



IEC 62271-203

Edition 3.0 2022-05
COMMENTED VERSION

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

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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 60137:20082017, ~~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:

- 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 60071-1:2006/2019 [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.

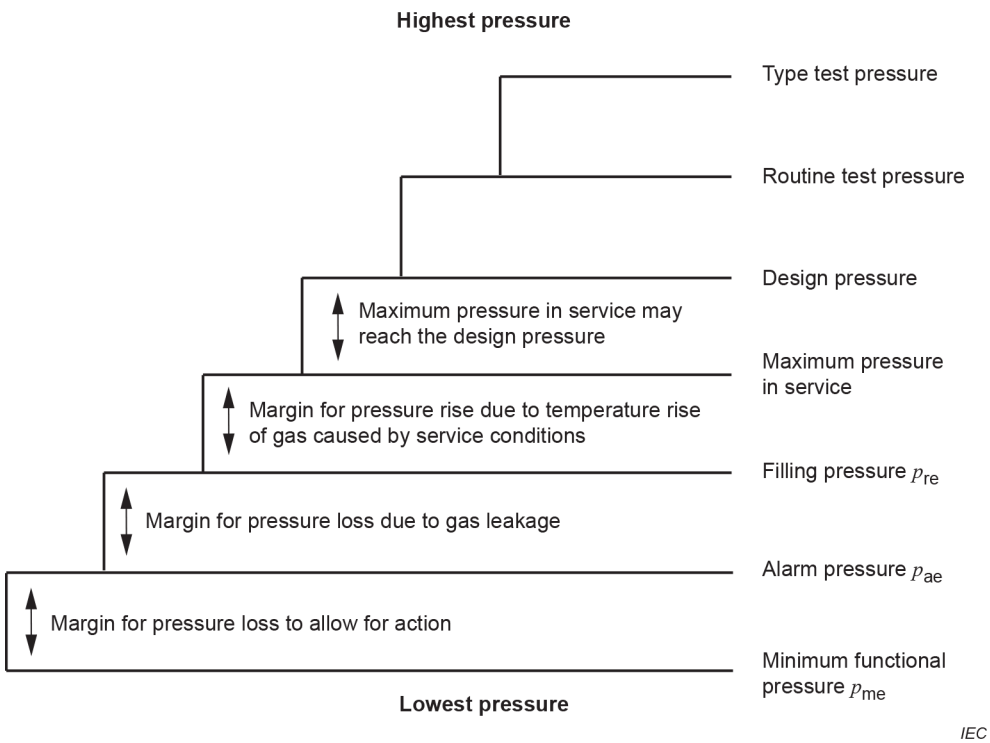
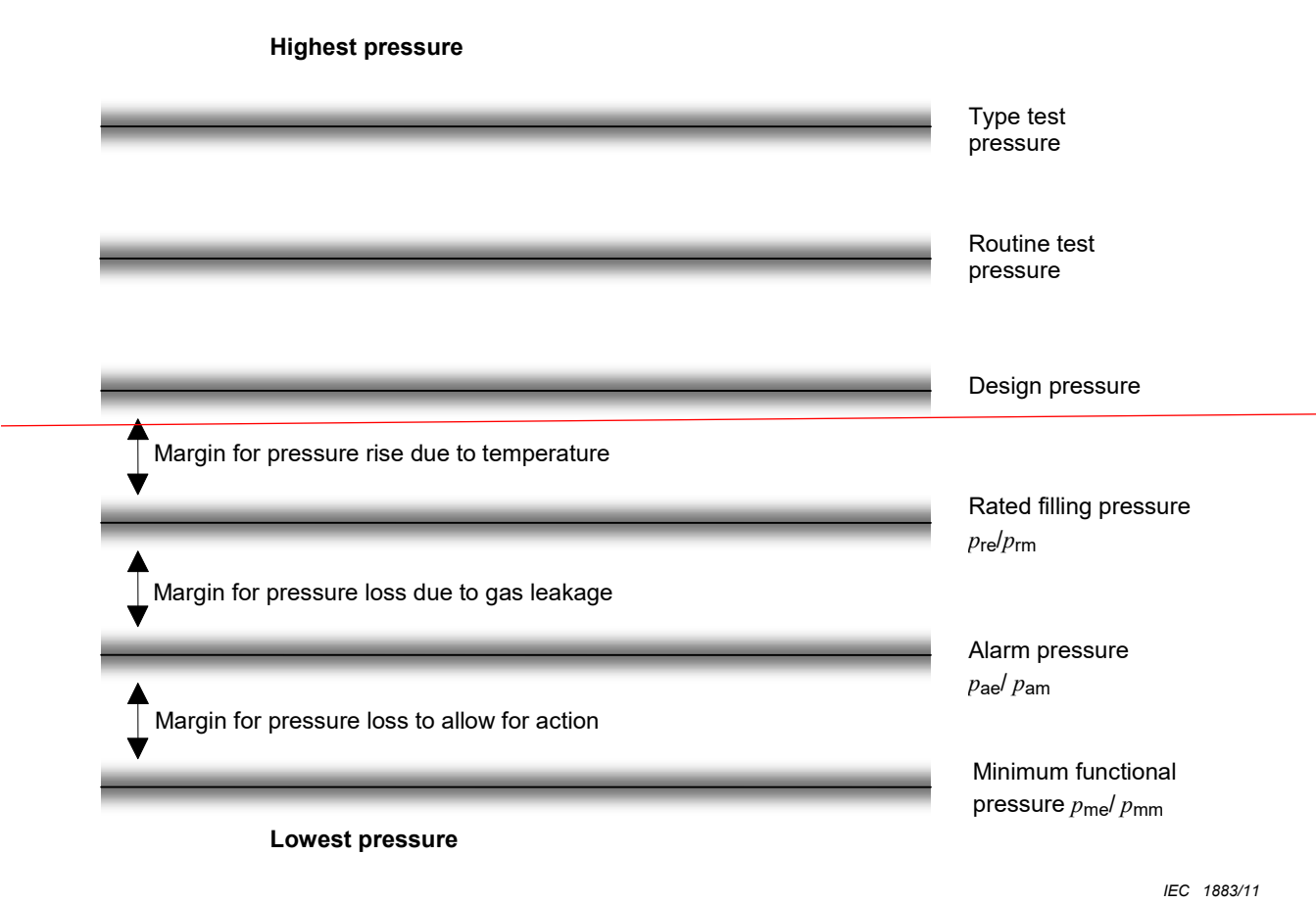


Figure 1 – Pressure coordination

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.

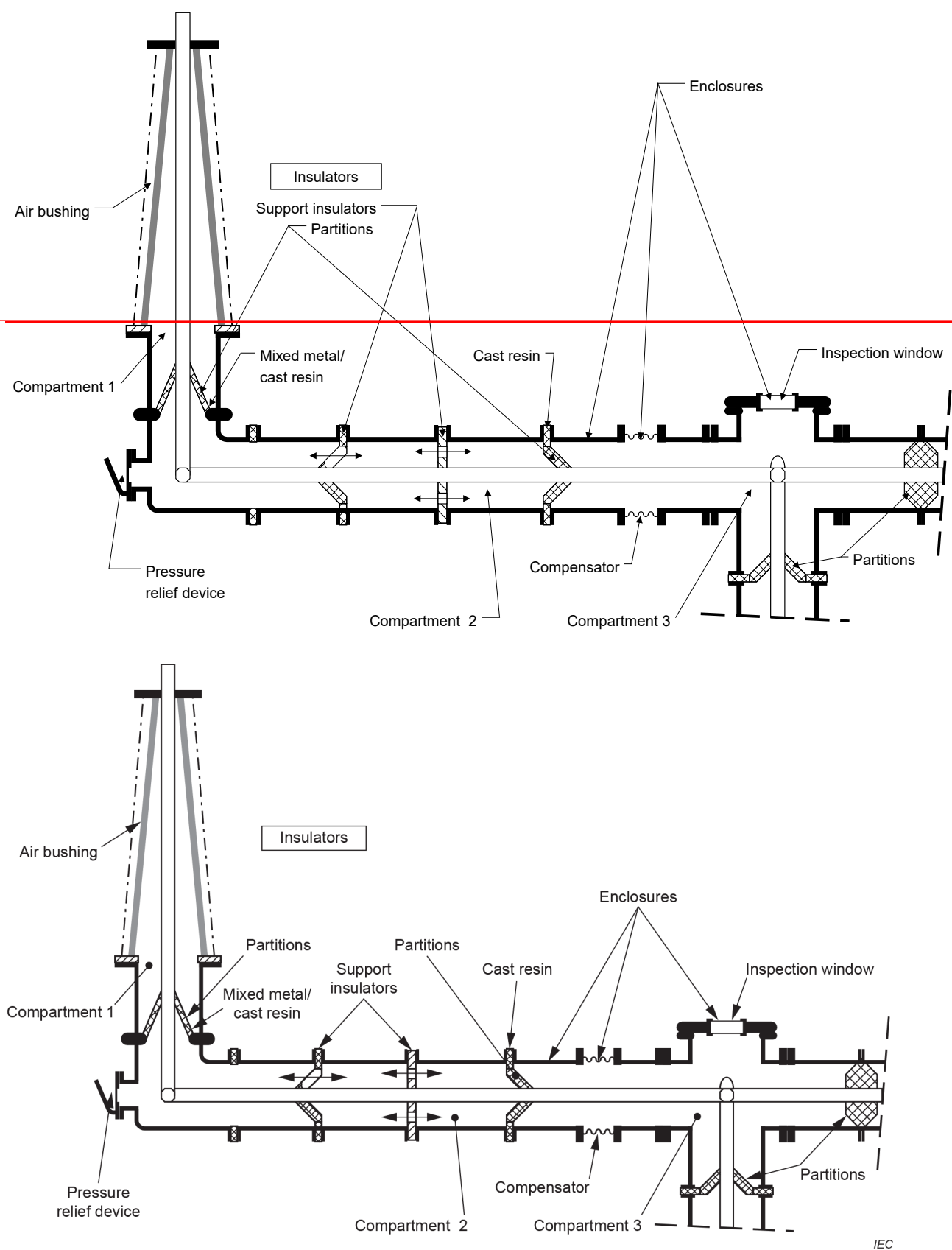


Figure 2 – Example of arrangement of enclosures and gas compartments

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.~~

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:

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

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 ~~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.