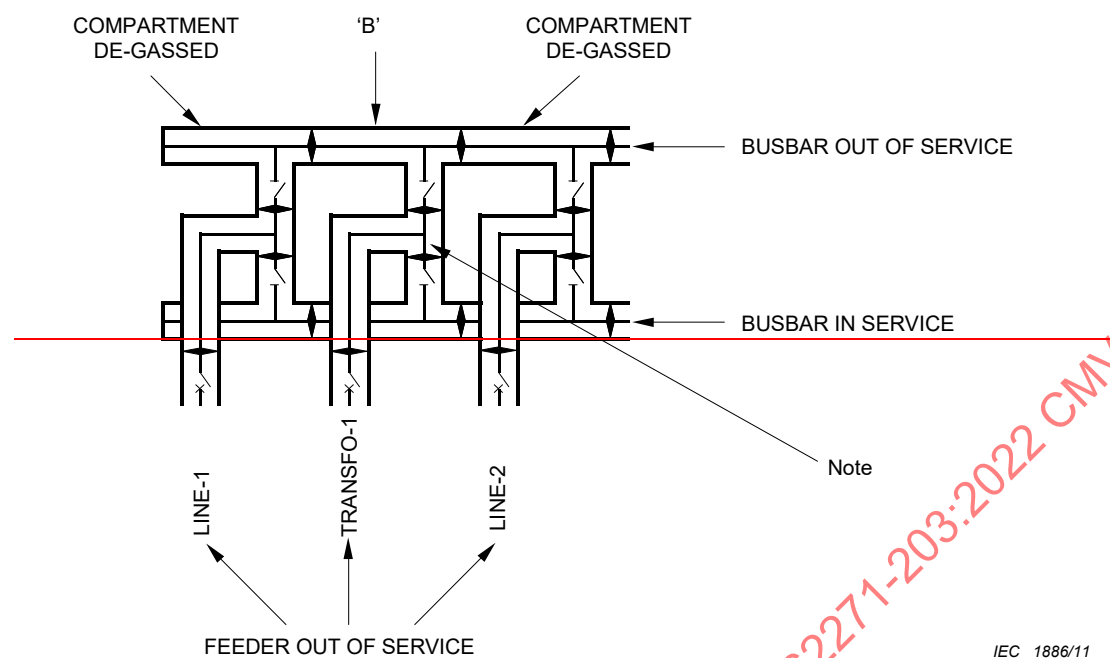


Figure F.2 – Impact of GIS partitioning on service continuity

NOTE If working adjacent to a pressurised partition is not allowed an outage of the second busbar could be needed also.

F.4 Case study

F.4.1 General

As an example to illustrate different aspects of the service continuity a double busbar arrangement with the below chosen partitioning scheme is shown in Figure F.3. These aspects are generally applicable for all single line schemes and all partitioning schemes. Different partitioning schemes can be used to fulfil the service continuity requirements and the example shown in this case study is therefore nothing more than an example and shall not in any way be regarded as a standardization.

In the example the substation has a total number of six feeders, four line and two transformer feeders. The busbars are divided by a busbar separation and linked with a coupler. A future extension is planned at the right side of the substation.

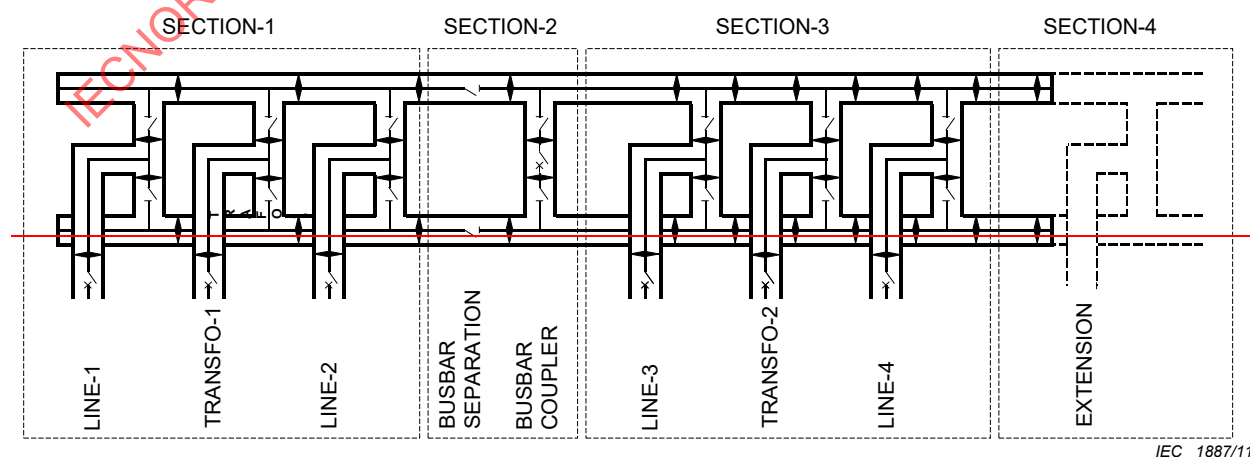


Figure F.3 – Single-line diagram with gas partitioning scheme

~~In the case study it is assumed, that working adjacent to a pressurized partition is allowed. In the case study a failure in a busbar disconnecter is considered.~~

~~The service continuity does not apply in the situation where a fault occurs while maintenance is in progress on other equipment. Only single events are considered. The GIS is divided in four sections. Section 1 and section 3 have different service continuity requirements which results in a different partitioning.~~

~~The main situations affecting GIS service continuity are:~~

- ~~— maintenance,~~
- ~~— repair after failure,~~
- ~~— extensions,~~
- ~~— on-site dielectric test.~~

~~In the following paragraphs these situations are discussed.~~

~~F.4.2 — Maintenance~~

~~Maintenance includes inspections and planned activities to deal with normal wear and aging of the equipment. Such activities can be:~~

- ~~— visual inspections,~~
- ~~— test of drives and monitoring systems,~~
- ~~— exchange of contact systems of circuit breakers, disconnectors and earthing switches,~~
- ~~— on-site dielectric test (if applicable) see F.3,~~
- ~~— etc.~~

~~Such maintenance activities may impact the service continuity of the substation. In our case study (Figure F.3) maintenance on “LINE 1” may only affect the availability of “LINE 1”, keeping all other feeders in service.~~

~~F.4.3 — Repair after failure~~

~~F.4.3.1 — General~~

~~The following activities are normally involved after a major failure:~~

- ~~— localisation and isolation of the faulty compartments, in order to restore service, even partial (In case of a minor failure, for example leakage, isolation of the faulty compartment is not needed),~~
- ~~— repair,~~
- ~~— on-site dielectric test (if applicable) see F.3.~~

~~F.4.3.2 — Localisation and isolation of the faulty compartments~~

- ~~— Localisation of a fault after the operation of the protective system (see 5.102.3) by an appropriate device,~~
- ~~— isolation of the faulty compartment by operating switching devices or opening removable links (see 3.104),~~
- ~~— Partially or fully restore service.~~

~~In the case study a defect in compartment “C” of SECTION 1 will only affect the feeder TRAFO-1 and one busbar. See Figure F.4.~~

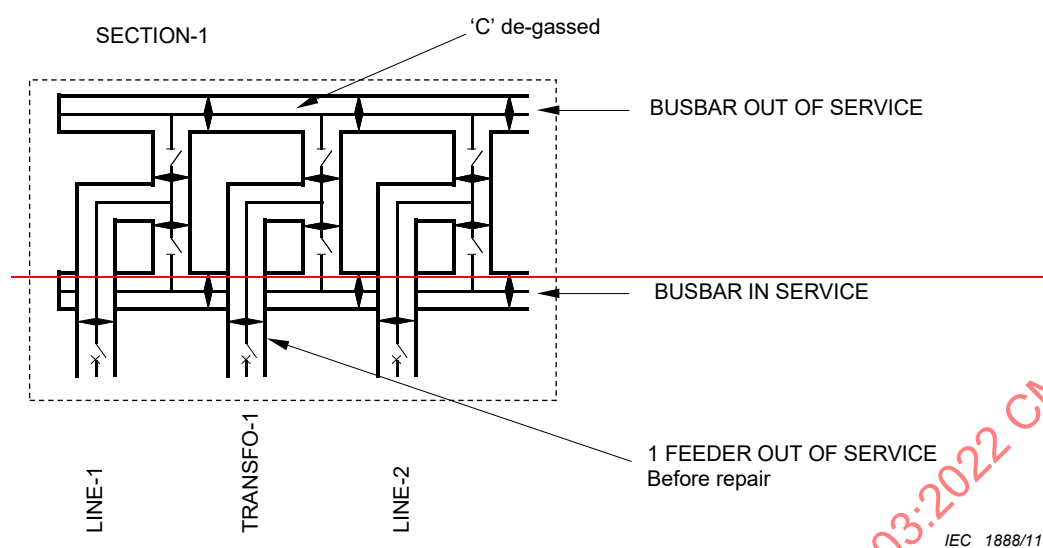


Figure F.4 – Localisation and isolation

F.4.3.3 Repair

In the case study, the removal of the disconnector at 'C' in SECTION-1 requires an outage of the adjacent feeders. See Figure F.5.

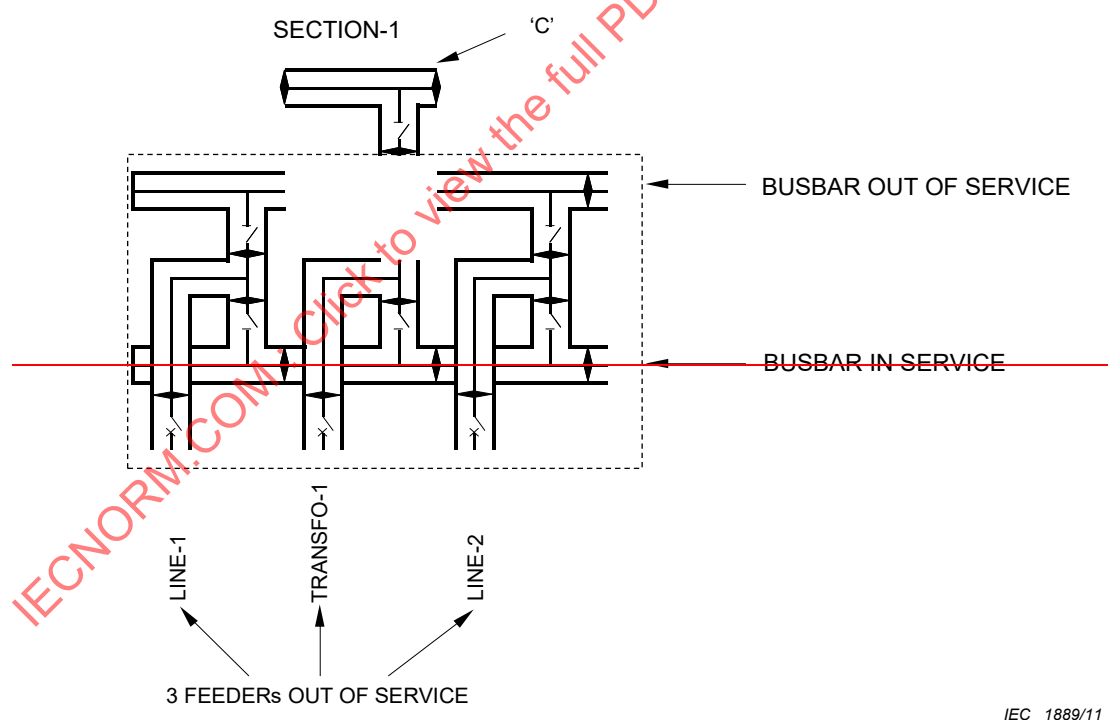


Figure F.5 – Removal of busbar disconnector in SECTION-1

In the case study, the removal of the disconnecter at 'D' in SECTION-3 requires only the outage of the faulty feeder and not of the adjacent feeders. See Figure F.6.

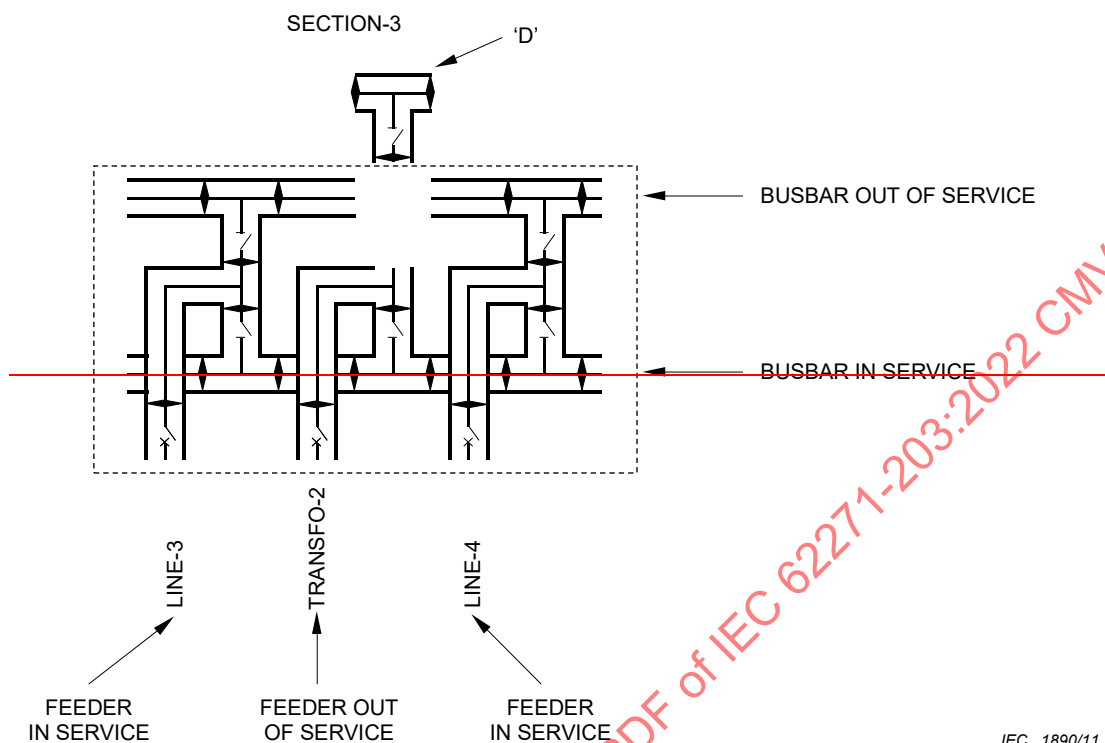


Figure F.6 — Removal of busbar disconnecter in SECTION-3

F.4.4 — Extension

The user should specify the location of possible future extension so that the manufacturer take it into account for partitioning.

On-site dielectric test of the extension could be performed separately before connecting to the existing GIS or if connected to the existing GIS by an additional isolation.

In the case study an additional busbar compartment "F" is installed in SECTION 4. This allows future extension without taking the adjacent feeder out of service. See Figure F.7.

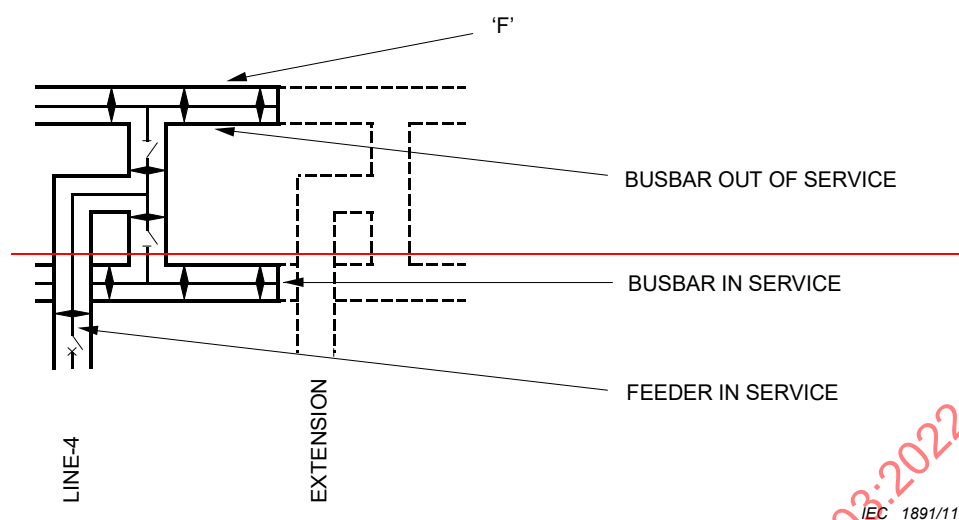


Figure F.7 – Extension

F.4.5 On-site dielectric test

On-site dielectric tests may be needed after maintenance, repair after failure or extension. Test procedure should be according to 10.2.101.2.3.

For instance in the case study testing of the new installed compartment “D” is performed by HV test equipment at position “E”. As consequence only three feeders of section 1 and one section of one busbar will stay in service. See Figure F.8.

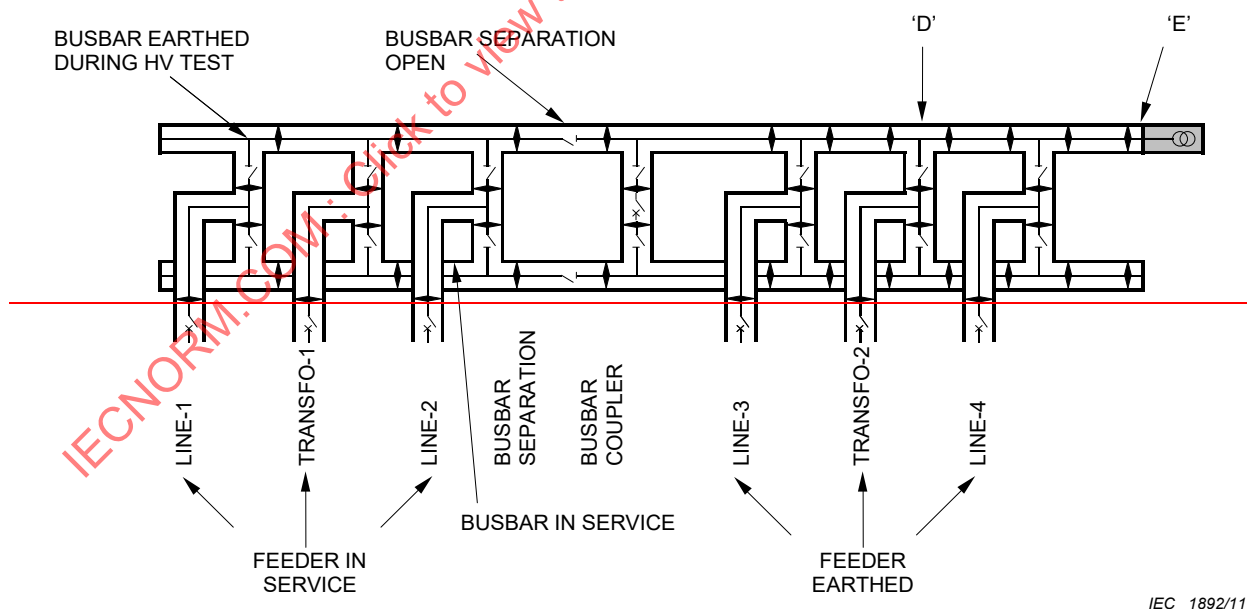


Figure F.8 – On-site dielectric test

F.5 — User requirements on service continuity

It is the responsibility of users to define a strategy of maintenance relatively to the impact on service continuity and, it is the responsibility of manufacturers to design and define partitioning in order to fulfil users need.

The service continuity requirements should achieve an appropriate balance between equipment cost and the criticality of the substation in the user's network.

The user may define some general statements that allow a quantitative assessment of the service continuity during maintenance, repair or extension. The following general statements are given as examples:

- at least one line and transformer feeder must remain in service during maintenance and repair;
- maximum one busbar and one feeder permitted out of service during maintenance and repair;
- the power flow must be maintained between specified feeders during extension.

The user may also define more detailed service continuity requirements. An example is given in Table F.1 based on the GIS of the case study. This can be used as a template.

Table F.1 — Example for service continuity requirements

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[illegible]

- ~~a) Specific service continuity requirements should be given by the user as proposed in F.2 or by statements as in F.5.~~
- ~~b) Accepted duration should be given by the user. Duration after failure until repair depends on spare parts, tools, test equipment and skilled staff available on-site. If not available duration can be months.~~

F.6 Factors improving service continuity

~~In order to achieve required service continuity the following factors may be considered among others:~~

- ~~— single line diagram (number of busbars, sequence of feeders, number and position of disconnectors...);~~
- ~~— gas compartment: partitioning, configuration and design, number of gas compartments, additional gas buffer compartments;~~
- ~~— additional isolating links...;~~
- ~~— position of earthing switches and temporary earthing facilities;~~
- ~~— physical arrangement of components;~~
- ~~— facilities for dismantling;~~
- ~~— design of partitions: whether the design allows or disallows working in a compartment with the adjacent under full pressure. In addition working conditions and procedures are to be considered in order to avoid injuries to persons or damage to partitions;~~
- ~~— provision for on-site dielectric test (GIS and interfaces);~~
- ~~— necessity to carry out on-site dielectric tests after maintenance or repair;~~
- ~~— provision for future extensions: buffer gas compartments, appropriate disconnect facilities for extensions without de-energization of complete GIS;~~
- ~~— availability of spare parts, tools and skilled staff.~~

F.1 General

This annex defines service continuity of a GIS in relation to switchgear design. The system requirements for service continuity are fulfilled by choice of single-line diagram, sequence of feeders, physical arrangement of components and gas compartments. The continuity of service due to maintenance, repair after failure, extension or on-site dielectric test should be the prime concern.

The service continuity levels are defined through the MRE code (Maintenance, Repair, Extension) specific to feeder and busbar sections of the GIS on out of service condition during maintenance, repair, extension or on-site dielectric test (see examples provided in F.4.3).

A guideline on how to handle service continuity requirements can be found in CIGRE Technical Brochure 870, *Service Continuity Guide for HV GIS above 52 kV* [27].

F.2 Terms and conditions

F.2.1 Terms

F.2.1.1 Feeder

A feeder is a connection from a substation to another substation, a transformer, a generator, a reactor, capacitor bank, etc. The feeder can be an overhead line, a cable or a gas-insulated transmission line. The feeder is connected to the GIS by interfaces like bushings, cable- or transformer-connections.

F.2.1.2 Feeder-bay

A feeder-bay connects a feeder to a busbar section or another feeder (e.g. ring configurations). A feeder-bay consists of a set of interconnected circuit elements. Circuit elements can be: circuit-breaker, disconnecter, earthing switches, current transformer, voltage transformer, surge arrester and connecting elements.

NOTE Although the term feeder-bay is described here, it is not required to define the service continuity level.

F.2.1.3 Busbar section

A busbar section is the common connection of several feeder-bays. A busbar can be sectionalized in several busbar sections. A busbar without sectionalizing is one busbar section.

F.2.2 Conditions

Only single events are considered. The service continuity does not apply in the situation where a fault occurs on other equipment still in service while the main situations affecting GIS service continuity are in progress.

The main situations affecting GIS service continuity are:

- maintenance;
- repair after failure;
- extensions;
- on-site dielectric test.

The service continuity levels (see Clause F.4) should be defined for each of these situations.

F.3 Responsibilities

F.3.1 Service continuity requirements

It is the user's responsibility to

- define the service continuity requirements;
- e.g.: MRE11 during maintenance and repair on any feeder or busbar section;
- specify the location of future extension, if applicable.

It is the manufacturer's responsibility to

- design the GIS, define partitioning and specify other measures in order to fulfil the user's requirements;
- take into account the location of future extension, if applicable;

- demonstrate compliance with the users service continuity requirements in a common format, e.g. series of GIS gas single-line diagrams (e.g. in colour) indicating the pressure in each gas compartment, during maintenance, repair, extension or on-site dielectric test.

F.3.2 Work on partitions

The manufacturer should design the GIS with due consideration to safe working practices in the vicinity of pressurised gas compartments. The manufacturer should provide the user with a GIS product related design risk assessment and recommended procedures for work on or adjacent to a pressurised gas compartment partition. The manufacturer should define rules for such work under the following headings:

- forbidden;
- recommended;
- authorised.

The manufacturer should outline the controls required to allow recommended and authorised work to proceed.

The user should consider the manufacturers design risk assessment and work procedures in conjunction with user's safety policy when assessing compliance with service continuity requirements.

NOTE The manufacturers design risk assessment can proactively assess and eliminate or reduce the personnel safety risks over the full life-cycle of the GIS from assembly to operation, maintenance, repair and de-commissioning.

F.4 Service continuity levels

F.4.1 General

The continuity of service of a GIS during maintenance (M), repair (R), extension (E) or on-site dielectric testing is indicated by the MRE code.

F.4.2 Definition of the MRE code

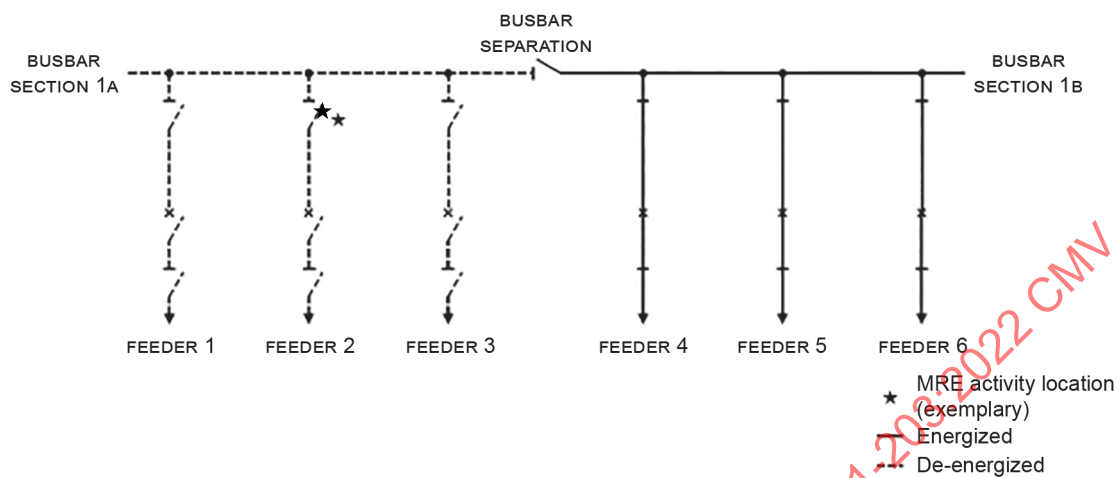
	MRE	0	1
Code letters _____ (Maintenance, Repair, Extension)			
First characteristic numeral _____ (numerals 0 to 4, or letter X)			
Second characteristic numeral _____ (numerals 0 to 5, or letter X)			

Element	Numerals or letters	GIS availability
Code letters	MRE	Maintenance, Repair, Extension
First characteristic numeral	0 1 2 3 4 X	Number of busbar section(s) out of service during maintenance, repair, extension or on-site dielectric test 0 busbar sections out of service 1 busbar section out of service 2 busbar sections out of service 3 busbar sections out of service 4 busbar sections out of service All busbar sections out of service
Second characteristic numeral	0 1 2 3 4 5 X	Number of feeder(s) out of service during maintenance, repair, extension or on-site dielectric test 0 feeders out of service 1 feeder out of service 2 feeders out of service 3 feeders out of service 4 feeders out of service 5 feeders out of service All feeders of the related busbar section(s) out of service

F.4.3 Examples for service continuity levels

The following Figure F.1 to Figure F.9 illustrate the definition of some service continuity levels. For visualisation purposes simplified figures are used. Only relevant switchgear components are shown.

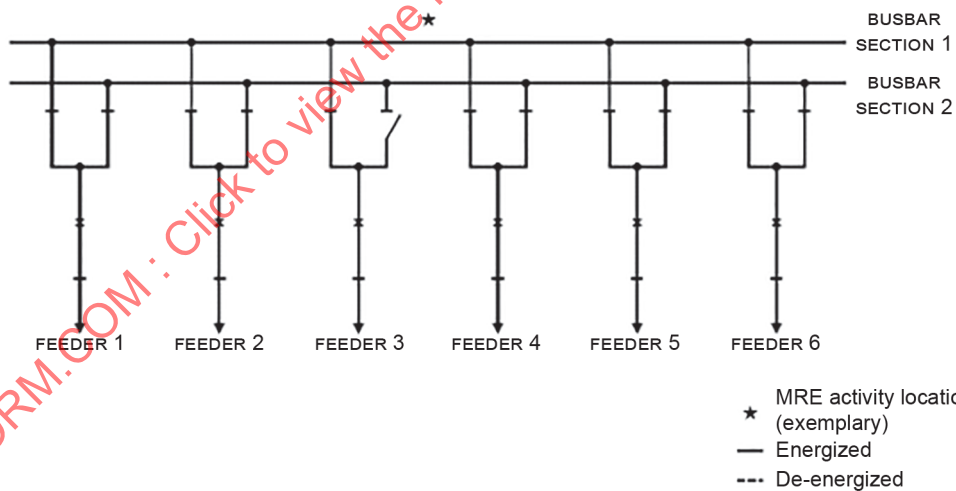
Single busbar configurations



IEC

Figure F.1 – MRE1X (e.g. repair of disconnector to busbar)

Double busbar configurations



IEC

Figure F.2 – MRE00 (e.g. during visual inspection)

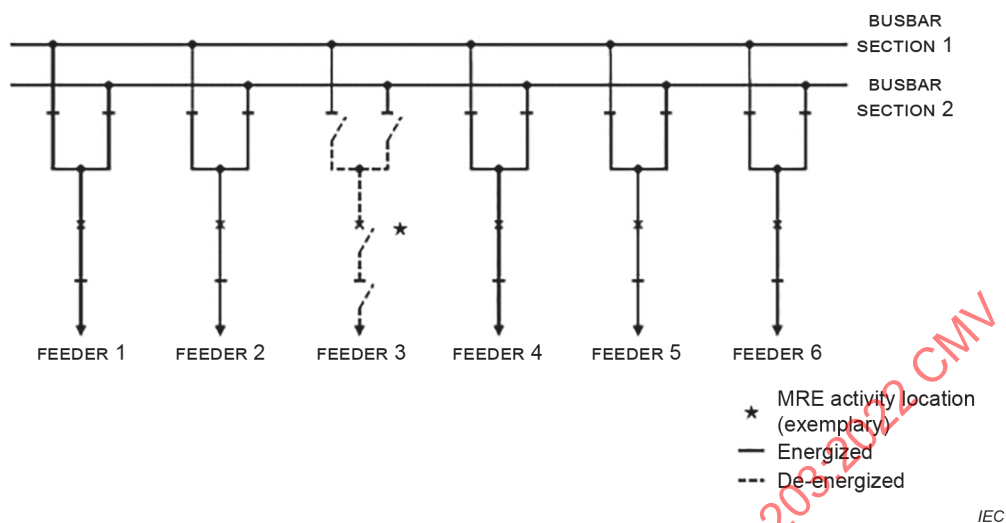


Figure F.3 – MRE01 (e.g. repair of circuit-breaker)

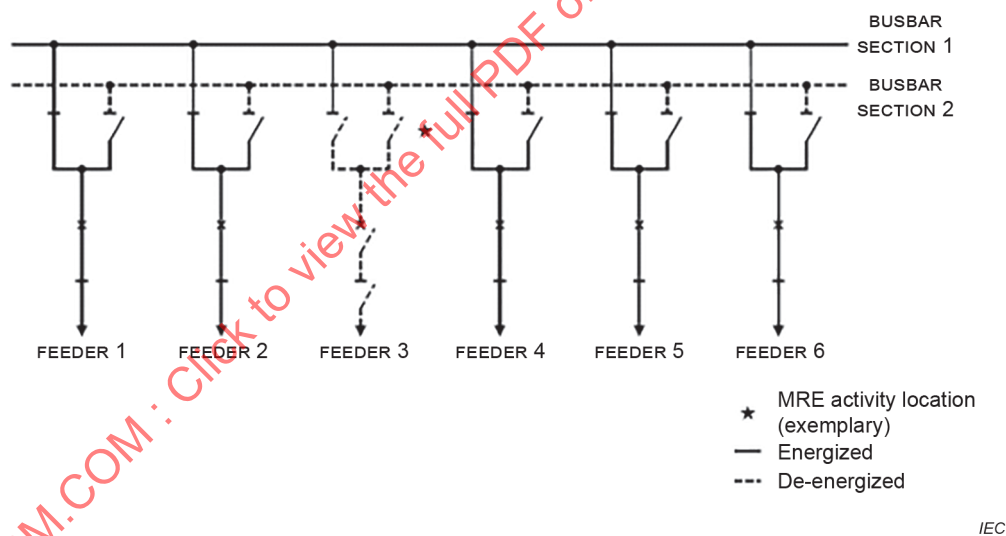


Figure F.4 – MRE11 (e.g. repair of disconnector)

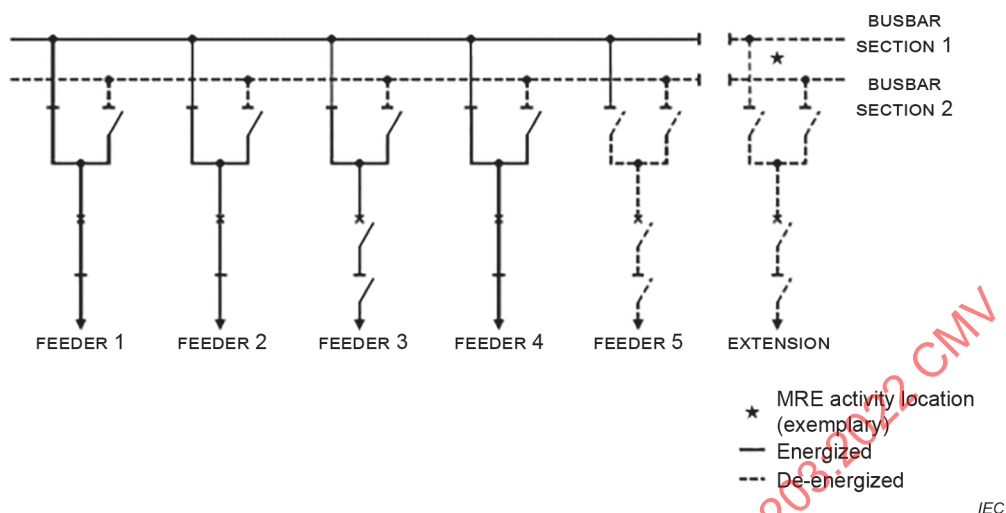


Figure F.5 – MRE11 (e.g. extension of switchgear with a feeder bay)

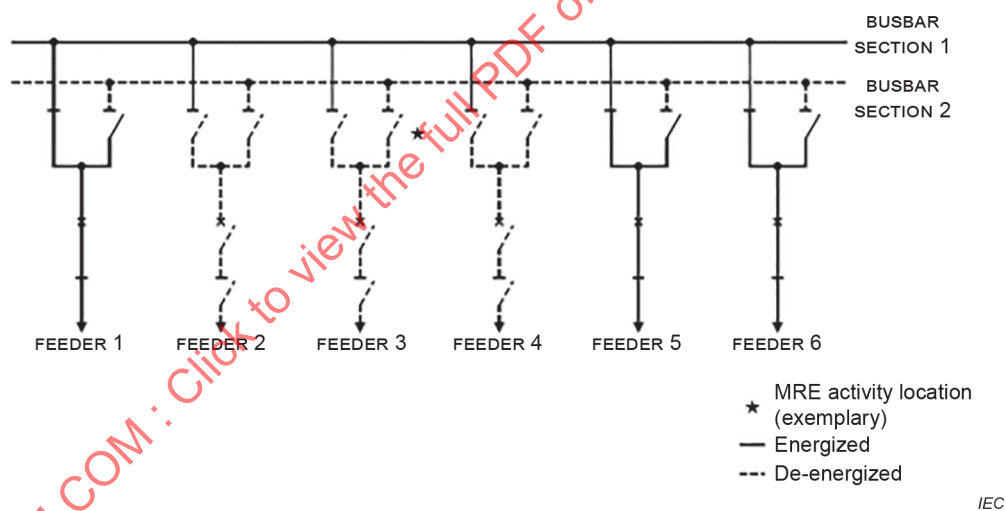
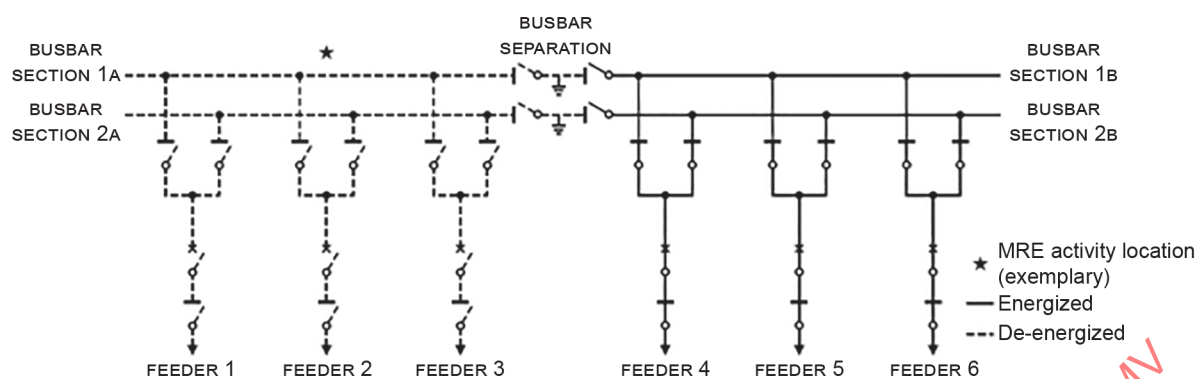
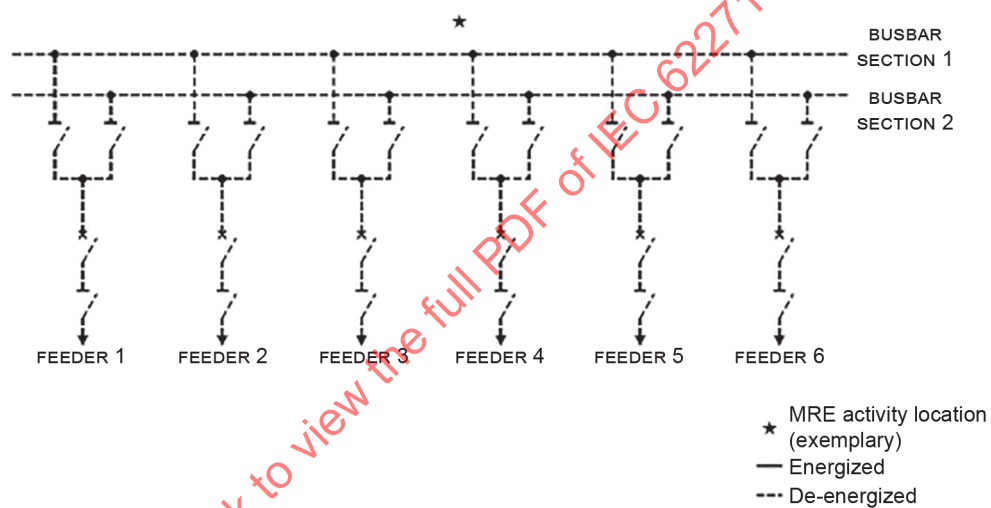


Figure F.6 – MRE13 (e.g. repair of disconnector)



IEC

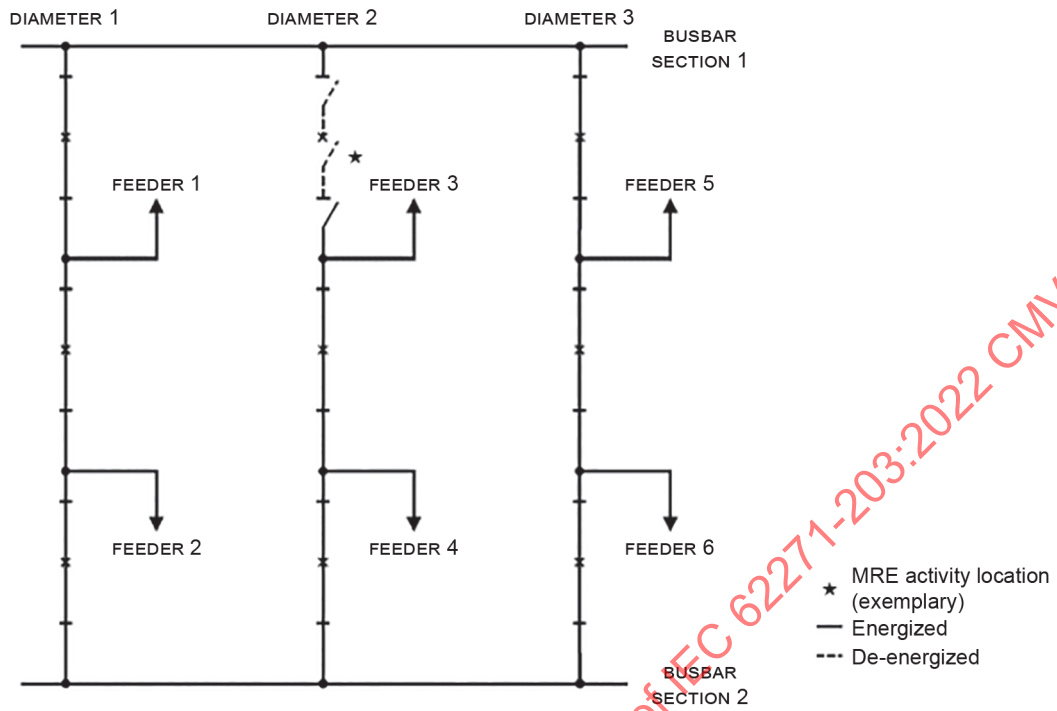
Figure F.7 – MRE2X (e.g. on-site dielectric test of busbar section A)



IEC

Figure F.8 – MRE2X (e.g. on-site dielectric test of busbar section 1)

One and half breaker configurations



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Figure F.9 – MRE00 (e.g. repair of circuit-breaker)

Annex G (informative)

Insulation levels for GIS with rated voltages higher than 800 kV 49

G.1 General

The present UHV market for GIS with rated voltages higher than 800 kV is very small, with past installation in Italy, some installations in Japan and China, and planned installations in India. As these countries have already defined ratings, more experience is needed before standard ratings can be defined in this standard.

The rated insulation levels for these GIS are introduced in this annex.

G.2 Insulation level

The insulation levels used by different countries are summarized in Table G.1.

Table G.1 — Insulation levels used for GIS with rated voltages higher than 800 kV in different countries

Applied country	Rated voltage for equipment U_r kV (r.m.s. value)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s. value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
		Phase-to-earth and between phases	Across open switching device and/or isolating distance	Phase-to-earth	Between phases (Note 1)	Across open switching device and/or isolating distance	Phase-to-earth and between phases	Across open switching device and/or isolating distance
Italy	1 050	910	910	1 675	Not applicable	1 675 (+857)	2 250	2 250 (+857)
Japan	1 100	1 100	1 100/1 265 (Note 2)	1 550	Not applicable	1 550	2 250	2 250 (+900)
China	1 100	1 100	1 100 (+635)	1 800	Not applicable	1 675 (+900)	2 400	2 400 (+900)
India	1 200	-	-	1 800	Not applicable	1 800 (+980)	2 400	2 400 (+980)
NOTE 1—Present designs are single phase encapsulated.								
NOTE 2—1 100 kV across open switching device and 1 265 kV across open isolating device.								
NOTE 3—General standard values are specified in IEC 60038.								

The insulation levels in the above table are chosen on the condition to apply metal oxide surge arrester (MOSA) and pre-insertion resistor (PIR). The details are in the document listed on bibliography.

Annex G
(informative)

List of notes concerning certain countries

Subclause	Text
5.11 and 6.104.2	National exceptions are required for Italy where rules for the design pressure is required by law.
7.2.12	National exceptions are required for Canada, France and Italy where it is required by law that the test voltage during condition check across the isolating distance of a disconnector be 100 % of the rated power-frequency test voltage.

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Bibliography 50

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- [19] EN 50089, *Specification for cast resin partitions for metal-enclosed gas-filled high-voltage switchgear and controlgear*

~~EN 61264:1998, Ceramic Pressurized Hollow Insulators For High Voltage Switchgear And Controlgear~~

~~IEEE 1416:1998, IEEE Recommended Practice for the interface of New Gas-insulated Equipment in Existing Gas-Insulated Substations~~

- [20] IEEE C37.122.6, *IEEE Recommended Practice for the Interface of New Gas-Insulated Equipment in Existing Gas-Insulated Substations Rated above 52 kV*
- [21] IEEE C37.24, *IEEE Guide For Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear*
- [22] IEEE C37.122.1, *IEEE Guide For Gas-Insulated Substations Rated above 52 kV*
- [23] CIGRE Technical Brochure 125, *User guide for the application of gas-insulated switchgear (GIS) for rated voltages of 72,5 kV and above*

~~CIGRE Technical Brochure 400: Technical requirements for substation exceeding 800 kV.~~

- [24] CIGRE Technical Brochure 602, *Tools for simulation of the internal effects in HV and MV switchgear*
- [25] CIGRE Technical Brochure 654, *UHF partial discharge detection system for GIS – Application guide for sensitivity verification*
- [26] CIGRE Technical Brochure 802, *Application of non-SF₆ gases or gas-mixtures in medium and high voltage gas insulated switchgear*
- [27] CIGRE Technical Brochure 870, *Service Continuity Guide for HV GIS above 52 kV*
- [28] CIGRE Session 1998 – WG 21/23/33-03, *Assessment of the behaviour of gas-insulated electrical components in the presence of an internal arc*, by G. Babusci. E. Colombo. R. Speziali. G. Aldrovandi. R. Bergmann. M. Lissandrin. G. Cordioli. C. Piazza.

~~CIGRE Working Group A3.22, Technical requirements for substations exceeding 800 kV, No. 400, December 2009.~~

~~Electra 183 (1999), PD detection system for GIS sensitivity for the UHF method and the acoustic method, by CIGRE TF15/33-03-05~~

- [29] RGE: 04/82, *Electrical faults mastery in high voltage SF₆ insulated substations*, by Gilles Bernard, EDF, France. Published in *Revue Générale de L'Electricité* RGE 4/82, April 1982. (only available in French)

- [30] CIGRE Technical Brochure of working group B3.57, *Impact on Engineering and Lifetime Management of outdoor HV GIS*²
- [31] IPCC Fifth Assessment Report – AR5 Climate Change 2013, *The Physical Science Basis*

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² To be published. Expected publication date 2022.

List of comments

- 1 This document has been aligned with IEC 62271-1:2017.
The structural changes in IEC 62271-1:2017 have required major changes in the structure of IEC 62271-203.
Many of the RLV markings are therefore only editorial changes.
- 2 The here listed topics are the major technical changes in this revision of IEC 62271-203.
- 3 To be in line with IEC 62271-1 and other IEC 62271-series standards the word “AC” (alternating current) has been added to the title of the standard.
- 4 Beside SF₆ also alternative gases and gas mixtures are now mentioned wherever needed.
Most of these changes are editorial changes, as the old version of the standard did not explicit distinguish between gases and gas mixture. Often SF₆ was mentioned, but the requirements were meant to be applicable for all gases and gas mixtures.
- 5 The references have been updated and not used references have been removed.
- 6 The terms and definitions have been updated and not used terms and definitions have been removed.
- 7 A definition of “isolating link” has been added.
Isolating links are often used in GIS during maintenance and repair work in order to minimize the section of the GIS, which needs to be switched off during this work.
Isolating links are needed where the other side of the open link can be in service during maintenance and repair work inside the GIS. The open isolating link shall therefore be capable of withstanding the test voltages of an isolating distance according to Table 2 and Table 3.
- 8 The definition of “removable link” has been modified to be in accordance with the above new definition of “isolating link”.
The purpose of a removable link is to ensure electrical separation between sections of a GIS, where the other side of the open link is earthed.
This is for instance often the case during high voltage testing of GIS, where voltage transformers, surge arresters, cable connections and transformer connections often must be separated from the GIS during the test.
The open link shall therefore be capable of withstanding the phase-to-earth test voltages according to Table 2 and Table 3.
- 9 This section has been moved to subclause 6.103.2 “External effects of the arc” in order to improve the readability of the standard.
- 10 The term “functional unit” is used in subclause 7.1.1 to define the test objects for type tests.
In the past this term has often caused discussions between manufacturer and users, whether the type tests have been performed on the correct test objects. A major reason for this confusion was the term in IEC 60050-441:1984, 441-13-04, which is not directly applicable for GIS.
The term has therefore been adapted to GIS and examples relevant for GIS have been added, in order to clarify most of the discussed issues.
- 11 This section has been moved to new subclause 4.101 “General” below Table 1 due to alignment with IEC 62271-1.
- 12 This section has been moved to here from clause 4 “Normal and special service conditions” due to alignment with IEC 62271-1.

- 13 The old Note 1 was only applicable for SF₆ because the CIGRE studies mentioned were performed for SF₆ and may not be applicable for alternative gases.

However even if the natural ratio between the withstand voltages may be different for different gases, it would not be practical to define different withstand test voltages for different gases.

The higher values for GIS in IEC 62271-203 were introduced in edition 1.0 in 2003 and are now established as standard values for GIS, independent on the type of gas used.

- 14 The rated test voltages for 1 100 kV and 1 200 kV equipment have been moved to here from Annex G “Insulation levels for GIS with rated voltages higher than 800 kV”.

- 15 This section has been moved to clause 6.101 “General requirements for GIS” due to alignment with IEC 62271-1.

- 16 This section has been moved to subclause 6.109 “Interlocking”.

- 17 Subclause 6.16 “Gas and vacuum tightness” has been updated to be applicable for alternative gases and gas mixtures also.

- 18 For “Closed pressure systems for gas” two classes of gases and corresponding requirement for maximum leakage rates have been introduced.

As criteria for the classification the GWP according to IPCC – AR5 has been selected:

- SF₆, SF₆ mixtures and other gas mixtures with a GWP > 1 000 shall be type tested for maximum leakage rate ≤ 0,1 % per year,
- other gas mixtures with a GWP ≤ 1 000 shall be type tested for maximum leakage rate ≤ 0,5 % per year.

- 19 This section has been moved to here from clause 6 “Design and construction” due to alignment with IEC 62271-1.

- 20 The wording has been improved for better understanding.

- 21 This term has been moved to here from subclause 3.119 “Terms and definitions – Fragmentation” in order to improve the readability of the standard.

- 22 The wording has been improved for better understanding.

- 23 The design criteria for isolating and removable link have been added, in accordance with the definitions in subclauses 3.104 and 3.105.

- 24 Development of alternative gases for GIS often result in increased gas pressures, compared to GIS designs based on SF₆.

As a result the interfaces connected to GIS must be designed for the same increased pressures.

In order to give guidelines for cable and transformer interface manufacturer, the here mentioned maximum pressures values in service have been defined and implemented in the relevant standards IEC 62271- 203, IEC 62271-209 and IEC 62271-211.

- 25 The wording has been improved for better understanding.

- 26 This section has been moved to here from subclause 6.12 “Locking devices”.

- 27 Editorial changes are needed for alternative gases.

- 28 Editorial changes in Table 5 are needed due to the alignment with IEC 62271-1.

- 29 Multiple editorial changes in subclause 7.2 are needed due to the alignment with IEC 62271-1.

- 30 Multiple editorial changes in subclause 7.4 are needed due to the alignment with IEC 62271-1.
- 31 Multiple editorial changes in subclause 7.5 are needed due to the alignment with IEC 62271-1.
- 32 Multiple editorial changes in subclause 7.6 are needed due to the alignment with IEC 62271-1.
- 33 Multiple editorial changes in subclause 7.7 are needed due to the alignment with IEC 62271-1.
- 34 Multiple editorial changes in subclause 7.8 are needed due to the alignment with IEC 62271-1.
- 35 The wording of subclause 7.103 has been aligned with the latest versions of the EN standards (references [15], [16], [17] and [18] in the Bibliography).
- 36 Insulators in GIS are type tested as an electrical insulation system (EIS) with insulating material, conductors, enclosures and sealing material. The type tests verify that the EIS is correctly designed to withstand the thermal stresses.
- The upper limit temperatures defined in IEC 62271-1, Table 14 are therefore applicable to the EIS and not for the electrical insulation material (EIM).
- 37 Subclause 7.107 “Corrosion test on earthing connections” was introduced in edition 2.0 of IEC 62271-203.
- This subclause has now been updated based on the experience of the last years.
- 38 Subclause 7.108 “Corrosion tests on sealing systems of enclosures and auxiliary equipment” is a new subclause, which is based on subclause 7.107.
- Practically the corrosion tests on the sealing systems of enclosures can be combined with the corrosion tests on the earthing systems.
- 39 Editorial changes are needed for alternative gases.
- 40 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 62271-1: 2017, 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 rates below 0,5 % per year per gas compartment are not always easily possible to verify using the probing test method.
- 41 Multiple editorial changes in clause 9 are needed due to the alignment with IEC 62271-1.
- 42 On-site switching impulse withstand voltage testing was a commonly used test method in the last century, but is not used any more.
- The recommended on-site test methods are procedures A, B and C mentioned in subclause 11.101.2.2 “Test procedure”.
- 43 On-site switching impulse withstand voltage testing was a commonly used test method in the last century, but is not used any more.
- The recommended on-site test methods are procedures A, B and C mentioned in subclause 11.101.2.2 “Test procedure”.
- 44 Resistance measurements between earthing switches are valuable reference measurements, because these measurements can be repeated after the GIS has been installed, e.g. during maintenance or repair activities.
- 45 Editorial changes are needed for alternative gases.

- 46 The criteria to pass the test has been aligned with IEC 62271-200, subclause 7.105.5 “Criteria to pass the test”.
- 47 Sensitivity verification of acoustic and UHF measuring method are described in detail in the here mentioned new reference documents.
- 48 Annex F “Service continuity” has been completely rewritten according to latest practise. The experience from the last years with Annex F of IEC 62271-203, edition 2.0 has been consolidated in the CIGRE Technical Brochure 870 “Service Continuity Guide for HV GIS above 52 kV” (reference [27] in the Bibliography).
Annex F has been aligned with this CIGRE Technical Brochure and shall preferable be read in conjunction with this document.
- 49 The rated test voltages for 1 100 kV and 1 200 kV equipment have been moved to subclause 5.3 “Rated insulation level (U_d , U_p , U_s), Table 3.
Annex G is therefore not needed.
- 50 The references have been updated and not used references have been removed.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**High-voltage switchgear and controlgear –
Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above
52 kV**

**Appareillage à haute tension –
Partie 203: Appareillage sous enveloppe métallique à isolation gazeuse et à
courant alternatif de tensions assignées supérieures à 52 kV**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 203: AC gas-insulated metal-enclosed switchgear
for rated voltages above 52 kV**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62271-203 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the document has been aligned with IEC 62271-1:2017;
- b) beside SF₆ also alternative gases have been implemented where needed;
- c) the terms and definitions have been updated and terms not used have been removed;
- d) Subclause 6.16 “Gas and vacuum tightness” has been updated;

e) Subclause 6.16.3 “Closed pressure systems”: Two classes of gas has been introduced:

- 1) $GWP \leq 1\,000$
- 2) $GWP > 1\,000$

and the tightness requirements for type tests for gasses with $GWP > 1\,000$ has been reduced from 0,5 % to 0,1 % per year per gas compartment;

- f) Subclause 6.108 “Interfaces”: Typical maximum pressures in service for interfaces connected to GIS have been defined;
- g) Subclauses 7.2 through 7.8 have been restructured;
- h) Subclause 7.107 “Corrosion test on earthing connections” has been updated;
- i) Subclause 7.108 “Corrosion tests on sealing systems of enclosures and auxiliary equipment” has been updated;
- j) Annex F ‘Service Continuity’ has been modified and aligned with the recommendations of CIGRE WG B3.51.

The text of this International Standard is based on the following documents:

Draft	Report on voting
17C/835/FDIS	17C/844/RVD

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 International Standard 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 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,
- replaced by a revised edition, or
- amended.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above 52 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 alternating current of rated voltages above 52 kV, for indoor and outdoor installation, and for service frequencies up to and including 60 Hz.

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

The 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 standards applying to the individual components constituting GIS.

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

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

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

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

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

IEC 60141-1, *Tests on oil-filled and gas-pressure cables and their accessories – Part 1: Oil-filled, paper or polypropylene paper laminate insulated, metal-sheathed cables and accessories for alternating voltages up to and including 500 kV*

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

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

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

IEC 60840, *Power cables with extruded insulation and their accessories for rated voltages above 30 kV ($U_m = 36$ kV) up to 150 kV ($U_m = 170$ kV) – Test methods and requirements*

IEC 61869-1, *Instrument transformers – Part 1: General requirements*

IEC 61869-2, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

IEC 62067, *Power cables with extruded insulation and their accessories for rated voltages above 150 kV ($U_m = 170$ kV) up to 500 kV ($U_m = 550$ kV) – Test methods and requirements*

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 sulphur hexafluoride (SF_6) and its mixtures*

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

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

IEC 62271-209:2019, *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 62271-211:2014, *High-voltage switchgear and controlgear – Part 211: Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62271-1:2017 and the following, apply.

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

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

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

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

Note 2 to entry: Three-phase enclosed gas-insulated switchgear applies to switchgear with the three phases enclosed in a common enclosure.

Note 3 to entry: Single-phase enclosed gas-insulated switchgear applies to switchgear with each phase enclosed in a single independent enclosure.

[SOURCE: IEC 60050-441:1984, 441-12-05, modified – "or gas mixture" has been added in the definition, and Note 2 and 3 to entry have been added.]

3.103

gas-insulated switchgear enclosure

part of 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

Note 1 to entry: The enclosure can be single-phase or three-phase.

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 Table 2 and Table 3.

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.

3.105

removable link

part of the conductor which can easily be opened or removed in order to separate 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 Table 2 and Table 3.

Note 2 to entry: The purpose of a removable link is to ensure electrical separation between sections of a GIS, where the equipment is separated from the rest of the GIS, e.g. in front of voltage transformers, surge arresters, cable connections and transformer connections during high voltage testing of GIS or testing of the components.

3.106

compartment

part of 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. circuit-breaker compartment, busbar compartment.

3.107

component

essential part of the main or earthing circuits of gas-insulated metal-enclosed switchgear which serves a specific function (for example circuit-breaker, disconnecter, switch, fuse, instrument transformer, bushing, busbar, etc.)

3.108

support insulator

internal insulator supporting one or more conductors

3.109**partition**

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

3.110**bushing**

a 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 – “an enclosure” inserted after “pass through” and “a partition such as a wall or a tank” deleted. Notes 1 and 2 were deleted.]

3.111**main circuit**

all the conductive parts of 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 – “gas-insulated metal-enclosed switchgear” inserted after “parts of” and “an assembly” deleted]

3.112**auxiliary circuit**

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

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

3.113**enclosure design temperature**

maximum temperature that the enclosures can reach under specified maximum service conditions

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.

Note 2 to entry: The transient pressure occurring during and after a breaking operation (e.g. circuit-breaker) is not considered in the determination of the design pressure.

3.115**partition design pressure**

relative pressure across the partition used to determine the design of the partition

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

Note 2 to entry: The transient pressure occurring during and after a breaking operation (e.g. circuit-breaker) is not considered in the determination of the design pressure.

3.116**operating pressure**

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

3.117

routine test pressure

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

3.118

type test pressure

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

3.119

fragmentation

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

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

3.121

transport unit

part of gas-insulated metal-enclosed switchgear suitable for shipment without being dismantled

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 can be distinguished according to the function for which they are intended, for example complete single-phase or three-phase bay or functional parts of a bay like complete circuit-breaker, disconnector, earthing switch, voltage transformer, current transformer, operating mechanism, enclosure, etc.

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

4 Normal and special service conditions

4.1 Normal service conditions

Subclause 4.1 of IEC 62271-1:2017 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 62271-1:2017 is applicable, taking into account the recommended values presented in Table 1 of this document.

In the cases where higher than (>) is used in Table 1, the values shall be specified by the user as described in IEC 62271-1:2017.

4.101 General

Table 1 – Reference table of service conditions relevant to GIS

Item	Normal		Special	
	Indoor	Outdoor	Indoor	Outdoor
Ambient air temperature:				
Minimum (°C)	–5	–25	–25	–50
Maximum (°C)	+40	+40	+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
Site pollution severity ^a	Not applicable	c	c, d or e	d or e
Ice coating (mm)	Not applicable	20	Not applicable	>20
Wind (m/s)	Not applicable	34	Not applicable	>34
Average humidity over 24 h (%)	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 Site pollution severity c, d or e according to IEC TS 60815-1:2008, 8.3 [5] ¹				

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 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 62271-1:2017 is applicable with the following modifications:

- e) rated short-time withstand current (I_k) (for main and earthing circuits);
- f) rated peak withstand current (I_p) (for main and earthing circuits);

and with the following addition:

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

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 is applicable with the following addition:

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

¹ Numbers in square brackets refer to the Bibliography.

5.3 Rated insulation level (U_d , U_p , U_s)

Subclause 5.3 of IEC 62271-1:2017 is applicable with the following addition:

Tables 1, 2, 3 and 4 in Subclause 5.3 of IEC 62271-1:2017 are replaced with Table 2 and Table 3 below.

NOTE 1 The higher values for GIS in IEC 62271-203 compared to the values in IEC 62271-1 were introduced with revision 1 in 2003. They have now been established as standard values.

The 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 2 Regarding the external parts of bushings (if any), see to IEC 60137:2017.

NOTE 3 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 4 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.

**Table 2 – Rated insulation levels for rated voltages
for equipment of range I (245 kV and below)**

Rated voltage for equipment U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth, across open switching device and between phases	Across the isolating distance	Phase-to-earth, across open switching device and between phases	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
72,5	140	160	325	375
100	185	210	450	520
123	230	265	550	630
145	275	315	650	750
170	325	375	750	860
245	460	530	1 050	1 200
NOTE Values in column (2) are applicable: a) for type tests, phase-to-earth and between phases; b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device. Values in columns (3), (4) and (5) are applicable for type tests only.				

Table 3 – Rated insulation levels for rated voltages for equipment of range II (above 245 kV)

Rated voltage for equipment U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases (Notes 3 and 5)	Across open switching device and/or isolating distance (Note 3)	Phase-to-earth and across open switching device (Note 5)	Between phases (Notes 3 and 4)	Across isolating distance (Notes 1, 2 and 3)	Phase-to-earth and between phases (Note 5)	Across open switching device and/or isolating distance (Notes 2 and 3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	460	595	850	1 275	700 (+245)	1 050	1 050 (+170)
362	520	675	950	1 425	800 (+295)	1 175	1 175 (+205)
420	650	815	1 050	1 575	900 (+345)	1 425	1 425 (+240)
550	710	925	1 175	1 760	900 (+450)	1 550	1 550 (+315)
800	960	1 270	1 425	2 420	1 100 (+650)	2 100	2 100 (+455)
1 100	1 100	1 100	1 550	2 635	1 550 +(900)	2 250	2 250 + (630)
		1 100 +(635)	1 800	2 880	1 675 +(900)	2 400	2 400 + (630)
1 200	1 200	1 200	1 800	2 970	1 675 +(980)	2 400	2 400 + (685)
		1 200 +(695)	1 950	3 120		2 550	2 550 + (685)

NOTE 1 Column (6) is also applicable to some circuit-breakers, see IEC 62271-100:2021.

NOTE 2 In column (6), values in brackets are the peak values of the power-frequency voltage $U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

In column (8), values in brackets are the peak values of the power-frequency voltage $0,7 U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

NOTE 3 Values in column (2) are applicable:

- a) for type tests, phase-to-earth and between phases;
- b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

Values in columns (3), (4), (5), (6), (7) and (8) are applicable for type tests only.

NOTE 4 These values are derived using the multiplying factors stated in Table 3 of IEC 60071-1:2019 [4].

NOTE 5 For earthing switches only phase-to-earth tests according column (2), (4) and (7) are applicable.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 is applicable.

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 is applicable with the following addition:

Some main circuits of 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.

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 is applicable.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 is applicable.

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

Subclause 5.9 of IEC 62271-1:2017 is applicable.

5.10 Rated supply frequency of auxiliary and control circuits

Subclause 5.10 of IEC 62271-1:2017 is applicable.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is applicable.

6 Design and construction**6.1 Requirements for liquids in switchgear and controlgear**

Subclause 6.1 of IEC 62271-1:2017 is applicable.

6.2 Requirements for gases in switchgear and controlgear

Subclause 6.2 of IEC 62271-1:2017 is applicable.

6.3 Earthing of switchgear and controlgear

Subclause 6.3 of IEC 62271-1:2017 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 withstand capability.

The earthing circuit can be degraded after being subjected to the short-circuit current. After such event, earthing circuit can need to be replaced.

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 shall be ensured taking into account the thermal and electrical stresses caused by the current they can have to carry.

If using single-phase enclosed switchgear, a looping circuit, i.e. an interconnection between the enclosures of the three phases, should be installed for the induced current. Each of these looping circuits should be linked as directly as possible to the general earthing grid by a conductor capable to carry the short-circuit current.

NOTE The looping circuits are intended to avoid induced currents in the enclosures from flowing in the earthing circuits and earthing grid. They are usually dimensioned for the rated continuous current and located at the appropriate location according to the layout of the GIS installation.

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 and IEC 62271-1:2017/AMD1:2021 is applicable.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is applicable.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is applicable.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is applicable.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is applicable.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable with the following addition:

The performance of the GIS is depending on the gas density of the pure gas or the gas mixtures.

For 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 it is applicable for the GIS design.

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 isolate the density monitor from the gas compartment without mechanically removing it from the GIS, in order to minimize gas losses.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is applicable with the following addition:

A common nameplate shall be provided to identify the 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 standard is required where ratings are not detailed on the common nameplate.

The nameplates shall be durable and clearly legible for the lifetime of the 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 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 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

In case of disconnect switch and earthing switch 6.104.3.2 of IEC 62271-102:2018 is applicable.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

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

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 limits specified in this document.

6.16.2 Controlled pressure systems for gas

Subclause 6.16.2 of IEC 62271-1:2017 is applicable.

6.16.3 Closed pressure systems for gas

Subclause 6.16.3 of IEC 62271-1:2017 is applicable with the following addition:

The relative leakage rate from any single compartment of 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 E.

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

- $\leq 0,1$ % per year for SF₆, SF₆ mixtures and for other gas mixtures with GWP > 1 000;
- $\leq 0,5$ % per year for other gas mixtures with GWP ≤ 1 000.

NOTE 2 The global warming potential (GWP) of gases in 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 SF₆ is 23 500 according the IPCC – AR5 Climate Change 2013 [31].

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

- $\leq 0,2$ % per year for SF₆, SF₆ mixtures and for other gas mixtures with GWP > 1 000.

6.16.4 Sealed pressure systems

Subclause 6.16.4 of IEC 62271-1:2017 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 [12], the manufacturer shall demonstrate that the relative leakage rate from any compartment of GIS or between compartments complies with 6.16.3 or 6.16.4.

6.16.102 Gas handling

The 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.

The manufacturer shall recommend procedures for gas handling according to IEC 62271-4.

6.17 Tightness for liquid systems

Subclause 6.17 of IEC 62271-1:2017 is applicable.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 is applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is applicable.

6.20 X-Ray emission

Subclause 6.20 of IEC 62271-1:2017 is applicable with the following addition:

This applies only to GIS components which use vacuum interrupters.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable with the following addition:

The corrosion of bolted and screwed assemblies shall be taken into account when ensuring the continuity of the earthing circuits

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 is applicable.

6.101 General requirements for GIS

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, including the checking of phase sequence 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 standards except where modified by this document.

6.102 Pressure coordination

The pressure inside a 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, sun radiation).

Figure 1 shows the various pressure levels and their relationship.

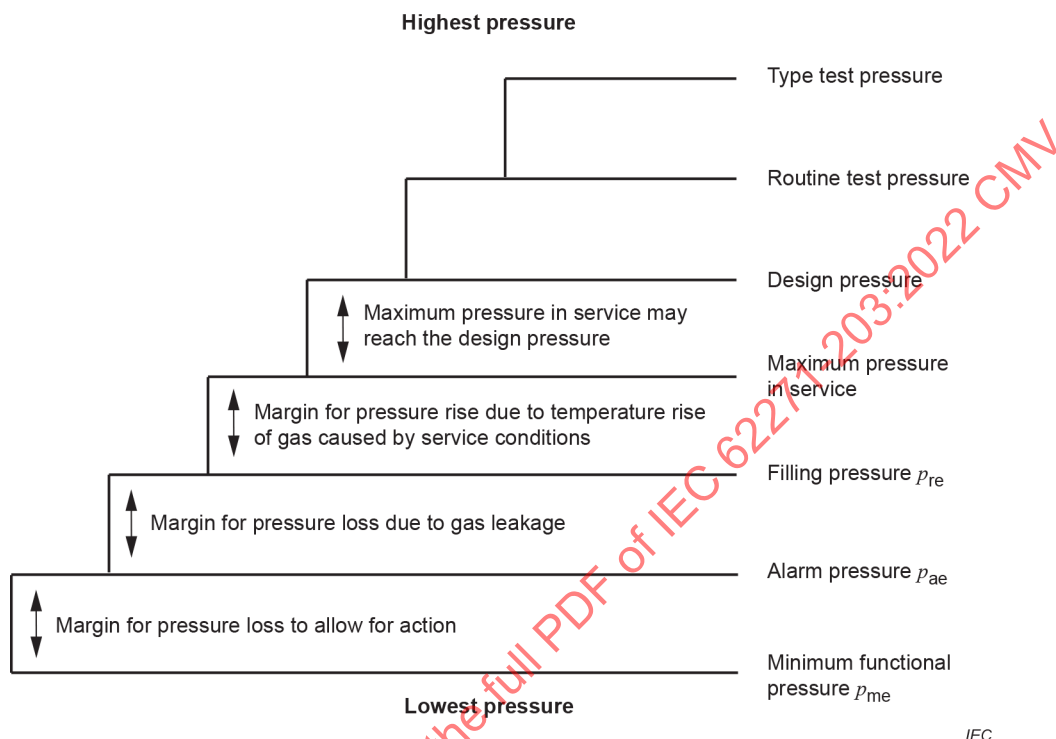


Figure 1 – Pressure coordination

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 GIS using gas with a GWP > 1 000, 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 aware the user 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 time period 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 GIS built to this document has a very low order of probability of occurrence. 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.

GIS shall be designed, manufactured and operated in order to prevent the occurrence of internal fault within 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 GIS design shall permit the restoration of the part of GIS which is not affected in order to satisfy the service continuity requirements when defined (see Annex F).

6.103.2 External effects of the arc

The effects of an internal arc are:

- pressure increase of gas (see Annex D);
- possible burn-through of enclosure.

The external effects of the arc shall be limited by a suitable protective system to the appearance of a hole or a tear in the enclosure without any fragmentation. The duration of the arc is related to the performance of the protective system determined by the first stage (main protection) and second stage (back-up protection).

Table 4 gives the performance criteria for the duration of the arc according to the performance of the protective system.

Table 4 – Performance criteria

Rated short-circuit current	Protection stage	Duration of short-circuit current	Performance criteria
<40 kA RMS	1	≤0,2 s	No external effect other than the operation of suitable pressure relief devices
	2	≤0,5 s	No fragmentation (burn-through is acceptable)
≥40 kA RMS	1	≤0,1 s	No external effect other than the operation of suitable pressure relief devices
	2	≤0,3 s	No fragmentation (burn-through is acceptable)

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 (D.1).

The duration of current without burn-through for different values of the short-circuit current can be estimated from an acknowledged calculation procedure like CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

6.103.3 Internal fault location

The manufacturer of the 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 standards for pressurized enclosures of gas-filled high-voltage switchgear and controlgear with inert, non-corrosive, low pressurized gases. For further information, see EN 50052 [15], EN 50064 [16], EN 50068 [17], EN 50069 [18].

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 of 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 adsorb 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 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 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 or short-circuit fault breaking.

The design pressure of a partition is defined by the situation where the partition is pressurized on one side and the other side is 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 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 provides guidance for specifying service continuity.

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

- during various activities requiring de-energization of parts of the 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 is 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 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 GIS bus-duct pass between indoor and outdoor locations (for example, 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 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.

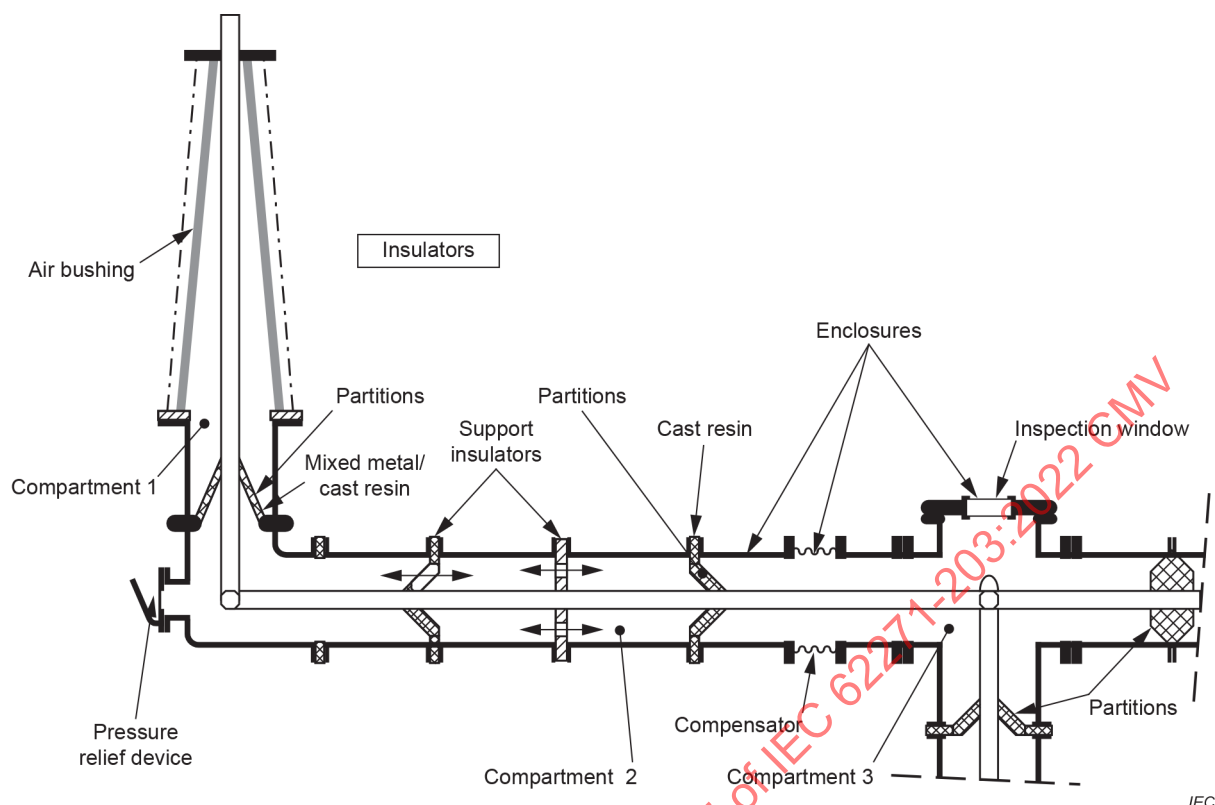


Figure 2 – Example of arrangement of enclosures and gas compartments

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 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 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. For the calculation method, see Annex D.

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, e.g. circuit-breaker) shall be taken into account when determining the operating pressure of the pressure relief device.

NOTE 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 [9] and IEC 61672-2 [10]).

6.108 Interfaces

6.108.1 General

In order to facilitate testing of GIS, isolating or removable links can be included in the design in each of the components mentioned below. This type of separation is preferable to 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 Table 2 and Table 3.

A removable link shall be designed to withstand the phase-to-earth test voltages according Table 2 and Table 3.

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

Those interfaces connected to the GIS shall be capable of withstanding the maximum pressure in service of the GIS. Typical maximum pressures in service are up to 1,1 MPa (absolute) for SF₆ 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.

Those parts of the 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.

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

During dielectric tests on cables in general, the adjacent parts of the 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 GIS.

The location of bushings for cable testing should be provided at the cable connection enclosure or at the 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 60840 and IEC 62067 the electrical tests after installation are AC voltage tests in such case; part of the GIS in the vicinity of the cable termination can be subject to AC test voltage of the cable.

6.108.2.3 Oil-filled cable

According to IEC 60141-1 the electrical tests after installation are DC voltage tests, in such case; if it is not acceptable to apply DC cable test voltages to the 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

See IEC 62271-211.

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

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

6.108.4 Bushings

See IEC 60137:2017, IEC TS 60815-1 [5], IEC TS 60815-2 [6], IEC TS 60815-3 [7], IEC 61462 [8] and IEC 62155 [11].

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 technical specification.

In the case of later extension with another 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 [20].

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 limit the part of the existing GIS to be re-tested and allow the connection to the existing GIS without further dielectric testing (see Clause C.3). It shall be designed to withstand the rated insulation levels across the isolating distance.

6.109 Interlocking

Disconnectors should be interlocked with the associated circuit-breaker to prevent opening or closing of the disconnector unless the associated circuit-breaker is open. However, on-load bus-transfer switching operations at multiple busbar substations shall be possible.

Earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit should be interlocked with the associated circuit-breaker and/or disconnectors to prevent opening or closing of the earthing switch unless the associated circuit-breaker and/or disconnector is open. Similar interlocking can be applied for earthing switches with making capability.

7 Type tests

7.1 General

Subclause 7.1 of IEC 62271-1:2017 is applicable with the following addition:

For type tests, technical grade SF₆ and its mixtures in accordance with IEC 60376 or used SF₆ and its mixtures in accordance with IEC 60480 can be used.

If the GIS is designed to use any other gas than SF₆, 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 GIS and documented in the type test reports.

NOTE A working group of IEC TC10 is currently working on standardisation of technical grade of SF₆ free gas mixtures (IEC 63359 and IEC 63360).

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

7.1.1 Basics

Subclause 7.1.1 of IEC 62271-1:2017 is applicable with the following addition:

As a general rule, tests on GIS components should be carried out in accordance with their relevant standards, 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 may 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 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 5 below.

Table 5 – 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) Tests to prove the radio interference voltage (RIV) level (if applicable)	7.3
c) Tests to prove the continuous current of any part of the equipment and measurement of the resistance of the main circuit	7.4 and 7.5
d) Tests to prove the rated peak and the rated short-time withstand current	7.6
e) Tests to verify the making and breaking capacity of the included switching devices	7.101
f) Tests to prove the satisfactory operation of the included switching devices	7.102.1
g) Tests to prove the strength of enclosures	7.103
h) Verification of the degree of protection of the enclosure	7.7
i) Gas tightness tests	7.8
j) Electromagnetic compatibility tests (EMC)	7.9
k) Additional tests on auxiliary and control circuits	7.10
l) Tests on partitions	7.104
m) Tests to prove the satisfactory operation at limit temperatures	7.102.2
n) Tests to prove performance under thermal cycling and gas tightness tests on insulators	7.106
o) Corrosion test on earthing connections (if applicable)	7.107
p) X-radiation test procedure for vacuum interrupters (if applicable)	7.11
Type tests, when requested by the user	
	Subclause
q) Tests to assess the effects of arcing due to an internal fault	7.105
r) Corrosion tests on sealing systems of enclosures and auxiliary equipment (if applicable)	7.108

7.1.2 Information for identification of test objects

Subclause 7.1.2 of IEC 62271-1:2017 is applicable.

7.1.3 Information to be included in type-tests reports

Subclause 7.1.3 of IEC 62271-1:2017 is applicable.

7.2 Dielectric tests**7.2.1 General**

Subclause 7.2.1 of IEC 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

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

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 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 60137:2017.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is applicable.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable with the following addition:

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 62271-1:2017 is applicable with the following addition:

The test voltages are specified in 7.2.7 and 7.2.8.

When each phase is individually enclosed in a metallic enclosure (single-phase design), only tests to earth, and no test between phases, shall be carried out. Bushings, used for external connections, shall be tested according to the relevant standards.

Current transformers 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 transformers and/or surge arresters forming an integral part of the 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 transformers and/or surge arresters shall be separately tested in accordance with the relevant standards.

Special requirements are prescribed in detail in Annex A.

7.2.6.2 General case

Subclause 7.2.6.2 of IEC 62271-1:2017 is applicable.

7.2.6.3 Special cases

Subclause 7.2.6.3 of IEC 62271-1:2017 is applicable with the following addition:

When the test voltage across the open switching device or across the isolating distance is higher than the phase-to-earth withstand level, but equal to the phase-to-phase withstand level, the test voltage shall be applied according to 7.2.6.3 of IEC 62271-1:2017.

For switchgear and controlgear of $U_r \leq 245$ kV, 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 grounded or according to 7.2.6.3 of IEC 62271-1:2017.

When the phase-to-phase withstand level is higher than the phase-to-earth withstand level, the test voltage shall be applied according to Annex A.

7.2.7 Tests of switchgear and controlgear of $U_r \leq 245$ kV

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-1:2017 is applicable with the following addition:

The rated withstand voltages shall be those specified in Table 2.

7.2.7.2 Power-frequency voltage tests

Subclause 7.2.7.2 of IEC 62271-1:2017 is applicable with the following addition:

The main circuits of the GIS shall be subjected to power-frequency voltage tests in dry conditions only.

7.2.7.3 Lightning impulse voltage tests

Subclause 7.2.7.3 of IEC 62271-1:2017 is applicable with the following addition:

If the alternative method described in 7.2.6.3 of IEC 62271-1:2017 is used, the test voltage is defined in column (5) of Table 2.

7.2.8 Tests of switchgear and controlgear of $U_r > 245$ kV

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-1:2017 is applicable with the following addition:

The rated withstand voltages shall be those specified in Table 3.

7.2.8.2 Power-frequency voltage tests

Subclause 7.2.8.2 of IEC 62271-1:2017 is applicable.

7.2.8.3 Switching impulse voltage tests

Subclause 7.2.8.3 of IEC 62271-1:2017 is applicable with the following addition:

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

Special test requirements shall be used for the phase-to-phase switching test for a three-phase design. They are defined in detail in Annex A.

7.2.8.4 Lightning impulse voltage tests

Subclause 7.2.8.4 of IEC 62271-1:2017 is applicable.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is applicable with the following addition:

This test applies only to bushings.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 is applicable with the following addition:

7.2.10.1 General

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.

NOTE Power-frequency voltage tests and partial discharge tests can be performed at the same time.

7.2.10.2 Test procedure

The applied power-frequency voltage is raised to a pre-stress value which is identical to the power-frequency withstand voltage test 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 6 depending on the configuration of equipment and system neutral.

The extinction voltage shall be recorded.

Table 6 – Test voltage for measuring PD intensity

	System with effectively earthed neutral		System without effectively earthed neutral	
	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test}}$ (>1 min)	Pre-stress voltage $U_{\text{pre-stress}}$ (1 min)	Test voltage for PD measurement $U_{\text{pd-test}}$ (>1 min)
Single-phase enclosures design (phase-to-earth voltage)	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test}} = 1,2 U_r / \sqrt{3}$	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test}} = 1,2 U_r$
Three-phase enclosures design	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test, ph-ea}} = 1,2 U_r / \sqrt{3}$ $U_{\text{pd-test, ph-ph}} = 1,2 U_r$	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test, ph-ea}} = 1,2 U_r$
U_r : rated voltage for equipment. U_d : power-frequency withstand test voltage as per Table 2 and Table 3. $U_{\text{pre-stress}}$: pre-stress voltage. $U_{\text{pd-test}}$: test voltage for PD measurement. $U_{\text{pd-test, ph-ea}}$: test voltage for PD measurement, phase-to-earth. $U_{\text{pd-test, ph-ph}}$: test voltage for PD measurement, phase-to-phase.				

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

7.2.10.3 Maximum permissible partial discharge intensity

The maximum permissible partial discharge level shall not exceed 5 pC at the test voltage specified in Table 6.

The values stated above apply to individual components as well as to the sub-assemblies in which they are contained. However, some equipment, such as voltage transformers insulated with liquid, immersed or solid, have an acceptable level of partial discharge in accordance with their relevant standard 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.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 is applicable.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 is applicable with the following addition:

The test voltage shall be 80 % of the value in Table 2 and Table 3, columns (2) and (3).

In the case of three-phase enclosed designs, this test shall be performed across open switching devices, isolating distances, phase-to-earth and phase-to-phase.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 and 7.9.1 of IEC 62271-1:2017 are applicable with the following addition:

This test applies only to bushings.

7.4 Resistance measurement

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

Subclause 7.4.1 of IEC 62271-1:2017 is applicable.

7.4.2 Measurement of the resistance of auxiliary contacts class 3

Subclause 7.4.2 of IEC 62271-1:2017 is applicable.

7.4.3 Electrical continuity of earthed metallic parts test

Subclause 7.4.3 of IEC 62271-1:2017 is applicable.

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

7.4.4.1 Resistance measurement test procedure

Subclause 7.4.4.1 of IEC 62271-1:2017 is applicable with the following addition:

The current used for the measurement shall be equal or greater than 100 A DC 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.

7.4.4.2 Making and breaking tests

Subclause 7.4.4.2 of IEC 62271-1:2017 is applicable.

7.4.4.3 Other tests

Subclause 7.4.4.3 of IEC 62271-1:2017 is applicable.

7.5 Continuous current tests

7.5.1 Conditions of the test object

Subclause 7.5.1 of IEC 62271-1:2017 is applicable.

7.5.2 Arrangement of the equipment

Subclause 7.5.2 of IEC 62271-1:2017 is applicable with the following addition:

GIS with three-phase enclosures shall be subject to three-phase testing.

GIS with single-phase enclosures shall be single-phase tested with the test current flowing through the main conductor and back 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.

7.5.3 Test current and duration

7.5.3.1 Test on main circuit

Subclause 7.5.3.1 of IEC 62271-1:2017 is applicable.

7.5.3.2 Test on the auxiliary and control equipment

Subclause 7.5.3.2 of IEC 62271-1:2017 is applicable.

7.5.4 Temperature measurement during test

Subclause 7.5.4 of IEC 62271-1:2017 is applicable.

7.5.5 Resistance of the main circuit

Subclause 7.5.5 of IEC 62271-1:2017 is applicable.

7.5.6 Criteria to pass test

Subclause 7.5.6 of IEC 62271-1:2017 is applicable with the following addition:

Insulators for GIS are electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC 62271-1 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 [21].

The temperature rise of components contained in the GIS which are subject to standards not covered by the scope of IEC 62271-1:2017 shall not exceed the temperature-rise limits permitted in the relevant standard 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, precaution can be taken to ensure that no damage is caused to the surrounding insulating materials.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable.

7.6.2 Arrangement of the equipment and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is applicable with the following additions.

GIS with three-phase enclosures shall be subject to three-phase testing. GIS with single-phase enclosures shall be tested in a single-phase circuit with the full 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 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.

7.6.3 Test current and duration

Subclause 7.6.3 of IEC 62271-1:2017 is applicable.

7.6.4 Conditions of the test object after test

Subclause 7.6.4 of IEC 62271-1:2017 is applicable.

7.6.101 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 not show any deformation or damage, which can impair the intended operation.

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

7.6.102 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 GIS which are factory assembled and comprise earthing conductors, earthing connections and earthing devices shall be tested as installed in the 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.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1 is applicable.

7.7.1 Verification of the IP coding

Subclause 7.7.1 of IEC 62271-1:2017 is applicable with the following addition.

Verification of IP coding is not applicable to pressurized 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).

7.7.2 Verification of the IK coding

Subclause 7.7.2 of IEC 62271-1:2017 is applicable with the following addition:

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

7.8 Tightness tests

7.8.1 General

Subclause 7.8.1. of IEC 62271-1:2017 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 GIS compartments comprising sealings and accessories (e.g. gas filling valves, gas monitoring and control devices, 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.

7.8.2 Controlled pressure systems for gas

Subclause 7.8.2 of IEC 62271-1:2017 is applicable.

7.8.3 Closed pressure systems for gas

Subclause 7.8.3 of IEC 62271-1:2017 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).

7.8.4 Sealed pressure systems

Subclause 7.8.4 of IEC 62271-1:2017 is applicable.

7.8.5 Liquid tightness tests

Subclause 7.8.5 of IEC 62271-1:2017 is applicable.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is applicable.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is applicable.

7.11 X-radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is applicable.

7.101 Verification of making and breaking capacities

Switching devices forming part of the main circuit of GIS shall be tested to verify their rated making and breaking capacities according to the relevant standards and under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the 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 GIS shall be submitted to mechanical operation and environmental tests in accordance with their relevant standards 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 7.8 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 standards.

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 [15], EN 50064 [16], EN 50068 [17], EN 50069 [18].

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 = $[3,5 / 0,7] \times \text{design pressure}$

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 = $[(2,3 / \nu) \times (\sigma_t / \sigma_a)] \times \text{design pressure}$

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 nonlinearity, 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:

$$p = \frac{1}{1,1 k} \left(p_y \frac{\sigma_a}{\sigma_t} \right)$$

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 [19].

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 type test 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 B.

NOTE Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

The short-circuit current applied during the arcing should correspond to the rated short-time withstand current or, in some applications of the switchgear in isolated neutral systems, it can be the earth fault current occurring in such a system.

Two assessments are made. The first concerns the performance of the equipment during the operation of the first stage (main) protection and the second concerns the case when the fault is cleared by the operation of the second stage (back-up) protection.

In order to verify both assessments, the duration of the test shall be at least equal to the time delay of operation for the second stage of protection. The maximum time setting for the operation of the second stage is defined in Table 4. A shorter test duration can be used if it is not shorter than the operation of the second stage of protection defined by the user.

The switchgear shall be considered adequate if the performance criteria defined in Clause 6.103 and in Table 4 are met.

7.106 Insulator tests

7.106.1 General

Tests on insulators (partitions and support insulators) shall be performed as follows:

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 (e.g. $-40\text{ }^{\circ}\text{C}$);
- b) 2 h at room temperature;
- c) 4 h at limit of temperature according to Table 14 row 7 of IEC 62271-1:2017 (e.g. $+105\text{ }^{\circ}\text{C}$);
- d) 2 h at room temperature.

NOTE Insulators for GIS are electrical insulation system (EIS) according to IEC 60085:2007. The upper limit temperatures defined in IEC 62271-1 are therefore applicable for the EIS and not for the electrical insulation material (EIM).

The given thermal cycle times are minimum times and shall be prolonged in case stable end temperatures are not reached.

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.

Precaution 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 7.8. 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 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 [12].

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 life time management of outdoor HV GIS [30]. 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 7.4.4, 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 7.108.

The tested sub-assemblies shall be representative of a 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 [12].

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 7.8.

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 life time management of outdoor HV GIS [30]. The recommendations of this Cigre guide can be considered.

8 Routine tests

8.1 General

Subclause 8.1 of IEC 62271-1:2017 is applicable with the following addition:

For routine tests technical grade SF₆ and its mixtures in accordance with IEC 60376, or used SF₆ and its mixtures in accordance with IEC 60480, can be used. See 6.2.

If the GIS is designed to use any other gas than SF₆, 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 GIS and documented in the routine test reports.

The routine tests shall be performed on all components of a 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 62271-1:2017 is applicable with the following additions:

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

8.2.101 Power-frequency voltage tests on the main circuit

The power-frequency voltage test of GIS shall be performed according to the requirements in 7.2.6.1 or 7.2.7.1 to earth, between phases (if applicable) and across the open switching devices. The voltage test across the open switching device can be carried out at one side of the switching device. The withstand voltages for routine tests shall be those specified in column (2) of Table 2 and Table 3.

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 62271-1:2017 is applicable.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1:2017 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 62271-1:2017 is applicable with the following addition:

The tightness test shall preferably be performed at filling pressure 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 62271-1:2017, 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 62271-1:2017 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

- 1,3 for welded aluminium and welded steel enclosure;
- 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 GIS shall be submitted to a mechanical routine test in accordance with their relevant standards. 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 62271-1:2017 is applicable with the following addition:

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

NOTE IEEE C37.122.1 [22] and CIGRE Technical Brochure 125 [23] describe the general guideline for the selection of a gas-insulated switchgear.

9.2 Selection of rated values

Subclause 9.2 of IEC 62271-1:2017 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 62271-1:2017 is applicable.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC 62271-1:2017 is applicable.

9.5 Environmental aspects

Subclause 9.5 of IEC 62271-1:2017 is applicable.

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

10.1 General

Subclause 10.1 of IEC 62271-1:2017 is applicable with the following addition:

Annex E 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 62271-1:2017 is applicable.

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 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 62271-1:2017 is applicable.

11.2 Conditions during transport, storage and installation

Subclause 11.2 of IEC 62271-1:2017 is applicable.

11.3 Installation

Subclause 11.3 of IEC 62271-1:2017 is applicable.

11.4 Operating instructions

Subclause 11.4 of IEC 62271-1:2017 is applicable.

11.5 Maintenance

Subclause 11.5 of IEC 62271-1:2017 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.

11.101 Tests after installation on-site

11.101.1 General

After installation, and before being put into service, the 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 gas-insulated substation 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 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 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 GIS, see Clause C.3.

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

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

11.101.2.2 Test procedure

The 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 line;
- power transformers and, occasionally, voltage transformers;
- surge arresters and protective spark gaps.

NOTE 1 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.

NOTE 2 Voltage transformers can remain connected for the test when saturation of the voltage transformer is prevented, e.g. by using voltage transformers which are designed for the test voltage or by performing the power-frequency testing at a frequency, where saturation does not occur.

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

In the case of extensions, in general, the adjacent existing part of the 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 GIS.

Application of the test voltage can 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 GIS.

One of the following test procedures shall be chosen:

a) Procedure A (recommended for 170 kV and below):

Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2).

b) Procedure B (recommended for 245 kV and above):

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2); and
- partial discharge measurements according to Table 6, however with $U_{\text{pre-stress}} = U_{\text{ds}}$ of Table 7, column (2).

In the few cases, where $U_{\text{pd-test}}$ is higher than $U_{\text{pre-stress}}$ the $U_{\text{pd-test}}$ shall be reduced to $U_{\text{pre-stress}}$.

A PD measurement at $U_r / \sqrt{3}$ 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 C.

c) Procedure C (recommended for 245 kV and above, alternative to procedure B):

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 7, column (2); and
- lightning impulse tests with three impulses of each polarity and with the value specified in Table 7, column (3).

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 7.

Table 7 – On-site test voltages

Rated voltage for equipment	On-site short-duration power-frequency withstand voltage	On-site lightning impulse withstand voltage
U_r kV (RMS value)	U_{ds} kV (RMS value)	U_{ps} kV (peak value)
(1)	(2)	(3)
72,5	120	260
100	165	360
123	200	440
145	235	520
170	270	600
245	380	840
300	380	840
362	425	940
420	515	1 140
550	560	1 240
800	760	1 680
1 100	865	1 920
1 200	865	1 920

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

$$U_{ds} \text{ (on-site test value)} = U_p \times 0,45 \times 0,8 \quad (\text{column (2)})$$

$$U_{ps} \text{ (on-site test value)} = U_p \times 0,8 \quad (\text{column (3)})$$

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

NOTE 2 If other insulation levels than the preferred values of Table 2 and Table 3 (e.g. the lower insulation levels of Tables 1 and 2 in IEC 62271-1:2017) are specified, then the on-site test voltage can be calculated according to Note 1.

NOTE 3 The UHV on-site test voltages for $U_r = 1\,100\text{ kV}$ and $1\,200\text{ kV}$ are according to IEC TS 63042-301 [14].

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

11.101.2.4 Voltage waveforms

For the choice of an appropriate voltage waveform, IEC 60060-1 [3] 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 Clause C.1.

a) Power-frequency voltage tests

Power-frequency 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 μ s are acceptable. When using oscillating lightning impulse voltages, the front time can be extended to approximately 15 μ s.

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

c) DC voltage tests

A DC voltage test is not recommended. The existing test specifications for cables are not applicable to GIS (see 6.108.1).

11.101.2.5 Voltage application

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

It is often convenient to divide the whole installation of GIS into sections by opening circuit-breakers and/or 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 circuit-breaker or 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.

For 3-phase enclosed GIS, the specified test voltage shall be applied between each phase conductor, one at a time, and the enclosure, the other phase conductors being connected to the earthed enclosure. The insulation between phase conductors shall not be subjected to any other separate dielectric test 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 Clause C.6.

If Procedure B is used and if the partial discharges are measured with the conventional method according to IEC 60270, the maximum permissible intensity of partial discharge shall be 10 pC.

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 can consider this possibility in the test sequence, and can be 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 C.7.5, IEC TS 62478 [13] and CIGRE Technical Brochure 654 [25] can be performed.

11.101.3 Dielectric tests on auxiliary circuits

Subclause 8.3 of IEC 62271-1:2017 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 62271-1:2017 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 standards. 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 62271-1:2017.

For checking the condition of the gas during service, reference is made to IEC 60480 for SF₆ 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 SF₆ and manufacturer recommendations for other gases.

12 Safety

Clause 12 of IEC 62271-1:2017 is applicable with the following addition:

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

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:2017 is applicable with following addition:

Handling releases during manufacturing, installation, on-site tests, repair and maintenance shall be accounted according local regulation, see IEC 62271-4.

For environmental aspects of gases and gas mixtures see CIGRE Technical Brochure 802 [26].

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Annex A (normative)

Test procedure for dielectric test on three-phase encapsulated GIS, range II (above 245 kV)

A.1 Dielectric procedures for three phases in one GIS enclosure

If the requirements for phase-to-earth and phase-to-phase insulation levels are different, the test requirements following IEC 62271-1:2017 shall be reconsidered. This is applicable only for switching impulse tests of range II.

A.2 Application of test requirements

In order to fully cover the tests to be carried out, Table A.1 lists the test conditions in relation to the enclosure, open switching device and phase-to-phase. The table symbols are the same as in IEC 62271-1:2017 (Figure 2).

The preferred method is the use of combined voltage test. The voltage levels required can be delivered by two different voltage sources in opposite polarity.

Table A.1 – Switching impulse test conditions above 245 kV

Test condition	Connecting device	Switching impulse	Alternating voltage at power-frequency	Earth connected to
Phase-to-phase test		Main part of U_s between phases (Table 3, column (5)) applied to	Complementary part to obtain U_s between phases (Table 3, column (5)) applied to	
1	Closed	Aa	BbCc	F
2	Closed	Bb	AaCc	F
3	Closed	Cc	AaBb	F
4	Open	A	BC	abcF
5	Open	B	AC	abcF
6	Open	C	AB	abcF
7	Open	a	bc	ABCF
8	Open	b	ac	ABCF
9	Open	c	ab	ABCF
NOTE 1 Test conditions 3, 6 and 9 can be omitted if the arrangement of the outer phases is symmetrical with respect to the centre phase and the enclosure.				
NOTE 2 Test conditions 2, 3, 5, 6, 8, 9 can be omitted if the arrangement of the phases is fully symmetrical with respect to each other and to the enclosure.				
NOTE 3 Test conditions 7, 8 and 9 can be omitted if the arrangement of the terminals of each phase is symmetrical with respect to the enclosure.				

For switching functions and disconnecting functions, respective values shall be taken in Table 3 for open conditions.

Annex B

(normative)

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

B.1 General

The occurrence of an arc inside 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).

B.2 Short-circuit current arcing test

B.2.1 Test arrangements

When choosing the object to be tested, reference shall be made to the design documents for the 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} .

B.2.2 Current and voltage applied

B.2.2.1 General

Single-phase enclosures shall be tested single-phase, and three-phase enclosures shall be tested three-phase.

B.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.

B.2.2.3 Current

a) AC component

The AC component at the beginning of the test shall lie within a tolerance of $^{+10}_0$ %. Within the duration of the first stage protection, the tolerance shall be ± 10 % and within the duration of the second stage protection 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 of at least 1,7 times the RMS value of the stated short-circuit current AC component. For three-phase tests, this applies to the current in at least one phase.

B.2.2.4 Frequency

For rated frequencies of 50 Hz or 60 Hz, the frequency at the beginning of the test shall lie within the limits of 48 Hz and 62 Hz.

B.2.2.5 Duration of the test

The current duration shall be such as to cover the second stage protection chosen on the basis of the expected duration as determined by the protection devices. See Table 4.

B.2.3 Test procedure

B.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.

B.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.

B.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.

B.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 times 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 from a fault in the stage 2 protection according to Table 4.

B.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;
- currents, voltages, energies, pressures 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.

B.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.

B.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.

Information about experience of internal arc tests and calculation principles are present in CIGRE Technical Brochure 602 [24], CIGRE Session 1998 – WG 21/23/33-03 [28] and RGE: 04/82 [29].

Annex C (informative)

Technical and practical considerations of site testing

C.1 Test voltage generators

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

- power-frequency voltage tests, especially at higher U_r , 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) power-frequency voltage sources

The power-frequency 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.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.

C.3 Special test procedures

C.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 (6.108.4) the user shall be responsible for any flashovers in the existing GIS and the manufacturer of the extension equipment shall be responsible for any flashovers in the extension equipment.

C.3.2 Testing at reduced voltage

C.3.2.1 Simplified method for units transported without dismantling

In accordance with the practice in some countries, gas-insulated metal-enclosed switchgear, or at least one bay or an equivalent part of the 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 reduced to the following.

AC voltage test with $1,1 \times U_r / \sqrt{3}$ for earthed neutral systems or $1,9 \times U_r / \sqrt{3}$ for isolated neutral or resonant earthed systems; with a 10 min voltage application.

C.3.2.2 Deviations due to practical needs

In certain circumstances due to technical or practical reasons, an AC voltage test can be performed at reduced voltage for an extended duration. Additionally, partial discharge detection can be applied in accordance with Clause C.7. The procedure is subject to agreement between the manufacturer and the user.

C.3.2.3 Application of service voltage

In some cases, it is impracticable to perform a dielectric test on-site. In such a case, special care should be taken for shipment, transportation and storage and particular attention should be given to the workmanship on-site. The GIS to be tested should be energized by the service voltage through the largest possible impedance in order to reduce damage caused by a possible disruptive discharge. The test period should be at least 30 min.

C.3.3 Testing at reduced gas density

Tests with reduced gas density are not generally advisable.

C.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.

C.5 Electrical conditioning

The term “electrical conditioning” means a progressive application of an AC 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 AC 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.

C.6 Repetition tests

C.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 C.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.

C.6.2 Recommended procedure

C.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 specified dielectric test once more.

C.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.

C.7 Partial discharge detection method

C.7.1 General

For partial discharge detection on-site, the electrical VHF/UHF and the acoustic method can be used in 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.

C.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 GIS is preferable. In such a case, a sensitivity below 5 pC is achievable for GIS with cable terminations and for GIS sections which are separated by an open disconnector from open-air bushings.

C.7.3 VHF/UHF method

The discharge currents at the defects of 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 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 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 spacers.

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 C.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.

C.7.4 Acoustic method

Acoustic signals (mechanical waves) are emitted from defects in a 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 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.

C.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 GIS in order to verify the detection sensitivity for the 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 GIS section between these sensors.

For further information see IEC TS 62478 [13] and CIGRE Technical Brochure 654 [25].

Annex D (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 Formula (D.1):

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

where

- Δp is the pressure rise (MPa);
- I_{arc} is the fault arc 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 (D.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.

Annex E (informative)

Information to be given with enquiries, tenders and orders

E.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.

E.2 Normal and special service conditions

See Clause 4.

Table E.1 – Normal and special service conditions

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

E.3 Ratings

See Clause 5.

Table E.2 – Ratings

		User requirements	Supplier proposals
Nominal voltage of system	kV		
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase-to-earth and between phases	kV		
Rated short-duration power-frequency withstand voltage (U_d)			
Rated switching impulse withstand voltage (U_s)			
Phase-to-earth			
Between phases			
Rated lightning impulse withstand voltage (U_p)	kV		
Rated frequency (f_r)	Hz		
Rated continuous current (I_r)	A	According single-line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short-circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 Hz or 60 Hz	
Neutral earthing		Effectively or not effectively	

E.4 Design and construction

See Clause 6.

Table E.3 – Design and construction

		User requirements	Supplier proposals
Number of phases			
Single- or three-phase design			
Maximum relative gas leakage rate	% / year		
Filling pressure p_{re}			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Alarm pressure p_{ae}			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Minimum functional pressure p_{me}			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Design pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Type test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Routine test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Operating pressure of pressure relief device			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Internal fault			
Short-circuit current	kA		
Duration of current (as per Table 4)	s		
Quantity of gas of complete GIS at filling pressure p_{re}	kg	Supplier information	
Quantity of gas of the largest compartment at filling pressure p_{re}	kg	Supplier information	
Maximum permissible gas dew point	°C	Supplier information	
Recommendation for dew point measurement and adequate correction			
Number of gas compartments		Supplier information	
Length of longest section for transportation	m		
Weight of the heaviest piece of equipment to be handled during installation on-site	kg		
Noise			

E.5 Bus ducts

Table E.4 – Bus ducts

		User requirements	Supplier proposals
Inductance	H/m	Supplier information	
Capacitance	pF/m	Supplier information	
Resistance of enclosure at f_r	Ω/m	Supplier information	
Resistance of conductor at f_r	Ω/m	Supplier information	
Surge impedance	Ω	Supplier information	

E.6 Circuit-breaker

Clause 10 of IEC 62271-100:2021 is applicable.

E.7 Disconnecter and earthing switch

Clause 10 of IEC 62271-102:2018 is applicable.

E.8 Bushing

Clause 6 of IEC 60137:2017 is applicable with the following additions:

Table E.5 – Bushing

Outdoor-immersed bushing (see IEC 60137:2017, 3.20)		User requirements	Supplier proposals
Type of internal insulation		Gas-insulated or resin-impregnated paper	
Type of external insulation		Porcelain or composite	
Nominal specific creepage distance	mm/kV		
Shed profile		Normal or alternating	
Rated short-duration, power-frequency withstand voltage (U_d)	kV	As GIS or special	
Rated switching impulse withstand voltage (U_s)	kV	As GIS or special	
Rated lightning impulse withstand voltage (U_p)	kV	As GIS or special	
Cantilever test load	N		
Cantilever operation load	N		
Type of line termination		According drawing	

E.9 Cable connection

Clause 10 of IEC 62271-209:2019 is applicable with the following additions:

Table E.6 – Cable connection

		User requirements	Supplier proposals
Type of cable termination		Fluid-filled or dry type	
Supplier of cable insulator		GIS or cable supplier	

E.10 Transformer connection

Clause 9 of IEC 62271-211:2014 is applicable with the following additions:

Table E.7 – Transformer connection

		User requirements	Supplier proposals
Insulated junction between transformer tank and GIS enclosure		Yes or no	

E.11 Current transformer

Markings which are listed in IEC 61869-1 and IEC 61869-2 are applicable with the following additions:

Table E.8 – Current transformer

		User requirements	Supplier proposals
Position of current transformer		According single-line	
Number of cores		According single-line	
Burdens and accuracy classes	VA / -	According single-line	

E.12 Inductive voltage transformer

Markings which are listed in IEC 61869-1 and IEC 61869-3 are applicable with the following additions:

Table E.9 – Inductive voltage transformer

		User requirements	Supplier proposals
Position of voltage transformer		According single-line	
Number of secondary windings		According single-line	
Burdens and accuracy classes	VA / -	According single-line	
On-site test voltage	kV/Hz	Supplier information	

E.13 Metal-oxide surge arrester

Annex D of IEC 60099-4:2014 is applicable for GIS arresters.

E.14 Documentation for enquiries and tenders**Table E.10 – Documentation for enquiries and tenders**

		User requirements	Supplier proposals
Single-line diagram			
Requirements for service continuity during maintenance, repair, extension and on-site testing			
General arrangement drawings of substation layout			
Foundation loading		Supplier information	
Gas schematic diagrams		Supplier information	
List of type test reports		Supplier information	
List of recommended spare parts		Supplier information	
GIS interface drawings (in case of later extension)			

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Annex F (informative)

Service continuity

F.1 General

This annex defines service continuity of a GIS in relation to switchgear design. The system requirements for service continuity are fulfilled by choice of single-line diagram, sequence of feeders, physical arrangement of components and gas compartments. The continuity of service due to maintenance, repair after failure, extension or on-site dielectric test should be the prime concern.

The service continuity levels are defined through the MRE code (Maintenance, Repair, Extension) specific to feeder and busbar sections of the GIS on out of service condition during maintenance, repair, extension or on-site dielectric test (see examples provided in F.4.3).

A guideline on how to handle service continuity requirements can be found in CIGRE Technical Brochure 870, *Service Continuity Guide for HV GIS above 52 kV* [27].

F.2 Terms and conditions

F.2.1 Terms

F.2.1.1 Feeder

A feeder is a connection from a substation to another substation, a transformer, a generator, a reactor, capacitor bank, etc. The feeder can be an overhead line, a cable or a gas-insulated transmission line. The feeder is connected to the GIS by interfaces like bushings, cable- or transformer-connections.

F.2.1.2 Feeder-bay

A feeder-bay connects a feeder to a busbar section or another feeder (e.g. ring configurations). A feeder-bay consists of a set of interconnected circuit elements. Circuit elements can be: circuit-breaker, disconnector, earthing switches, current transformer, voltage transformer, surge arrester and connecting elements.

NOTE Although the term feeder-bay is described here, it is not required to define the service continuity level.

F.2.1.3 Busbar section

A busbar section is the common connection of several feeder-bays. A busbar can be sectionalized in several busbar sections. A busbar without sectionalizing is one busbar section.

F.2.2 Conditions

Only single events are considered. The service continuity does not apply in the situation where a fault occurs on other equipment still in service while the main situations affecting GIS service continuity are in progress.

The main situations affecting GIS service continuity are:

- maintenance;
- repair after failure;

- extensions;
- on-site dielectric test.

The service continuity levels (see Clause F.4) should be defined for each of these situations.

F.3 Responsibilities

F.3.1 Service continuity requirements

It is the user's responsibility to

- define the service continuity requirements;
- e.g.: MRE11 during maintenance and repair on any feeder or busbar section;
- specify the location of future extension, if applicable.

It is the manufacturer's responsibility to

- design the GIS, define partitioning and specify other measures in order to fulfil the user's requirements;
- take into account the location of future extension, if applicable;
- demonstrate compliance with the users service continuity requirements in a common format, e.g. series of GIS gas single-line diagrams (e.g. in colour) indicating the pressure in each gas compartment, during maintenance, repair, extension or on-site dielectric test.

F.3.2 Work on partitions

The manufacturer should design the GIS with due consideration to safe working practices in the vicinity of pressurised gas compartments. The manufacturer should provide the user with a GIS product related design risk assessment and recommended procedures for work on or adjacent to a pressurised gas compartment partition. The manufacturer should define rules for such work under the following headings:

- forbidden;
- recommended;
- authorised.

The manufacturer should outline the controls required to allow recommended and authorised work to proceed.

The user should consider the manufacturers design risk assessment and work procedures in conjunction with user's safety policy when assessing compliance with service continuity requirements.

NOTE The manufacturers design risk assessment can proactively assess and eliminate or reduce the personnel safety risks over the full life-cycle of the GIS from assembly to operation, maintenance, repair and de-commissioning.

F.4 Service continuity levels

F.4.1 General

The continuity of service of a GIS during maintenance (M), repair (R), extension (E) or on-site dielectric testing is indicated by the MRE code.

F.4.2 Definition of the MRE code

	MRE	0	1
Code letters _____ (Maintenance, Repair, Extension)			
First characteristic numeral _____ (numerals 0 to 4, or letter X)			
Second characteristic numeral _____ (numerals 0 to 5, or letter X)			

Element	Numerals or letters	GIS availability
Code letters	MRE	Maintenance, Repair, Extension
First characteristic numeral	0 1 2 3 4 X	Number of busbar section(s) out of service during maintenance, repair, extension or on-site dielectric test 0 busbar sections out of service 1 busbar section out of service 2 busbar sections out of service 3 busbar sections out of service 4 busbar sections out of service All busbar sections out of service
Second characteristic numeral	0 1 2 3 4 5 X	Number of feeder(s) out of service during maintenance, repair, extension or on-site dielectric test 0 feeders out of service 1 feeder out of service 2 feeders out of service 3 feeders out of service 4 feeders out of service 5 feeders out of service All feeders of the related busbar section(s) out of service

F.4.3 Examples for service continuity levels

The following Figure F.1 to Figure F.9 illustrate the definition of some service continuity levels. For visualisation purposes simplified figures are used. Only relevant switchgear components are shown.

Single busbar configurations

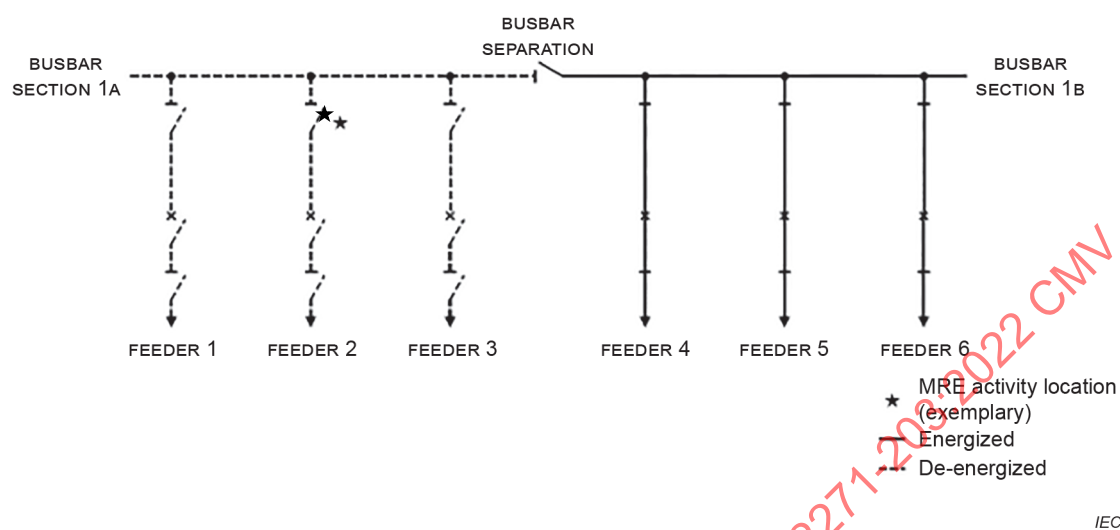


Figure F.1 – MRE1X (e.g. repair of disconnector to busbar)

Double busbar configurations

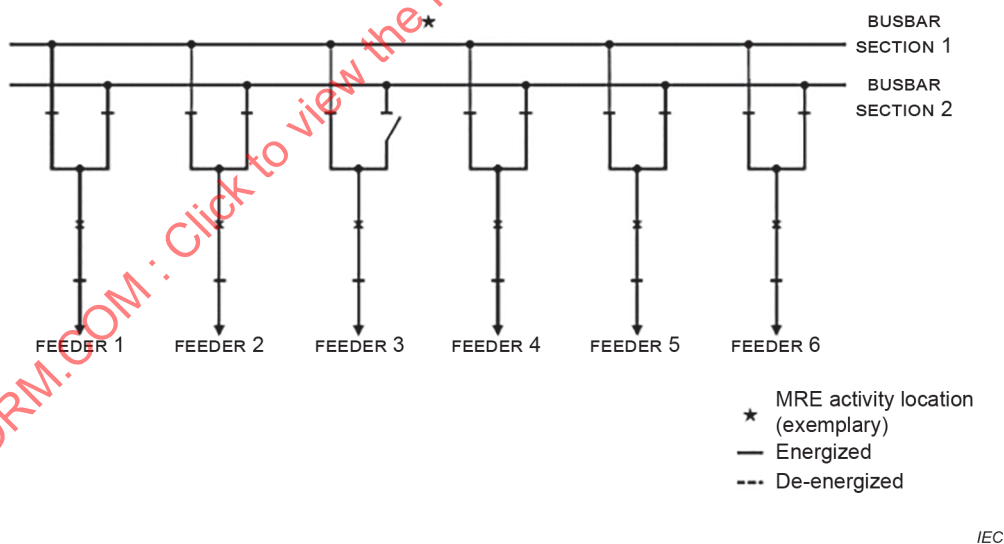


Figure F.2 – MRE00 (e.g. during visual inspection)

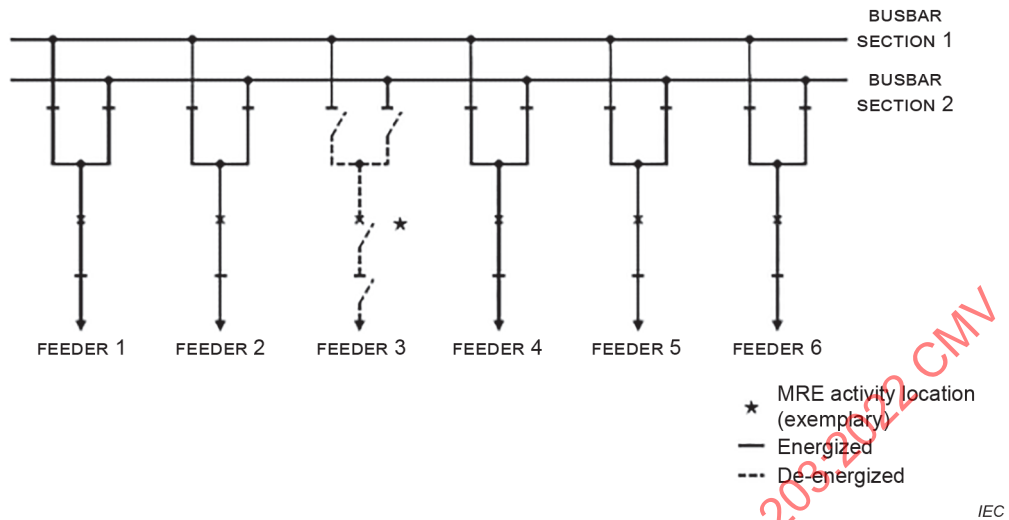


Figure F.3 – MRE01 (e.g. repair of circuit-breaker)

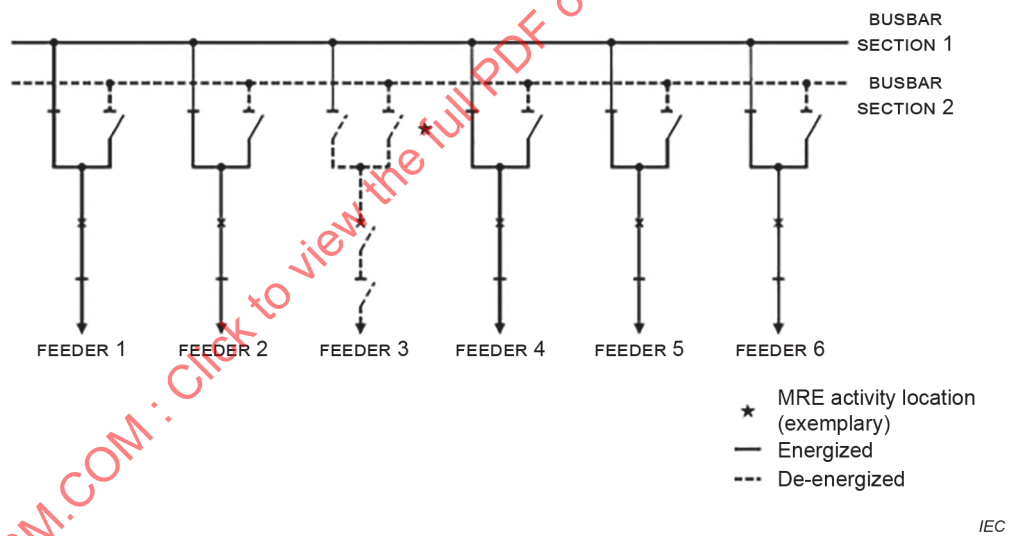


Figure F.4 – MRE11 (e.g. repair of disconnector)

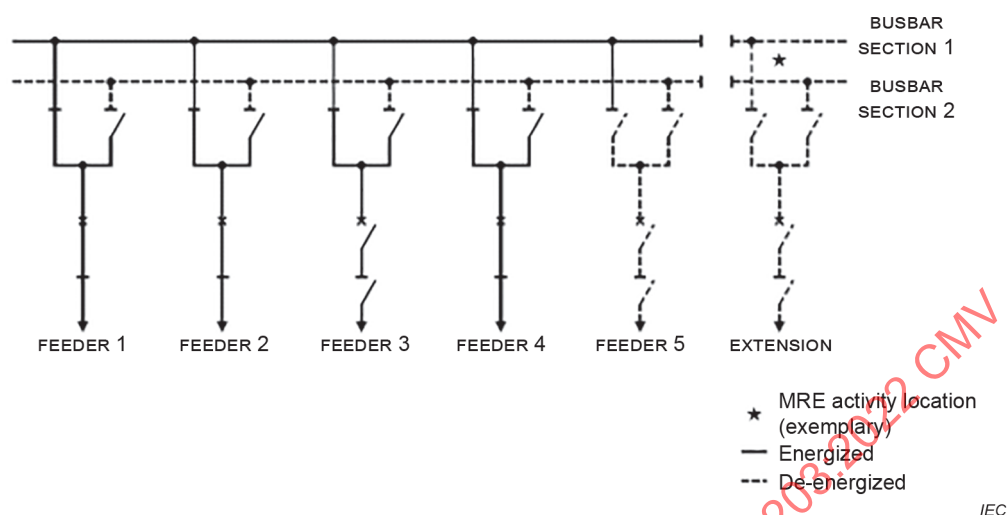


Figure F.5 – MRE11 (e.g. extension of switchgear with a feeder bay)

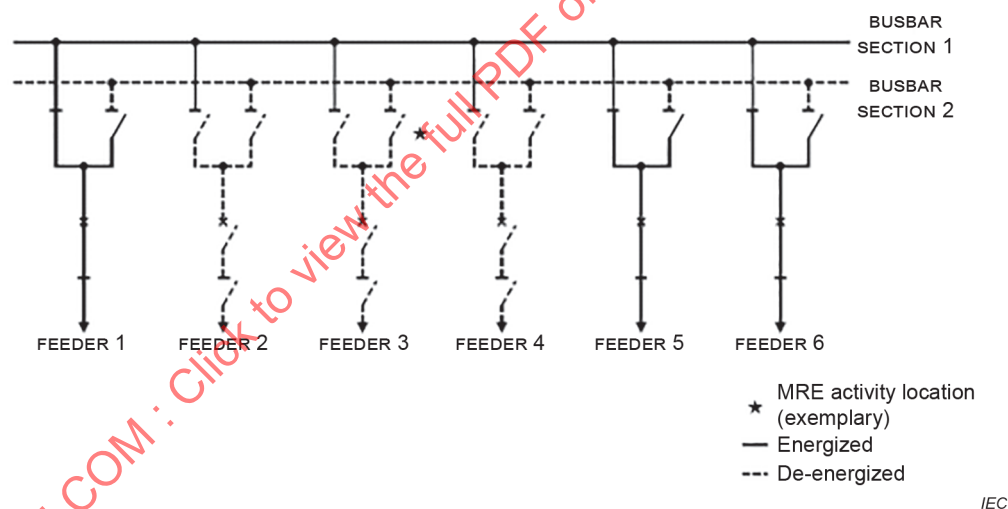
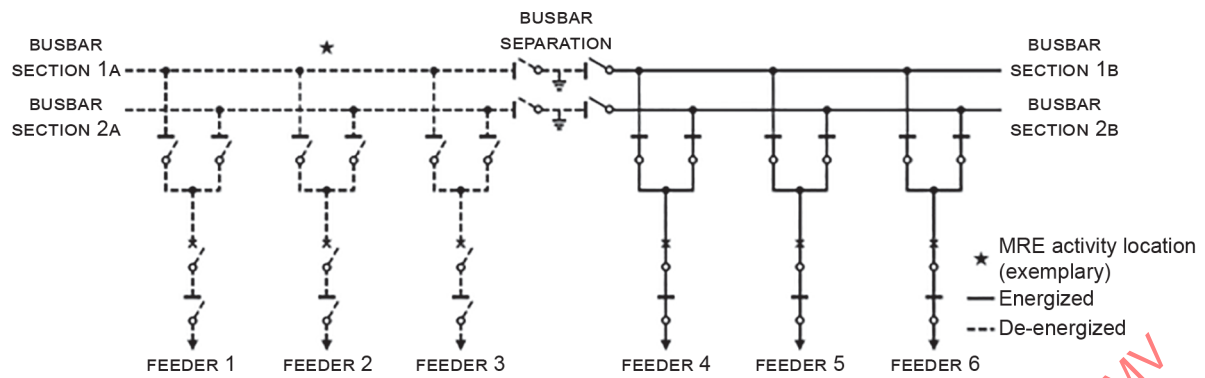
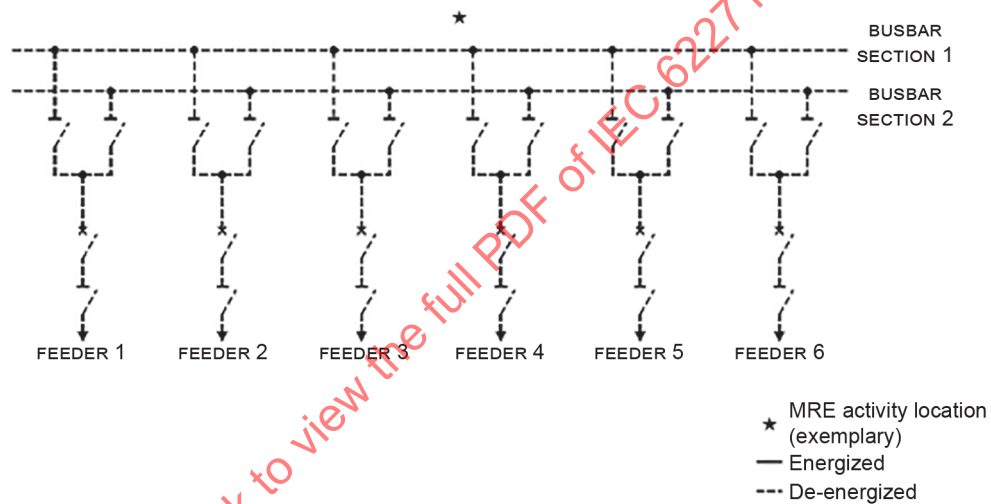


Figure F.6 – MRE13 (e.g. repair of disconnector)



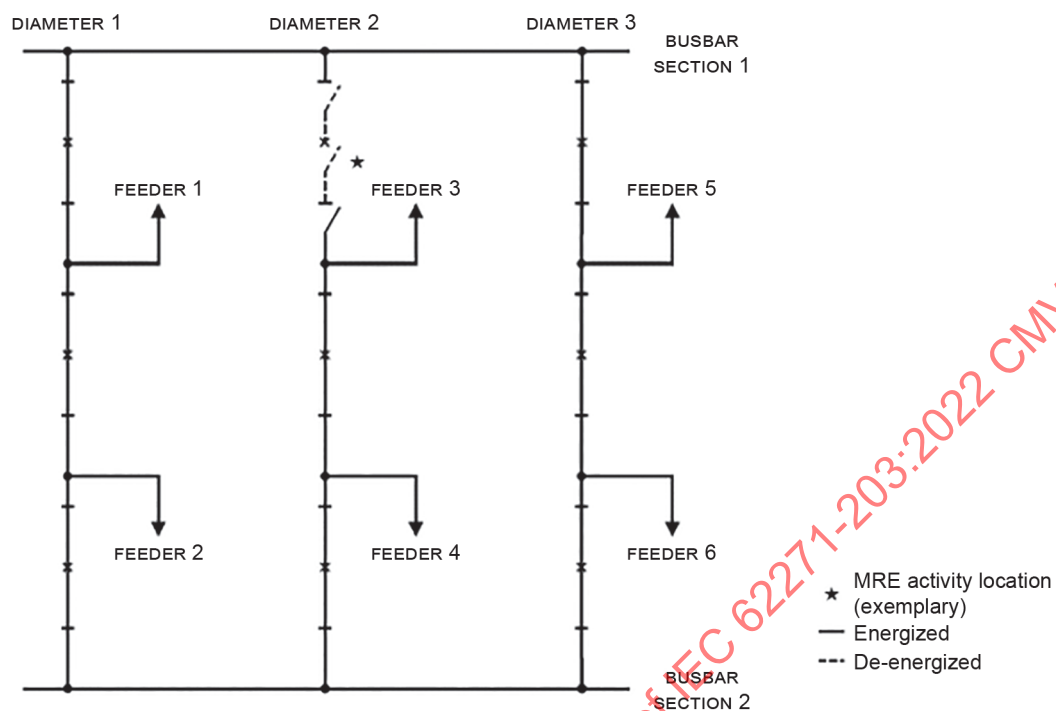
IEC

Figure F.7 – MRE2X (e.g. on-site dielectric test of busbar section A)



IEC

Figure F.8 – MRE2X (e.g. on-site dielectric test of busbar section 1)

One and half breaker configurations

IEC

Figure F.9 – MRE00 (e.g. repair of circuit-breaker)

Annex G
(informative)

List of notes concerning certain countries

Subclause	Text
5.11 and 6.104.2	National exceptions are required for Italy where rules for the design pressure is required by law.
7.2.12	National exceptions are required for Canada, France and Italy where it is required by law that the test voltage during condition check across the isolating distance of a disconnector be 100 % of the rated power-frequency test voltage.

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- [2] IEC 60050-471, *International Electrotechnical Vocabulary (IEV) – Part 471: Insulators* (available at www.electropedia.org)
- [3] IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*
- [4] IEC 60071-1:2019, *Insulation co-ordination – Part 1: Definitions, principles and rules*
- [5] 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*
- [6] IEC TS 60815-2, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*
- [7] IEC TS 60815-3, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*
- [8] IEC 61462, *Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V – Definitions, test methods, acceptance criteria and design recommendations*
- [9] IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*
- [10] IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*
- [11] IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*
- [12] 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
- [13] IEC TS 62478, *High voltage test techniques – Measurement of partial discharges by electromagnetic and acoustic methods*
- [14] IEC TS 63042-301, *UHV AC transmission systems – Part 301: On-site acceptance tests*
- [15] EN 50052, *High-voltage switchgear and controlgear – Gas-filled cast aluminium alloy enclosures*
- [16] EN 50064, *High-voltage switchgear and controlgear – Gas-filled wrought aluminium and aluminium alloy enclosures*
- [17] EN 50068, *High-voltage switchgear and controlgear – Gas-filled wrought steel enclosures*
- [18] EN 50069, *High-voltage switchgear and controlgear – Gas-filled welded composite enclosures of cast and wrought aluminium alloys*

- [19] EN 50089, *Specification for cast resin partitions for metal-enclosed gas-filled high-voltage switchgear and controlgear*
- [20] IEEE C37.122.6, *IEEE Recommended Practice for the Interface of New Gas-Insulated Equipment in Existing Gas-Insulated Substations Rated above 52 kV*
- [21] IEEE C37.24, *IEEE Guide For Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear*
- [22] IEEE C37.122.1, *IEEE Guide For Gas-Insulated Substations Rated above 52 kV*
- [23] CIGRE Technical Brochure 125, *User guide for the application of gas-insulated switchgear (GIS) for rated voltages of 72,5 kV and above*
- [24] CIGRE Technical Brochure 602, *Tools for simulation of the internal effects in HV and MV switchgear*
- [25] CIGRE Technical Brochure 654, *UHF partial discharge detection system for GIS – Application guide for sensitivity verification*
- [26] CIGRE Technical Brochure 802, *Application of non-SF₆ gases or gas-mixtures in medium and high voltage gas insulated switchgear*
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² To be published. Expected publication date 2022.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPAREILLAGE À HAUTE TENSION –

Partie 203: Appareillage sous enveloppe métallique à isolation gazeuse et à courant alternatif de tensions assignées supérieures à 52 kV

AVANT-PROPOS

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L'IEC 62271-203 a été établie par le sous-comité 17C: Ensembles, du comité d'études 17 de l'IEC: Appareillage haute tension. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2011. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) le document a été aligné sur l'IEC 62271-1:2017;
- b) outre le SF₆, des gaz alternatifs ont également été mis en œuvre lorsque nécessaire;
- c) les termes et définitions ont été actualisés et les termes non employés ont été supprimés;

- d) le paragraphe 6.16 “Étanchéité au gaz et au vide” a été actualisé;
- e) paragraphe 6.16.3 “Systèmes à pression autonome”: Deux classes de gaz ont été présentées:
- 1) $PRC \leq 1\,000$
 - 2) $PRC > 1\,000$
- et les exigences d'étanchéité relatives aux essais de type pour des gaz avec $PRC > 1\,000$ ont été réduites de 0,5 % à 0,1 % par an et par compartiment de gaz;
- f) paragraphe 6.108 “Interfaces”: des pressions maximales types en service pour les interfaces reliées au PSEM ont été définies;
- g) les paragraphes 7.2 à 7.8 ont été restructurés;
- h) le paragraphe 7.107 “Essai de corrosion sur les connexions de terre” a été actualisé;
- i) le paragraphe 7.108 “Essais de corrosion sur les systèmes d'étanchéité des enveloppes et des équipements auxiliaires” a été actualisé;
- j) l'Annexe F “Continuité de service” a été modifiée et alignée sur les recommandations du groupe de travail B3.51 du CIGRE.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
17C/835/FDIS	17C/844/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

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APPAREILLAGE À HAUTE TENSION –

Partie 203: Appareillage sous enveloppe métallique à isolation gazeuse et à courant alternatif de tensions assignées supérieures à 52 kV

1 Domaine d'application

La présente partie de l'IEC 62271 spécifie les exigences pour l'appareillage sous enveloppe métallique à isolation gazeuse dont l'isolation est réalisée, au moins partiellement, par un gaz isolant ou un mélange de gaz autre que l'air à la pression atmosphérique, pour courant alternatif de tensions assignées supérieures à 52 kV, pour l'installation à l'intérieur et à l'extérieur, et pour des fréquences de service inférieures ou égales à 60 Hz.

Pour les besoins du présent document, les termes "poste sous enveloppe métallique" (PSEM) et "appareillage" sont utilisés pour "appareillage sous enveloppe métallique à isolation gazeuse".

L'appareillage sous enveloppe métallique à isolation gazeuse auquel s'applique le présent document est constitué par des matériels individuels destinés à être directement raccordés entre eux et qui ne peuvent fonctionner que sous cette forme.

Le présent document complète et modifie, le cas échéant, les différentes normes pertinentes applicables aux matériels individuels constitutifs de l'appareillage sous enveloppe métallique à isolation gazeuse.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-11, *Essais d'environnement – Partie 2-11: Essais – Essai Ka: Brouillard salin*

IEC 60068-2-17, *Essais fondamentaux climatiques et de robustesse mécanique – Partie 2-17: Essais – Essai Q: Étanchéité*

IEC 60085:2007, *Isolation électrique – Évaluation et désignation thermiques*

IEC 60099-4:2014, *Parafoudres – Partie 4: Parafoudres à oxyde métallique sans éclateur pour réseaux à courant alternatif*

IEC 60137:2017, *Traversées isolées pour tensions alternatives supérieures à 1 000 V*

IEC 60141-1, *Essais de câbles à huile fluide, à pression de gaz et de leurs dispositifs accessoires – Partie 1: Câbles au papier à huile fluide et à gaine métallique et accessoires pour des tensions alternatives inférieures ou égales à 400 kV*

IEC 60270, *Technique des essais à haute tension – Mesures des décharges partielles*

IEC 60376, *Spécification de la qualité technique de l'hexafluorure de soufre (SF₆) et des gaz complémentaires à employer dans les mélanges de SF₆ pour utilisation dans les matériels électriques*

IEC 60480, *Spécifications pour la réutilisation de l'hexafluorure de soufre (SF₆) et des mélanges contenant du SF₆ dans le matériel électrique*

IEC 60840, *Câbles d'énergie à isolation extrudée et leurs accessoires pour des tensions assignées supérieures à 30 kV (U_m = 36 kV) et jusqu'à 150 kV (U_m = 170 kV) – Méthodes et exigences d'essai*

IEC 61869-1, *Transformateurs de mesure – Partie 1: Exigences générales*

IEC 61869-2, *Transformateurs de mesure – Partie 2: Exigences supplémentaires concernant les transformateurs de courant*

IEC 61869-3, *Transformateurs de mesure – Partie 3: Exigences supplémentaires concernant les transformateurs inductifs de tension*

IEC 62067, *Câbles d'énergie à isolation extrudée et leurs accessoires pour des tensions assignées supérieures à 150 kV (U_m = 170 kV) et jusqu'à 500 kV (U_m = 550 kV) – Méthodes et exigences d'essai*

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-4, *Appareillage à haute tension – Partie 4: Utilisation et manipulation de l'hexafluorure de soufre (SF₆) et des mélanges contenant du SF₆*

IEC 62271-100:2021, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif*

IEC 62271-102:2018, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

IEC 62271-209:2019, *Appareillage à haute tension – Partie 209: Raccordement de câbles pour appareillage sous enveloppe métallique à isolation gazeuse de tension assignée supérieure à 52 kV – Câbles remplis d'un fluide ou à isolation extrudée – Extrémité de câble de type sec ou remplie d'un fluide*

IEC 62271-211:2014, *Appareillage à haute tension – Partie 211: Raccordements directs entre transformateurs de puissance et appareillage sous enveloppe métallique à isolation gazeuse de tensions assignées supérieures à 52 kV*

ISO 22479, *Corrosion des métaux et alliages – Essai au dioxyde de soufre en atmosphère humide (méthode avec volume fixe de gaz)*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 62271-1:2017 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- ISO Online browsing platform: disponible à l'adresse <https://www.iso.org/obp>
- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>

3.101

appareillage sous enveloppe métallique

ensemble d'appareillage avec une enveloppe métallique externe destinée à être mise à la terre, entièrement terminé, à l'exception des connexions extérieures

[SOURCE: IEC 60050-441:1984, 441-12-04, modifié – La note a été supprimée.]

3.102

appareillage sous enveloppe métallique à isolation gazeuse

appareillage de connexion sous enveloppe métallique dans laquelle l'isolation est obtenue, au moins partiellement, par un gaz isolant ou un mélange de gaz autre que l'air à pression atmosphérique

Note 1 à l'article: Ce terme s'applique généralement à l'appareillage à haute tension.

Note 2 à l'article: Le terme "appareillage triphasé sous enveloppe métallique à isolation gazeuse" s'applique à l'appareillage dont les trois phases sont comprises dans une enveloppe commune

Note 3 à l'article: Le terme "appareillage monophasé sous enveloppe métallique à isolation gazeuse" s'applique à l'appareillage dont chaque phase est comprise dans une enveloppe individuelle.

[SOURCE: IEC 60050-441:1984, 441-12-05, modifié – "ou un mélange de gaz" a été ajouté dans la définition, et les Notes 2 et 3 à l'article ont été ajoutées.]

3.103

enveloppe de l'appareillage de commutation à isolation gazeuse

partie d'un appareillage sous enveloppe métallique à isolation gazeuse qui contient le gaz isolant dans les conditions prescrites nécessaires pour conserver avec sûreté le niveau d'isolement le plus élevé, qui protège l'équipement contre les effets extérieurs et qui procure un haut degré de protection pour les personnes

Note 1 à l'article: L'enveloppe peut être monophasée ou triphasée.

3.104

liaison d'isolation

partie du conducteur qui peut être aisément ouverte ou retirée afin d'isoler deux parties du poste sous enveloppe métallique (PSEM) à isolation gazeuse entre elles

Note 1 à l'article: La distance créée par le démontage de la liaison est conçue pour supporter les tensions d'essai sur la distance d'isolement selon le Tableau 2 et le Tableau 3.

Note 2 à l'article: Une liaison d'isolation a pour objet d'assurer l'isolation électrique entre les sections d'un PSEM, par exemple, lors d'une opération de maintenance et de réparations.

3.105

liaison amovible

partie du conducteur qui peut être facilement ouverte ou démontée afin de séparer l'une de l'autre deux parties d'un PSEM

Note 1 à l'article: La distance créée par le démontage de la liaison est conçue pour supporter les tensions d'essai phase-terre selon le Tableau 2 et le Tableau 3.

Note 2 à l'article: Une liaison amovible a pour objet d'assurer la séparation électrique entre les sections d'un PSEM lorsque l'équipement est séparé du reste du PSEM, par exemple, devant les transformateurs de tension, les parafoudres, les raccordements de câbles et de transformateurs lors d'essais haute tension du PSEM ou des matériels individuels.

3.106**compartiment**

partie d'un appareillage sous enveloppe métallique à isolation gazeuse qui est entièrement étanche

Note 1 à l'article: Un compartiment peut être désigné par le matériel individuel principal qu'il contient, par exemple, "compartiment disjoncteur", "compartiment barre omnibus".

3.107**matériel individuel**

partie essentielle du circuit principal ou de mise à la terre de l'appareillage sous enveloppe métallique à isolation gazeuse qui possède une fonction spécifique (par exemple, disjoncteur, sectionneur, interrupteur, fusible, transformateur de mesure, traversée, barre omnibus, etc.)

3.108**isolateur support**

isolateur interne qui sert à supporter un ou plusieurs conducteurs

3.109**cloison**

isolateur support étanche au gaz d'un appareillage sous enveloppe métallique à isolation gazeuse qui sépare deux compartiments adjacents

3.110**traversée**

dispositif servant à faire passer un ou plusieurs conducteurs à travers une enveloppe, en isolant les conducteurs de cette paroi

[SOURCE: IEC 60050-471:2007, 471-02-01, modifié – "une paroi" remplacé par "une enveloppe" et "telle qu'un mur ou une cuve" supprimé. Les Notes 1 et 2 ont été supprimées.]

3.111**circuit principal**

toutes les pièces conductrices d'un appareillage sous enveloppe métallique à isolation gazeuse qui font partie d'un circuit destiné à transporter l'énergie électrique

[SOURCE: IEC 60050-441:1984, 441-13-02, modifié – "ensemble" remplacé par "appareillage sous enveloppe métallique à isolation gazeuse"]

3.112**circuit auxiliaire**

toutes les pièces conductrices d'un appareillage sous enveloppe métallique à isolation gazeuse insérées dans un circuit, destinées à la commande, le mesurage, la signalisation et la régulation

Note 1 à l'article: Les circuits auxiliaires d'un appareillage sous enveloppe métallique à isolation gazeuse comprennent les circuits de commande et les circuits auxiliaires des appareils de commutation.

3.113**température de calcul de l'enveloppe**

température maximale qui peut être atteinte par les enveloppes dans les conditions de service maximales spécifiées

3.114**pression de calcul de l'enveloppe**

pression relative utilisée pour déterminer la conception de l'enveloppe

Note 1 à l'article: Elle est au moins égale à la pression maximale de l'enveloppe à la température la plus élevée que le gaz utilisé pour l'isolation peut atteindre dans des conditions de service maximales spécifiées.

Note 2 à l'article: La pression transitoire qui apparaît pendant et après une manœuvre de coupure (par exemple, d'un disjoncteur) n'est pas prise en considération pour la détermination de la pression de calcul.

3.115

pression de calcul de la cloison

pression relative sur la cloison utilisée pour déterminer sa pression de calcul

Note 1 à l'article: Elle est au moins égale au différentiel de pression maximal sur la cloison pendant les activités de maintenance.

Note 2 à l'article: La pression transitoire qui apparaît pendant et après une manœuvre de coupure (par exemple, d'un disjoncteur) n'est pas prise en considération pour la détermination de la pression de calcul.

3.116

pression de fonctionnement

<dispositif limiteur de pression> pression relative retenue pour l'ouverture des dispositifs limiteurs de pression

3.117

pression d'essai individuel de série

<enveloppes et cloisons> pression relative à laquelle toutes les enveloppes et toutes les cloisons sont soumises après fabrication

3.118

pression d'essai de type

<enveloppes et cloisons> pression relative à laquelle les enveloppes et les cloisons sont soumises pour l'essai de type

3.119

fragmentation

tout dommage subi par l'enveloppe du fait d'une augmentation de la pression accompagnée de projection de matières

3.120

décharge disruptive

phénomènes associés à la défaillance de l'isolation sous l'action d'une contrainte électrique, dans lesquels la décharge court-circuite complètement l'isolation en cours d'essai, réduisant la tension entre les électrodes à une valeur nulle ou presque nulle

3.121

unité de transport

partie d'un appareillage sous enveloppe métallique à isolation gazeuse qui peut être transportée sans être démontée

3.122

unité fonctionnelle

partie d'un appareillage sous enveloppe métallique qui comprend tous les éléments des circuits principaux et des circuits auxiliaires qui concourent à l'exécution d'une seule fonction

Note 1 à l'article: Les unités fonctionnelles peuvent se différencier selon la fonction pour laquelle elles sont prévues, par exemple: travée monophasée ou triphasée ou parties fonctionnelles d'une travée comme le disjoncteur complet, le sectionneur, le sectionneur de terre, le transformateur de tension, le transformateur de courant, le mécanisme de commande, l'enveloppe, etc.

[SOURCE: IEC 60050-441:1984, 441-13-04, modifié – Dans la définition, "ensemble" remplacé par "appareillage sous enveloppe métallique". Dans la note, les exemples ont été remplacés par des exemples en rapport avec le PSEM.]

4 Conditions normales et spéciales de service

4.1 Conditions normales de service

Le paragraphe 4.1 de l'IEC 62271-1:2017 est applicable, compte tenu des valeurs recommandées présentées dans le Tableau 1 du présent document.

4.2 Conditions spéciales de service

Le paragraphe 4.2 de l'IEC 62271-1:2017 est applicable, compte tenu des valeurs recommandées présentées dans le Tableau 1 du présent document.

Lorsque le symbole "plus grand que" (>) est utilisé dans le Tableau 1, les valeurs doivent être spécifiées par l'utilisateur, comme cela est décrit dans l'IEC 62271-1:2017.

4.101 Généralités

Tableau 1 – Tableau de référence des conditions de service applicables aux PSEM

Désignation	Normales		Spéciales	
	Intérieur	Extérieur	Intérieur	Extérieur
Température de l'air ambiant:				
Minimale (°C)	-5	-25	-25	-50
Maximale (°C)	+40	+40	+50	+50
Rayonnement solaire (W/m ²)	Non applicable	1 000	Non applicable	>1 000
Altitude (m)	1 000	1 000	>1 000	>1 000
Sévérité de pollution d'un site ^a	Non applicable	c	c, d ou e	d ou e
Épaisseur de glace (mm)	Non applicable	20	Non applicable	>20
Vent (m/s)	Non applicable	34	Non applicable	>34
Humidité moyenne sur 24 h (%)	95	100	98	100
Condensation ou précipitation	Occasionnelle	Oui	Oui	Oui
Vibrations, chocs ou inclinaisons anormaux	Non applicable	Non applicable	Applicable	Applicable
NOTE La spécification de l'utilisateur peut utiliser une combinaison quelconque des conditions normales ou spéciales de service ci-dessus.				
^a Sévérité de pollution d'un site c, d ou e selon 8.3 de l'IEC TS 60815-1:2008 [5] ¹				

Quelle que soit l'altitude, les caractéristiques diélectriques de l'isolation interne sont identiques à celles qui sont mesurées au niveau de la mer. Pour cette isolation interne, aucune exigence spécifique n'est applicable concernant l'altitude.

Certains éléments d'un PSEM, tels que les dispositifs limiteurs de pression et les dispositifs de surveillance de pression et de densité, peuvent être sensibles aux effets de l'altitude. Le fabricant doit prendre, le cas échéant, les mesures nécessaires.

¹ Les chiffres entre crochets renvoient à la Bibliographie.

5 Caractéristiques assignées

5.1 Généralités

Le paragraphe 5.1 de l'IEC 62271-1:2017 est applicable avec les modifications suivantes:

- e) courant de courte durée admissible assigné (I_k) (pour les circuits principaux et les circuits de mise à la terre);
- f) valeur de crête du courant admissible assigné (I_p) (pour les circuits principaux et les circuits de mise à la terre);

et avec le complément suivant:

- k) valeurs assignées des matériels qui font partie intégrante de l'appareillage sous enveloppe métallique à isolation gazeuse, y compris leurs dispositifs de manœuvre et l'équipement auxiliaire.

5.2 Tension assignée (U_r)

Le paragraphe 5.2 de l'IEC 62271-1:2017 est applicable avec le complément suivant:

Les matériels individuels qui font partie intégrante du PSEM peuvent avoir leurs propres valeurs de tension assignée conformément aux normes correspondantes.

5.3 Niveau d'isolement assigné (U_d , U_p , U_s)

Le paragraphe 5.3 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Le Tableau 1, le Tableau 2, le Tableau 3 et le Tableau 4 du 5.3 de l'IEC 62271-1:2017 sont remplacés par le Tableau 2 et le Tableau 3 ci-dessous.

NOTE 1 Les valeurs plus élevées de PSEM de l'IEC 62271-203 comparées aux valeurs de l'IEC 62271-1 ont été présentées dans la révision 1 de 2003. Ce sont désormais des valeurs normalisées.

Le PSEM contient des matériels individuels qui ont un niveau d'isolement défini. Bien que les défauts internes puissent, dans une large mesure, être évités par le choix d'un niveau d'isolement convenable, il convient d'envisager des moyens de limitation des surtensions externes (par exemple, parafoudres).

NOTE 2 Pour ce qui est des pièces externes des traversées (si elles existent), voir l'IEC 60137:2017.

NOTE 3 Les formes d'onde sont des formes de choc de foudre et des formes de tension de choc de manœuvre normalisées, dans l'attente des résultats des études sur la tenue de ces matériels à d'autres types de chocs.

NOTE 4 Le choix entre les différents niveaux d'isolement qui correspondent à une tension assignée particulière peut reposer sur des études de coordination d'isolement qui tiennent également compte des surtensions transitoires engendrées par les manœuvres des matériels qui font partie de l'appareillage.

Tableau 2 – Niveaux d'isolement assignés pour les tensions assignées de l'équipement de la plage I (jusqu'à 245 kV)

Tension assignée de l'équipement U_r kV (valeur efficace)	Tension de tenue assignée de courte durée à fréquence industrielle U_d kV (valeur efficace)		Tension de tenue assignée au choc de foudre U_p kV (valeur de crête)	
	Entre phase et terre, entre contacts ouverts de l'appareil de commutation et entre phases	Sur la distance d'isolement	Entre phase et terre, entre contacts ouverts de l'appareil de commutation et entre phases	Sur la distance d'isolement
(1)	(2)	(3)	(4)	(5)
72,5	140	160	325	375
100	185	210	450	520
123	230	265	550	630
145	275	315	650	750
170	325	375	750	860
245	460	530	1 050	1 200
NOTE Les valeurs de la colonne (2) sont applicables: a) pour les essais de type, entre phase et terre et entre phases; b) pour les essais individuels de série, entre phase et terre, entre phases, et entre contacts ouverts de l'appareil de commutation. Les valeurs des colonnes (3), (4) et (5) sont applicables pour les essais de type seulement.				

Tableau 3 – Niveaux d'isolement assignés pour les tensions assignées de l'équipement de la plage II (au-delà de 245 kV)

Tension assignée de l'équipement U_r kV (valeur efficace)	Tension de tenue assignée de courte durée à fréquence industrielle U_d kV (valeur efficace)		Tension de tenue assignée au choc de manœuvre U_p kV (valeur de crête)			Tension de tenue assignée au choc de foudre U_p kV (valeur de crête)	
	Entre phase et terre et entre phases (Note 3 et Note 5)	Entre contacts ouverts de l'appareil de commutation et/ou sur la distance d'isolement (Note 3)	Entre phase et terre et entre contacts ouverts de l'appareil de commutation (Note 5)	Entre phases (Note 3 et Note 4)	Sur la distance d'isolement (Note 1, Note 2 et Note 3)	Entre phase et terre et entre phases (Note 5)	Entre contacts ouverts de l'appareil de commutation et/ou sur la distance d'isolement (Note 2 et Note 3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	460	595	850	1 275	700 (+245)	1 050	1 050 (+170)
362	520	675	950	1 425	800 (+295)	1 175	1 175 (+205)
420	650	815	1 050	1 575	900 (+345)	1 425	1 425 (+240)
550	710	925	1 175	1 760	900 (+450)	1 550	1 550 (+315)
800	960	1 270	1 425	2 420	1 100 (+650)	2 100	2 100 (+455)
1 100	1 100	1 100	1 550	2 635	1 550 +(900)	2 250	2 250 + (630)
		1 100 +(635)	1 800	2 880	1 675 +(900)	2 400	2 400 + (630)
1 200	1 200	1 200	1 800	2 970	1 675 +(980)	2 400	2 400 + (685)
		1 200 +(695)	1 950	3 120		2 550	2 550 + (685)

NOTE 1 La colonne (6) s'applique aussi à certains disjoncteurs, voir l'IEC 62271-100:2021.

NOTE 2 Dans la colonne (6), les valeurs entre parenthèses sont les valeurs de crête de la tension à fréquence industrielle $U_r \sqrt{2} / \sqrt{3}$ appliquée à la borne opposée (tension combinée).

Dans la colonne (8), les valeurs entre parenthèses sont les valeurs de crête de la tension à fréquence industrielle $0,7 U_r \sqrt{2} / \sqrt{3}$ appliquée à la borne opposée (tension combinée).

NOTE 3 Les valeurs de la colonne (2) sont applicables:

- pour les essais de type, entre phase et terre et entre phases;
- pour les essais individuels de série, entre phase et terre, entre phases, et entre contacts ouverts de l'appareil de commutation.

Les valeurs des colonnes (3), (4), (5), (6), (7) et (8) sont applicables pour les essais de type seulement.

NOTE 4 Il s'agit de valeurs qui proviennent des facteurs multiplicateurs indiqués dans le Tableau 3 de l'IEC 60071-1:2019 [4].

NOTE 5 Pour les sectionneurs de terre, seuls les essais entre phase et terre selon les colonnes (2), (4) et (7) sont applicables.

5.4 Fréquence assignée (f_r)

Le paragraphe 5.4 de l'IEC 62271-1:2017 est applicable.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Certains circuits principaux des PSEM (barres omnibus, circuits d'alimentation, etc.) peuvent avoir des valeurs différentes de courant permanent assigné. Cependant, il convient de choisir également ces valeurs dans la série R10.

5.6 Courant de courte durée admissible assigné (I_k)

Le paragraphe 5.6 de l'IEC 62271-1:2017 est applicable.

5.7 Valeur de crête du courant admissible assignée (I_p)

Le paragraphe 5.7 de l'IEC 62271-1:2017 est applicable.

5.8 Durée de court-circuit assignée (t_k)

Le paragraphe 5.8 de l'IEC 62271-1:2017 est applicable.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le paragraphe 5.9 de l'IEC 62271-1:2017 est applicable.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le paragraphe 5.10 de l'IEC 62271-1:2017 est applicable.

5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue

Le paragraphe 5.11 de l'IEC 62271-1:2017 est applicable.

6 Conception et construction

6.1 Exigences pour les liquides utilisés dans l'appareillage

Le paragraphe 6.1 de l'IEC 62271-1:2017 est applicable.

6.2 Exigences pour les gaz utilisés dans l'appareillage

Le paragraphe 6.2 de l'IEC 62271-1:2017 est applicable.

6.3 Raccordement à la terre de l'appareillage

Le paragraphe 6.3 de l'IEC 62271-1:2017 est applicable.

6.3.101 Raccordement à la terre du circuit principal

Pour assurer la sécurité lors d'interventions de maintenance, toutes les parties du circuit principal auquel l'accès est prévu ou exigé doivent pouvoir être mises à la terre.

La mise à la terre peut être réalisée par:

- a) des sectionneurs de terre avec un pouvoir de fermeture égal à la valeur de crête du courant admissible assignée, s'il reste une possibilité que le circuit connecté soit encore sous tension;

- b) des sectionneurs de terre sans pouvoir de fermeture ou avec un pouvoir de fermeture inférieur à la valeur de crête du courant admissible assignée, si le circuit raccordé est mis hors tension de façon certaine.

De plus, il doit être possible, après ouverture de l'enveloppe, de raccorder les dispositifs amovibles de mise à la terre pendant la durée de l'intervention sur un élément de circuit mis préalablement à la terre à l'aide d'un sectionneur de terre. Le dispositif amovible de mise à la terre doit présenter la capacité de tenue aux courts-circuits et/ou la capacité de tenue aux courants induits adaptées.

Le circuit de mise à la terre peut être dégradé après avoir été soumis au courant de court-circuit. Après cet événement, il peut être nécessaire de remplacer le circuit de mise à la terre.

6.3.102 Raccordement à la terre de l'enveloppe

Les enveloppes doivent être connectées à la terre. Toutes les parties métalliques qui ne font pas partie d'un circuit principal ou auxiliaire doivent être mises à la terre. Pour l'interconnexion des enveloppes, charpentes, etc., l'assemblage (par exemple, par boulonnage ou soudage) est acceptable pour assurer la continuité électrique.

La continuité des circuits de mise à la terre doit être assurée en tenant compte des contraintes thermiques et électriques provoquées par le courant qui peut devoir les traverser.

Pour les appareillages monophasés sous enveloppe, il convient qu'un circuit de bouclage, c'est-à-dire une interconnexion entre les enveloppes des trois phases, soit mis en place pour le courant induit. Il convient que chacun de ces circuits de bouclage soit relié aussi directement que possible au réseau général de terre par un conducteur qui peut supporter le courant de court-circuit.

NOTE Les circuits de bouclage sont destinés à empêcher que les courants induits dans les enveloppes ne circulent dans les circuits de mise à la terre et dans le réseau de terre. Ils sont habituellement dimensionnés pour le courant permanents assigné et sont installés à un emplacement approprié, en fonction de l'implantation de l'installation du PSEM.

6.4 Équipements et circuits auxiliaires et de commande

Le paragraphe 6.4 de l'IEC 62271-1:2017 et de l'IEC 62271-1:2017/AMD1:2021 est applicable.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 est applicable.

6.6 Manœuvre à accumulation d'énergie

Le paragraphe 6.6 de l'IEC 62271-1:2017 est applicable.

6.7 Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)

Le paragraphe 6.7 de l'IEC 62271-1:2017 est applicable.

6.8 Organes de commande à manœuvre manuelle

Le paragraphe 6.8 de l'IEC 62271-1:2017 est applicable.

6.9 Fonctionnement des déclencheurs

Le paragraphe 6.9 de l'IEC 62271-1:2017 est applicable.

6.10 Indication de la pression/du niveau

Le paragraphe 6.10 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Les performances du PSEM dépendent de la densité du gaz pur ou des mélanges de gaz.

Pour le PSEM, la surveillance de la pression de gaz sans compensation de la température n'est pas suffisante.

La densité de gaz ou la pression de gaz compensée en température dans chaque compartiment doit être surveillée en continu. Le dispositif de surveillance doit comporter au moins deux niveaux d'alarme pour la pression ou la densité (seuil de pression d'alarme et seuil de pression minimale de fonctionnement ou seuil de densité d'alarme et seuil de densité minimale de fonctionnement). Le bon fonctionnement des dispositifs de surveillance du gaz doit pouvoir être contrôlé avec l'équipement haute tension en service.

NOTE 1 Lorsque la conception du PSEM permet de l'appliquer et lorsque la pression de remplissage diffère entre compartiments adjacents, une alarme supplémentaire qui indique un seuil de pression excessif ou un seuil de densité excessif peut être mise en œuvre.

NOTE 2 Les tolérances du dispositif de surveillance, ainsi que les éventuels écarts de température (par exemple, intérieur/extérieur d'un bâtiment) entre le dispositif de surveillance et le volume de gaz sous surveillance, peuvent être pris en considération.

NOTE 3 Le contrôle du dispositif de surveillance du gaz peut générer des alarmes intempestives qui peuvent déclencher ou interdire des manœuvres.

NOTE 4 Il est préférable de placer les dispositifs de surveillance du gaz aussi près que possible du compartiment de gaz surveillé pour assurer la précision de mesure et pour réduire le plus possible les fuites de gaz. Toutefois, le choix de l'emplacement peut prendre en considération la sécurité et l'accessibilité.

NOTE 5 La solution préférentielle de contrôle du dispositif de surveillance du gaz consiste à isoler le dispositif de surveillance de la densité du gaz du compartiment de gaz sans le retirer mécaniquement du PSEM, afin de réduire le plus possible les pertes de gaz.

6.11 Plaques signalétiques

Le paragraphe 6.11 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Une plaque signalétique commune doit être fournie pour identifier le PSEM. Au moins, elle doit indiquer les caractéristiques assignées énumérées à l'Article 5 du présent document. La plaque signalétique commune doit être clairement lisible à partir de la position de l'exploitation locale.

Pour chaque matériel individuel, une plaque signalétique conforme à sa norme correspondante est exigée, lorsque les caractéristiques assignées ne sont pas indiquées sur la plaque signalétique commune.

Les plaques signalétiques doivent être durables et facilement lisibles pendant la durée de vie du PSEM.

Le fabricant doit donner des informations relatives au type, au volume et à la masse du gaz contenu dans chaque compartiment de gaz. La masse totale de l'ensemble de l'installation PSEM doit aussi apparaître, soit sur la plaque signalétique, soit sur une étiquette placée dans un endroit visible. Si cela est exigé, des informations plus complètes doivent être communiquées dans le manuel d'instructions.

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Les dispositions suivantes sont obligatoires pour les appareils installés dans les circuits principaux qui sont utilisés comme distance d'isolement et comme mise à la terre:

- les appareils installés dans les circuits principaux, qui servent à assurer les distances d'isolement durant des travaux de maintenance, doivent être équipés de dispositifs de verrouillage visibles pour éviter la fermeture (par exemple, cadenas);
- les sectionneurs de terre doivent être équipés de dispositifs de verrouillage pour éviter l'ouverture pendant les travaux de maintenance.

6.13 Indicateur de position

Le paragraphe 6.13 de l'IEC 62271-1:2017 est applicable avec le complément suivant:

Dans le cas du sectionneur et du sectionneur de terre, le 6.104.3.2 de l'IEC 62271-102:2018 est applicable.

6.14 Degrés de protection procurés par les enveloppes

Le paragraphe 6.14 de l'IEC 62271-1:2017 est applicable.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le paragraphe 6.15 de l'IEC 62271-1:2017 est applicable avec le complément suivant:

Ce paragraphe n'est applicable qu'aux traversées.

6.16 Étanchéité au gaz et au vide

6.16.1 Généralités

Le paragraphe 6.16.1 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Ce paragraphe s'applique uniquement au milieu isolant et au milieu de commutation, et non au milieu de fonctionnement de l'appareillage.

Le PSEM doit être un système à pression autonome ou un système à pression scellé.

Les pertes de gaz dues aux fuites et aux manipulations doivent être traitées séparément. L'objectif consiste à réduire le plus possible les pertes de gaz dans l'atmosphère dues à une fuite et à la manipulation (voir l'IEC 62271-4).

La cause d'une fuite doit être examinée avec soin et des actions correctives doivent être envisagées, en particulier si les valeurs associées à toute fuite dépassent les limites spécifiées dans le présent document.

6.16.2 Systèmes à pression entretenue de gaz

Le paragraphe 6.16.2 de l'IEC 62271-1:2017 est applicable.

6.16.3 Systèmes à pression autonome de gaz

Le paragraphe 6.16.3 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Le taux de fuite relatif à l'atmosphère de tout compartiment d'un PSEM, et entre les compartiments eux-mêmes ne doit pas dépasser 0,5 % par an pendant la durée de vie prévue de l'équipement.

NOTE 1 La durée de vie prévue est en général de 40 ans dans les conditions normales de service, comme spécifié dans l'Annex E.

Le taux de fuite relatif maximal F_{rel} pour les essais de type est spécifié comme suit:

- $\leq 0,1$ % par an pour les équipements qui fonctionnent au SF₆, aux mélanges de SF₆ et à d'autres mélanges de gaz avec PRC > 1 000.
- $\leq 0,5$ % par an pour les autres mélanges de gaz avec PRC ≤ 1 000.

NOTE 2 Le potentiel de réchauffement climatique (PRC) des gaz dans le PSEM constitue la principale raison de l'exigence de faibles taux de fuite admissibles. Il existe des solutions avec d'autres gaz dont le potentiel de réchauffement climatique est inférieur à 1 000. Le PRC (100 ans) du SF₆ est de 23 500, conformément à l'IPCC – AR5 Climate Change 2013 [31].

Pour les petits compartiments de gaz qui contiennent moins de 1 kg de gaz, le taux de fuite relatif admissible F_{rel} pour les essais de type est spécifié comme suit:

- $\leq 0,2$ % par an pour les équipements fonctionnant au SF₆, aux mélanges SF₆, et à d'autres mélanges de gaz avec PRC > 1 000.

6.16.4 Systèmes à pression scellés

Le paragraphe 6.16.4 de l'IEC 62271-1:2017 est applicable.

6.16.101 Fuite

Conformément à la procédure normalisée définie à l'Article 10 de l'IEC TR 62271-306:2012 et dans l'IEC TR 62271-306:2012/AMD1:2018 [12], le fabricant doit démontrer que le taux de fuite relatif de tout compartiment du PSEM ou que le taux de fuite relatif entre les compartiments est conforme à 6.16.3 ou 6.16.4.

6.16.102 Manipulation du gaz

Le PSEM doit être conçu pour réduire le plus possible les pertes provoquées par la manipulation du gaz sur sa durée de vie (y compris les activités de fin de vie). Le fabricant doit spécifier les procédures d'essai et de maintenance destinées à réduire le plus possible les pertes par manipulation du gaz et doit déterminer la perte de gaz associée à chaque procédure.

Le fabricant doit recommander des procédures de manipulation du gaz conformes à l'IEC 62271-4.

6.17 Étanchéité des systèmes de liquide

Le paragraphe 6.17 de l'IEC 62271-1:2017 est applicable.

6.18 Risque de feu (inflammabilité)

Le paragraphe 6.18 de l'IEC 62271-1:2017 est applicable.

6.19 Compatibilité électromagnétique (CEM)

Le paragraphe 6.19 de l'IEC 62271-1:2017 est applicable.

6.20 Émission de rayons X

Le paragraphe 6.20 de l'IEC 62271-1:2017 est applicable avec le complément suivant:

Ne s'applique qu'aux PSEM avec ampoules à vide.

6.21 Corrosion

Le paragraphe 6.21 de l'IEC 62271-1:2017 est applicable avec le complément suivant:

La corrosion des ensembles boulonnés et vissés doit être prise en compte pour assurer la continuité des circuits de mise à la terre.

6.22 Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre

Le paragraphe 6.22 de l'IEC 62271-1:2017 est applicable.

6.101 Exigences générales pour le PSEM

Le PSEM doit être conçu de sorte que les opérations normales d'exploitation, d'inspection et de maintenance, la mise à la terre des câbles raccordés, la localisation des défauts dans les câbles, les essais de tension sur les câbles ou les autres appareils raccordés et la suppression des charges électrostatiques dangereuses puissent être effectués en toute sécurité, y compris la vérification de l'ordre de succession des phases après installation et après extension.

La conception de l'équipement doit être telle que le déplacement admissible et accepté des fondations et les effets thermiques ou mécaniques n'affectent pas ses performances assignées.

Tous les matériels individuels de même type (caractéristiques assignées, conception et construction, etc.) qui peuvent être remplacés doivent être interchangeables.

Les différents matériels contenus dans l'enveloppe sont soumis aux normes correspondantes, sauf lorsque ces dernières sont modifiées par le présent document.

6.102 Coordination de pression

La pression à l'intérieur d'un PSEM peut ne pas correspondre à la pression de remplissage p_{re} en raison de conditions de service différentes.

Dans les conditions de service, les contraintes mécaniques sont associées à la pression interne, qui dépend de la température du gaz. En conséquence, la pression maximale en service correspond à la pression de remplissage à la température maximale que le gaz peut atteindre en raison d'un courant permanent et des conditions de service (température, rayonnement solaire, par exemple).

La Figure 1 représente les différents niveaux de pression et leur interactivité.

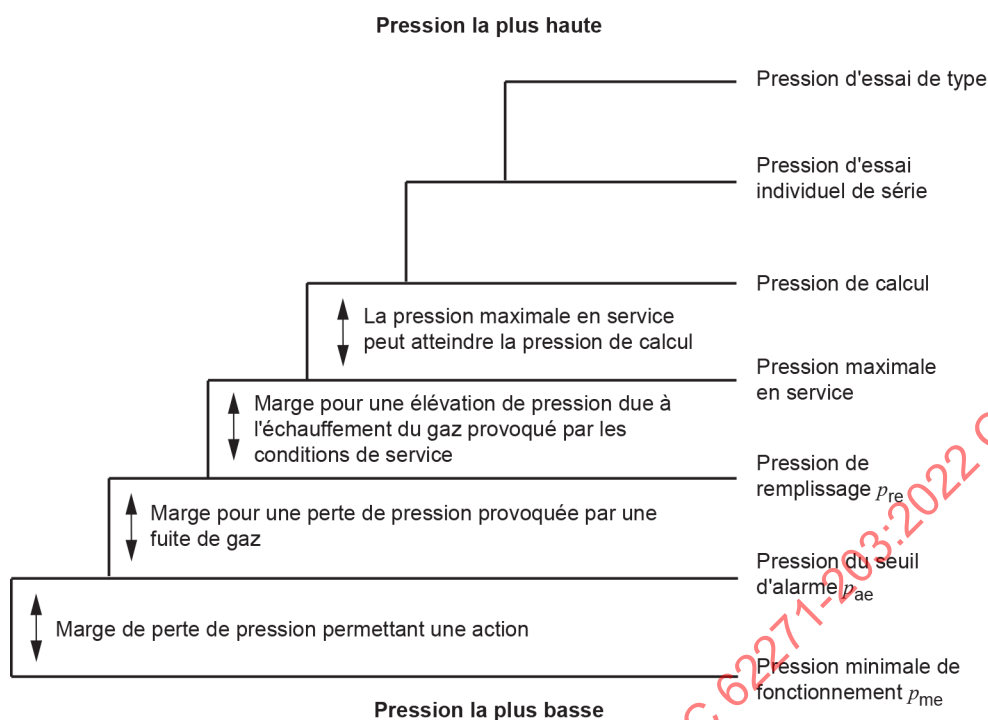


Figure 1 – Coordination de pression

Il incombe au fabricant de choisir la pression minimale de fonctionnement pour l'isolement p_{me} et la pression de remplissage p_{re} .

Le fabricant doit proposer la pression du seuil d'alarme p_{ae} liée à la pression de remplissage p_{re} et à la pression minimale de fonctionnement. La pression du seuil d'alarme p_{ae} informe l'utilisateur de la présence d'une fuite de gaz. Pour un PSEM qui utilise un gaz avec $PRC > 1\,000$, la pression de remplissage p_{re} et la pression du seuil d'alarme p_{ae} doivent être aussi proches que possible, en prenant en considération les tolérances des capteurs de densité, afin d'informer l'utilisateur le plus tôt possible des pertes de gaz.

Les conditions d'installation (intérieur, extérieur, rayonnements solaires directs, ...), la conception et les tolérances du dispositif de surveillance du gaz doivent être prises en considération.

L'intervalle de temps entre la pression du seuil d'alarme p_{ae} et la pression minimale de fonctionnement p_{me} permet à l'utilisateur d'entreprendre des actions correctives. Cet intervalle dépend du taux de fuite du gaz. Durant cet intervalle de temps, les tolérances des dispositifs de surveillance du gaz doivent être prises en considération.

6.103 Défaut d'arc interne

6.103.1 Généralités

La probabilité d'un défaut conduisant à un arc dans le PSEM, construit selon le présent document, est très faible. Cette probabilité résulte de l'utilisation d'un fluide isolant autre que l'air à la pression atmosphérique, exempt de pollution, d'humidité ou de vermine.

Un PSEM doit être conçu, fabriqué et exploité afin d'empêcher l'occurrence de tout défaut interne. Toutes les mesures possibles pour maintenir une très faible probabilité d'occurrence doivent être prises comme:

- coordination de l'isolement;
- limitation et maîtrise de toute fuite de gaz;
- contrôle de la qualité du gaz;
- haute qualité du travail sur site;
- interverrouillage de l'appareil de commutation.

La très faible probabilité d'un tel événement doit être prise en considération. Des dispositions doivent être prises pour réduire le plus possible les effets des défauts internes sur la continuité de service (par exemple, protection très rapide, commande à distance, compartiments de gaz supplémentaires). L'arc interne ne doit pas se propager dans les compartiments de gaz adjacents.

Après un tel événement, une intervention est nécessaire afin d'isoler le compartiment en défaut. La conception générale du compartimentage du PSEM doit permettre la restauration de la partie du PSEM non affectée, afin de satisfaire aux exigences de continuité de service, lorsque celles-ci sont définies (voir l'Annex F).

6.103.2 Effets externes de l'arc

Les effets d'un arc interne sont:

- l'augmentation de la pression du gaz (voir l'Annex D);
- l'éventuelle perforation de l'enveloppe.

Les effets externes de l'arc doivent être limités à l'apparition d'un trou ou d'une déchirure sur l'enveloppe sans aucune fragmentation. Cette limitation doit s'effectuer par un système de protection approprié. La durée de l'arc est liée aux performances du système de protection déterminées par le premier stade (protection principale) et par le second stade (protection de secours).

Le Tableau 4 donne les critères de performance pour la durée de l'arc en fonction des performances du système de protection.

Tableau 4 – Critères de performance

Courant de court-circuit assigné	Stade de protection	Durée du courant de court-circuit	Critères de performance
<40 kA (valeur efficace)	1	≤0,2 s	Absence d'effet externe autre que le fonctionnement de dispositifs limiteurs de pression adaptés
	2	≤0,5 s	Absence de fragmentation (perforation acceptable)
≥ 40 kA (valeur efficace)	1	≤0,1 s	Absence d'effet externe autre que le fonctionnement de dispositifs limiteurs de pression adaptés
	2	≤0,3 s	Absence de fragmentation (perforation acceptable)

L'expression "enveloppe sans fragmentation" est interprétée comme suit:

- absence d'explosion du compartiment;
- absence de projections de particules solides hors du compartiment.

Exceptions:

- les pièces du dispositif limiteur de pression ou des parties internes à celles-ci, si leur éjection est dirigée;
- les éléments incandescents et les matières fondues dus à la perforation de l'enveloppe.

De plus, le fabricant et l'utilisateur peuvent déterminer une durée pendant laquelle un arc provoqué par un défaut interne et caractérisé par une valeur donnée de courant de court-circuit ne provoque pas d'effets externes. Cette durée doit être définie en fonction des résultats d'essai ou d'une procédure de calcul reconnue. Voir l'Équation (D.1).

La durée du courant sans perforation pour différentes valeurs de courant de court-circuit peut être estimée à partir d'une procédure de calcul reconnue, comme celles présentées dans les publications suivantes: brochure technique 602 du CIGRE [24], CIGRE Session 1998 – WG 21/23/33-03 [28] et RGE: 04/82 [29].

6.103.3 Localisation de défaut interne

Il convient que le fabricant de PSEM propose des méthodes appropriées de détermination de la localisation d'un défaut, si cela est exigé par l'utilisateur.

6.104 Enveloppes

6.104.1 Généralités

L'enveloppe doit pouvoir supporter les pressions normales et transitoires auxquelles elle est soumise en service.

6.104.2 Conception des enveloppes

L'enveloppe doit être conçue conformément aux normes établies concernant les enveloppes sous pression des appareillages à haute tension remplis de gaz inertes non corrosifs et faiblement pressurisés. Pour plus d'informations, voir l'EN 50052 [15], l'EN 50064 [16], l'EN 50068 [17], l'EN 50069 [18].

Les méthodes de calcul de l'épaisseur et la construction des enveloppes, soudées ou moulées, doivent se fonder sur la pression de calcul (voir la définition en 3.114).

Pour la conception d'une enveloppe, il faut également tenir compte des données suivantes:

- a) la récupération ou la vidange éventuelle du gaz ou de l'air dans l'enveloppe au cours des opérations normales de remplissage;
- b) le différentiel de pression total de part et d'autre des parois de l'enveloppe ou des cloisons;
- c) la pression résultant d'une fuite accidentelle entre compartiments, pour des compartiments adjacents remplis à des pressions de service différentes, si la surpression n'est pas contrôlée;
- d) la possibilité d'apparition d'un défaut interne (voir 6.103);
- e) l'impact de la corrosion sur les enveloppes doit être pris en considération par des mesures appropriées (matériau filtrant pour absorber l'humidité et les produits de décomposition, par exemple).

Pour déterminer la pression de calcul, la température du gaz doit être considérée comme la moyenne des limites supérieures de la température de l'enveloppe et de celle du conducteur du circuit principal sous le courant permanent assigné, sauf si la pression de calcul peut être déduite des enregistrements d'essai de courant permanent existants.

Pour les enveloppes et parties d'enveloppes dont la résistance n'a pas été totalement démontrée par calcul, des essais d'épreuves (voir 7.103) doivent être réalisés pour démontrer qu'elles satisfont aux exigences.

Les matériaux utilisés dans la construction des enveloppes doivent avoir des caractéristiques physiques minimales connues et certifiées, sur lesquelles se fondent les calculs et/ou aux essais d'épreuves. Le fabricant doit être responsable du choix des matériaux et du respect de ces caractéristiques minimales, sur la base d'une certification du fournisseur de ces matériaux ou des essais réalisés par lui-même ou sur la base de ces deux critères à la fois.

6.105 Cloisons

6.105.1 Conception des cloisons

Les cloisons doivent être utilisées pour séparer les compartiments du PSEM et doivent être étanches au gaz, de sorte que la contamination entre des compartiments adjacents ne puisse pas se produire. Les cloisons doivent être constituées d'un matériau qui présente des propriétés d'isolation et des propriétés mécaniques telles qu'un bon fonctionnement soit assuré sur la durée de vie du PSEM. Les cloisons doivent conserver leur tenue diélectrique aux tensions qui peuvent se produire en service (y compris les tensions temporaires et transitoires) lorsqu'elles sont contaminées par des produits de décomposition de gaz et de mélanges de gaz générés lors d'une commutation de charge normale ou de la rupture d'un défaut de court-circuit.

La pression de calcul d'une cloison est définie par la situation dans laquelle la cloison est sous pression d'un côté tandis que l'autre côté est soumis à la pression atmosphérique (par exemple, lorsque des travaux de maintenance sont effectués). Dans ce cas, la pression à considérer sur le côté de la cloison maintenu sous pression est la pression à la température ambiante maximale, compte tenu des effets du rayonnement solaire (le cas échéant) et du courant permanent assigné (le cas échéant), sans limite de temps. La pression ainsi obtenue est la pression de calcul de la cloison.

Pendant les travaux de maintenance, la pression de gaz peut être réduite jusqu'à une pression contrôlée spécifiée. Lorsque cette pression est inférieure à la pression minimale de fonctionnement, les compartiments de gaz concernés doivent être mis hors tension. Des mises en garde et des procédures relatives à la manipulation du gaz doivent être stipulées dans les manuels d'utilisation et de maintenance.

Hormis la pression de calcul, les points suivants doivent être pris en compte, lorsqu'ils sont applicables:

- la récupération ou la vidange du gaz ou de l'air d'un compartiment de gaz d'un côté de la cloison avec l'autre côté sous pression de service, comme partie intégrante du processus de remplissage. S'il existe une limitation de différentiel de pression ou une limitation temporelle relative au différentiel de pression, celle-ci doit être clairement stipulée par le fabricant, dans les manuels d'utilisation et de maintenance;
- pour les cloisons non symétriques, en ce qui concerne la pression exercée sur la cloison, le sens de la pression la plus défavorable;
- les vibrations et charges superposées;
- la possibilité de travaux de maintenance effectués au voisinage d'une cloison sous pression, en veillant tout particulièrement à éviter la rupture de la cloison et le risque de blessures pour le personnel de maintenance.

NOTE Une pression accrue en raison d'un défaut interne n'est pas prise en considération pour établir la pression de calcul, puisque, dans une telle situation, la cloison est soigneusement examinée et remplacée, le cas échéant.

6.105.2 Compartimentage

Le choix du schéma unifilaire électrique est à considérer en premier lieu pour satisfaire aux exigences de continuité de service. Les dispositions d'implantation et l'introduction de

dispositifs de démontage ont une influence sur la continuité de service pendant la maintenance, la réparation et l'extension.

Le compartimentage d'un PSEM est influencé par les exigences de continuité de service pendant la maintenance, la réparation et l'extension. Des exigences locales de santé et de sécurité doivent également être prises en considération; voir l'Article 12.

L'Annex F donne des recommandations pour spécifier la continuité de service.

Le PSEM doit être divisé en compartiments de sorte que:

- lors des différentes activités qui exigent la mise hors tension de certaines parties du PSEM, les compartiments à mettre hors service satisfassent aux exigences de continuité de service de l'utilisateur. Ces activités comprennent:
 - la maintenance;
 - la réparation;
 - l'extension;
 - l'essai diélectrique sur site;
- les effets d'un arc à l'intérieur d'un compartiment sont limités à ce compartiment (voir 6.103.1);
- la durée de l'indisponibilité en cas de défaillance majeure doit satisfaire aux exigences de continuité de service de l'utilisateur;
- le gaz ou l'air du compartiment peut être récupéré ou vidangé et le compartiment peut être rempli en un temps raisonnable en considérant que les dispositifs de manipulation du gaz sont disponibles.

NOTE Pour les essais diélectriques sur site (après maintenance, réparation ou extension), voir 11.101.2.

Les cloisons sont généralement constituées d'un matériau isolant. Elles ne sont pas destinées à assurer la sécurité électrique du personnel. Dans ce but, d'autres moyens, tels que la séparation par une distance d'isolement et par la mise à la terre de l'équipement, peuvent être utilisés.

Les cloisons apportent une sécurité mécanique vis-à-vis de la pression de gaz encore présente dans le compartiment adjacent pendant la maintenance, la réparation et l'extension. Pendant ces activités, il convient de considérer d'autres contraintes mécaniques que la pression sur les cloisons, telles que des chocs dus à toute partie ou les contraintes mécaniques transitoires dues aux conducteurs, afin de définir les règles de sécurité et éviter les risques pour la santé des personnes.

Lorsqu'une barre omnibus du PSEM est intérieure et extérieure (par exemple, PSEM installé dans un bâtiment avec des traversées d'extérieure), le compartiment de gaz peut être équipé d'une cloison à proximité de la paroi, avec une séparation du compartiment entre les environnements intérieurs et extérieurs, pour s'affranchir des fausses alarmes des dispositifs de surveillance de gaz et des phénomènes de condensation qui se produisent du fait des différences de température entre l'intérieur et l'extérieur.

Chaque compartiment doit être équipé des accessoires suivants:

- coupleur de remplissage;
- dispositif de surveillance du gaz (voir 6.10).

Selon la conception du PSEM ou la demande des utilisateurs, chaque compartiment peut être équipé des accessoires suivants:

- dispositif limiteur de pression (voir 6.106.3);

- absorbeur d'humidité;
- détecteur de localisation de défaut d'arc interne (voir 6.103.3).

La Figure 2 donne un exemple de disposition des enveloppes et des cloisons pour différents types de compartiments adjacents.

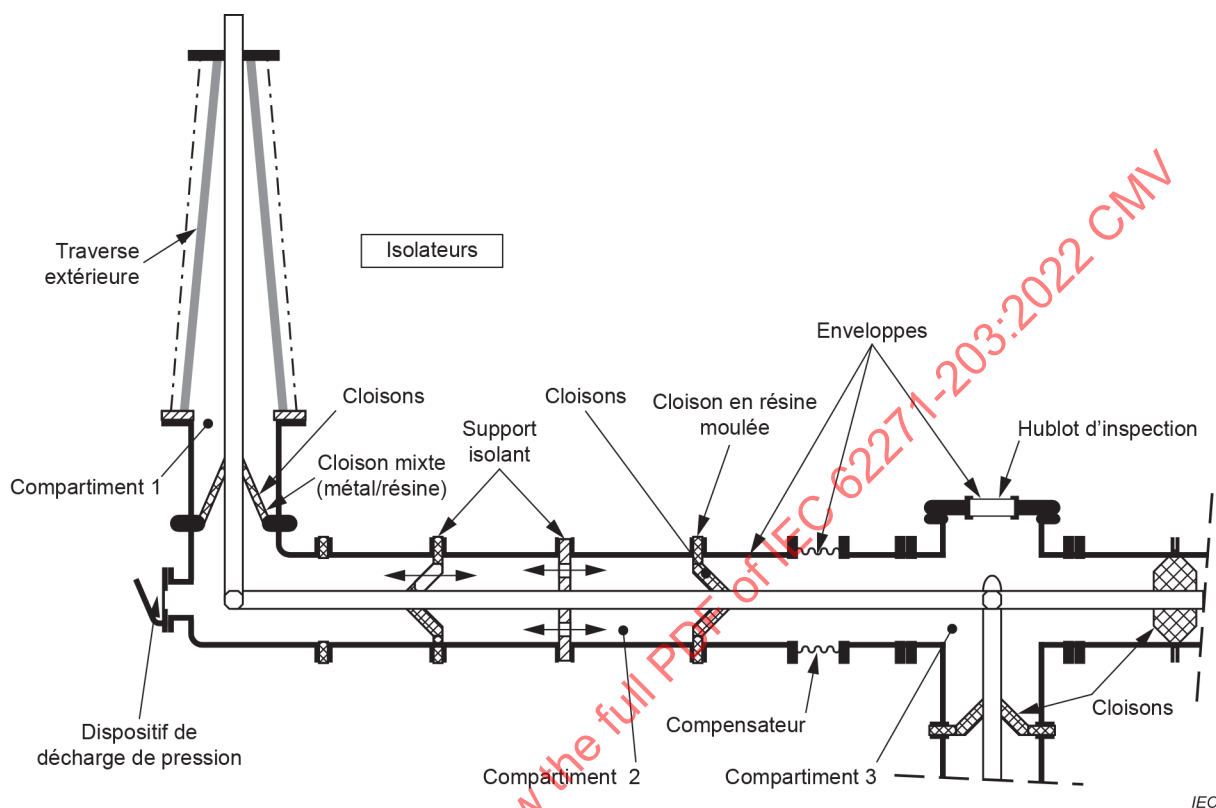


Figure 2 – Exemple de disposition des enveloppes et des compartiments de gaz

6.106 Limitation de pression

6.106.1 Généralités

Le dispositif limiteur de pression recouvre à la fois des limiteurs de pression caractérisés par une pression d'ouverture et une pression de fermeture, et des dispositifs limiteurs de pression sans refermeture, tels que les diaphragmes et les disques de rupture. Les dispositifs limiteurs de pression conformes aux dispositions du présent paragraphe doivent être placés de façon à réduire le plus possible le danger pour un opérateur pendant ses tâches normales d'exploitation dans le poste à isolation gazeuse, dans le cas où des gaz ou vapeurs s'échappent sous pression.

6.106.2 Dispositif limiteur de pression sans refermeture

Étant donné que les enveloppes endommagées sont remplacées après la formation d'un arc due à un défaut interne, les dispositifs limiteurs de pression sans refermeture ne doivent être dimensionnés que pour limiter les effets externes de l'arc (voir 6.103.2).

6.106.3 Limiteur de pression

Pour le remplissage d'un compartiment de gaz, un limiteur de pression doit être monté sur le tuyau de remplissage afin d'empêcher que la pression de gaz ne dépasse de plus de 10 % la pression de calcul de l'enveloppe durant le remplissage.

Après une ouverture, un limiteur de pression doit se refermer avant que la pression ne soit descendue à 75 % de la pression de calcul.

Il convient de corriger la pression de remplissage p_{re} pour tenir compte de la température du gaz et de la température ambiante au moment du remplissage.

6.106.4 Limitation de l'augmentation de la pression en cas de défaut interne

Les dispositifs limiteurs de pression protègent contre les surpressions lors d'un défaut interne. Pour des raisons de sécurité, et aussi pour limiter les conséquences d'un défaut interne sur le PSEM, il est recommandé d'équiper chaque compartiment d'un dispositif limiteur de pression sans refermeture, sauf dans le cas des compartiments à large volume dans lesquels les surpressions sont limitées à des valeurs qui ne dépassent pas la pression d'essai de type. Pour la méthode de calcul, voir l'Annex D.

Le dispositif limiteur de pression doit être équipé d'un déflecteur de manière à contrôler la direction des émissions afin d'assurer la sécurité d'un opérateur qui travaille en des endroits accessibles durant l'exploitation normale. Une marge suffisante est nécessaire entre la pression de fonctionnement du dispositif limiteur de pression et la pression de calcul afin d'éviter tout fonctionnement du dispositif limiteur dans des conditions normales d'exploitation. De plus, la pression transitoire qui apparaît lors d'une manœuvre (le cas échéant, par exemple, disjoncteur) doit être prise en compte pour la détermination de la pression de fonctionnement du dispositif limiteur de pression.

NOTE Dans le cas d'un défaut interne qui entraîne une déformation plastique de l'enveloppe, l'absence de déformation sur les enveloppes des compartiments adjacents peut être vérifiée.

6.107 Bruit

Lors d'une manœuvre, il convient que le niveau de bruit émis par l'appareillage ne dépasse pas une valeur spécifiée définie par l'utilisateur. Il convient que le fabricant et l'utilisateur conviennent de la procédure de vérification (voir l'IEC 61672-1 [9] et l'IEC 61672-2 [10]).

6.108 Interfaces

6.108.1 Généralités

Afin de faciliter les essais sur le PSEM, des liaisons d'isolation ou amovibles peuvent être incluses dans la conception de chacun des matériels individuels décrits ci-dessous. L'utilisation de ce type de dispositif de séparation est préférable au démontage. Pour les traversées aériennes, la connexion haute tension peut être retirée, de préférence du côté extérieur.

Une liaison d'isolation doit être conçue pour supporter les tensions d'essai sur la distance d'isolement selon le Tableau 2 et le Tableau 3.

Une liaison amovible doit être conçue pour supporter les tensions d'essai phase-terre selon le Tableau 2 et le Tableau 3.

Les liaisons d'isolation ou amovibles doivent être conçues pour supporter les tensions d'essai des matériels individuels mentionnés ci-dessous.

Ces interfaces reliées au PSEM doivent pouvoir supporter la pression maximale en service du PSEM. Généralement, ces pressions maximales en service atteignent jusqu'à 1,1 MPa (valeur absolue) pour le SF₆ et jusqu'à 1,5 MPa (valeur absolue) pour les autres gaz et mélanges de gaz.

6.108.2 Raccordements de câbles

6.108.2.1 Généralités

Voir l'IEC 62271-209.

Les parties du PSEM qui restent reliées au câble doivent être capables de supporter les tensions d'essai des câbles spécifiées dans les normes de câbles correspondantes pour la même tension assignée d'équipement.

NOTE Les parties qui ne sont pas capables de supporter les tensions d'essai des câbles peuvent être équipées de liaisons amovibles ou de liaisons d'isolation.

En général, pendant les essais diélectriques sur des câbles, il convient que les parties adjacentes du PSEM soient mises hors tension et à la terre, sauf si des mesures spéciales sont prises pour éviter que les décharges disruptives qui surviennent dans le câble ne se répercutent sur les parties sous tension du PSEM.

Il convient que l'emplacement des traversées pour l'essai des câbles soit prévu sur l'enveloppe de raccordement de câble ou sur le PSEM lui-même (voir l'IEC 62271-209) ou (pour réduire les pertes par manipulation du gaz) à l'autre extrémité du câble.

6.108.2.2 Câbles à isolation extrudée

Conformément à l'IEC 60840 et l'IEC 62067, les essais électriques après l'installation sont, dans ce cas, des essais de tension en courant alternatif. La partie du PSEM à proximité de l'extrémité de câble peut être soumise à la tension d'essai en courant alternatif du câble.

6.108.2.3 Câble à huile fluide

Conformément à l'IEC 60141-1, les essais électriques après l'installation sont, dans ce cas, des essais de tension en courant continu. S'il n'est pas acceptable d'appliquer les tensions d'essai en courant continu de câble au PSEM, des dispositions particulières doivent être prises pour soumettre les câbles aux essais (par exemple, dispositifs de déconnexion et/ou accroissement de la densité du gaz pour l'isolement).

6.108.3 Connexions directes des transformateurs

Voir l'IEC 62271-211.

Afin de faciliter les essais des transformateurs, un sectionneur de terre, qui peut être isolé de l'enveloppe du PSEM et de la terre, peut être intégré dans la conception de la traversée ou du PSEM.

NOTE Toute ouverture du PSEM pour les essais des transformateurs peut alors être évitée, et peut réduire les pertes par manipulation du gaz et la durée d'indisponibilité des équipements.

6.108.4 Traversées

Voir l'IEC 60137:2017, l'IEC TS 60815-1 [5], l'IEC TS 60815-2 [6], l'IEC TS 60815-3 [7], l'IEC 61462 [8] et l'IEC 62155 [11].

6.108.5 Interfaces pour des extensions futures

Lorsqu'une extension est planifiée, il convient que les emplacements des futures extensions possibles soient pris en considération et mentionnés par l'utilisateur dans la spécification technique.

Dans le cas d'une extension ultérieure avec un autre produit PSEM, et si cela est demandé par l'utilisateur, le fabricant doit fournir des informations suffisantes, de préférence sous forme de

dessins, afin de permettre la conception d'une interface de ce type à un stade ultérieur. Le fabricant et l'utilisateur doivent convenir de la procédure qui permet d'assurer la confidentialité des informations détaillées de conception. Voir l'IEEE C37.122.6 [20].

Il convient que l'interface se limite uniquement aux barres omnibus et non à des raccordements directs à des appareils "actifs" tels que les disjoncteurs ou sectionneurs. Lorsqu'une extension est planifiée, il est recommandé que l'interface comprenne les équipements nécessaires pour l'installation et les essais de l'extension limitent la partie du PSEM existant à soumettre à nouveau aux essais, et permettent la connexion au PSEM existant sans essais diélectriques additionnels (voir l'Article C.3). L'interface doit être conçue pour tenir les niveaux d'isolement assignés sur la distance d'isolement.

6.109 Interverrouillage

Il convient d'interverrouiller les sectionneurs avec le disjoncteur associé afin d'éviter l'ouverture ou la fermeture du sectionneur, sauf si le disjoncteur associé est ouvert. Cependant, la manœuvre de transferts de barres en charge doit demeurer possible pour les postes à plusieurs barres omnibus.

Il convient que les sectionneurs de terre qui présentent un pouvoir de fermeture en court-circuit inférieur à la valeur de crête du courant admissible assignée du circuit soient interverrouillés avec le disjoncteur associé et/ou aux sectionneurs pour éviter l'ouverture ou la fermeture du sectionneur de terre, sauf en cas d'ouverture du disjoncteur et/ou du sectionneur associé. Un interverrouillage similaire peut être appliqué pour les sectionneurs de terre avec un pouvoir de fermeture.

7 Essais de type

7.1 Généralités

Le paragraphe 7.1 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

Pour les essais de type, un gaz SF₆ et ses mélanges de qualité technique conformes à l'IEC 60376 ou un gaz SF₆ usagé et ses mélanges conformes à l'IEC 60480 peuvent être utilisés.

Si le PSEM est conçu pour utiliser d'autres gaz que SF₆, la qualité technique et les caractéristiques nécessaires du gaz/ mélange de gaz utilisés pour les essais de type doivent être définies et documentées par le fabricant du PSEM et indiquées dans les rapports d'essai de type.

NOTE Un groupe de travail du CE 10 de l'IEC se consacre actuellement à la normalisation de la qualité technique des mélanges de gaz sans SF₆ (IEC 63359 et IEC 63360).

En ce qui concerne la manipulation du gaz, l'IEC 62271-4 doit être prise en compte.

7.1.1 Principes fondamentaux

Le paragraphe 7.1.1 de l'IEC 62271-1:2017 est applicable avec les compléments suivants:

En règle générale, il convient d'effectuer les essais sur les matériels individuels du PSEM suivant leurs normes correspondantes, sauf lorsqu'une condition d'essai ou spécification d'essai particulière est définie dans le présent document. Dans de tels cas, les conditions indiquées dans le présent document doivent être prises en compte.

Les essais de type doivent être effectués sur une unité fonctionnelle complète à moins que des exigences d'essai spécifiques ne soient définies. Lorsque cela n'est pas réalisable, les essais de type peuvent être réalisés sur des ensembles ou sous-ensembles représentatifs.

Il n'est pas possible de soumettre toutes les dispositions prévues du PSEM à des essais de type, compte tenu de la multiplicité des types, des caractéristiques assignées et des combinaisons possibles des matériels individuels. Les performances d'une disposition donnée peuvent être déduites des résultats d'essai obtenus sur des ensembles ou sous-ensembles représentatifs. L'utilisateur et le fabricant doivent vérifier que les sous-ensembles soumis aux essais sont bien représentatifs des dispositions de l'utilisateur.

La liste des essais de type et des vérifications est donnée dans le Tableau 5 ci-dessous.

Tableau 5 – Essais de type

Essais de type obligatoires	
	Paragraphe
a) Essais de vérification du niveau d'isolement de l'équipement et essais diélectriques des circuits auxiliaires	7.2
b) Essais de vérification du niveau de tension de perturbation radioélectrique (le cas échéant)	7.3
c) Essais de vérification du courant permanent de toute partie de l'équipement et mesurage de la résistance du circuit principal	7.4 et 7.5
d) Essais de vérification de la valeur de crête du courant admissible assignée et du courant de courte durée admissible assigné	7.6
e) Essais de vérification du pouvoir de fermeture et du pouvoir de coupure des appareils de commutation contenus dans l'équipement	7.101
f) Essais de vérification du fonctionnement satisfaisant des appareils de commutation contenus dans l'équipement	7.102.1
g) Essais de vérification de la résistance des enveloppes	7.103
h) Vérification du degré de protection de l'enveloppe	7.7
i) Essais d'étanchéité au gaz	7.8
j) Essais de compatibilité électromagnétique (CEM)	7.9
k) Essais complémentaires sur les circuits auxiliaires et de commande	7.10
l) Essais sur les cloisons	7.104
m) Essais de vérification du fonctionnement satisfaisant aux températures limites	7.102.2
n) Essais de vérification des performances des isolateurs soumis aux cycles thermiques et aux essais d'étanchéité au gaz	7.106
o) Essai de corrosion sur les connexions de terre (le cas échéant)	7.107
p) Procédure d'essai des rayonnements X pour les ampoules à vide (le cas échéant)	7.11
Essais de type, lorsque demandés par l'utilisateur	
	Paragraphe
q) Essais pour évaluer les effets d'un arc dû à un défaut interne	7.105
r) Essais de corrosion sur les systèmes d'étanchéité des enveloppes et des équipements auxiliaires (le cas échéant)	7.108

7.1.2 Informations pour l'identification des objets d'essai

Le paragraphe 7.1.2 de l'IEC 62271-1:2017 est applicable.

7.1.3 Informations à inclure dans les rapports d'essai de type

Le paragraphe 7.1.3 de l'IEC 62271-1:2017 est applicable.