IEC 62271-204

Edition 2.0 2022-05
REDLINE VERSION

INTERNATIONAL STANDARD

High-voltage switchgear and controlgear –
Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62271-204:2011. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62271-204 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

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

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

a) update to be in line with IEC 62271-1:2017 and alignment of the voltage ratings and the test voltages.
b) addition of new information for welds on pressurized parts and gas tightness.

The text of this document is based on the following documents:

Draft	Report on voting
17C/840/FDIS	17C/846/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.

This document is to be read in conjunction with IEC 62271-1:2017 and IEC 62271-203:2022, to which it refers and which are applicable unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1:2017 and IEC 62271-203:2022. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

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

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV

~~1 General~~

1 Scope

This part of IEC 62271 applies to rigid HV gas-insulated transmission lines (GIL) in which the insulation is obtained, at least partly, by ~~a non-corrosive insulating gas,~~ an insulating gas or gas mixture other than air at atmospheric pressure, for alternating current of rated voltages above 52 kV, and for service frequencies up to and including 60 Hz.

This document is ~~intended that this international standard be used~~ applicable where the provisions of IEC 62271-203 do not cover the application of GIL (see Note 3).

At each end of the HV gas-insulated transmission line, a specific element ~~may be~~ is used for the connection between the HV gas-insulated transmission line and other equipment like bushings, power transformers or reactors, cable boxes, metal-enclosed surge arresters, voltage transformers or GIS, covered by their own specification.

Unless otherwise specified, the HV gas-insulated transmission line is designed to be used under normal service conditions.

NOTE 1 In this document, the term "HV gas-insulated transmission line" is abbreviated to "GIL".

NOTE 2 In this document, the word "gas" means gas or gas mixture, as defined by the manufacturer.

NOTE 3 Examples of GIL applications:

– where all or part of the HV gas-insulated transmission line is directly buried;
– where the HV gas-insulated transmission line is located, wholly or partly, in an area accessible to public;
– where the HV gas-insulated transmission line is long (typically longer than 500 m) and the typical gas compartment length exceeds the common practice of GIS technology.

2 Normative references

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

~~IEC 60050-151, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*~~

~~IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*~~

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

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60229:2007, *Electric cables – Tests on extruded oversheaths with a special protective function*

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

IEC 60287-3-1:~~1995~~2017, *Electric cables – Calculation of the current rating – Part 3-1:~~ Sections on~~ Operating conditions – ~~Reference operating conditions and selection of cable type~~ Site reference conditions*

IEC 60376, *Specification of technical grade sulfur hexafluoride (SF_6) 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 (SF_6) taken from electrical equipment and specification or its re-use*~~ *Specifications for the re-use of sulfur hexafluoride (SF_6) and its mixtures in electrical equipment*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 62271-1:~~2007~~2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-203:~~2011~~2022, *High-voltage switchgear and controlgear – Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*~~[1]~~

~~IEC 62271-303, *High-voltage switchgear and controlgear – Part 303:Use and handling of sulphur hexafluoride (SF_6)*~~

IEC 62271-4:2013, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures*

~~ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*~~

ISO 9606 (all parts), *Qualification test of welders – Fusion welding*

ISO 9712, *Non-destructive testing – Qualification and certification of NDT personnel*

ISO 14732, *Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure specification*

ISO 15614 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure test*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ~~IEC 60050-441, IEC 60050-151,~~ IEC 62271-1:2017 and the following apply.

~~[1] To be published.~~

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

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

3.101
area accessible to public
~~access not restricted to authorized personnel~~
area accessible without restriction to any person

Note 1 to entry: A GIL installed above the ground and outside a substation is considered to be "installed in an area accessible to public".

3.102
gas-insulated transmission lines
GIL
metal-enclosed lines in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure, with the external enclosure intended to be earthed

3.103
GIL enclosure
part of ~~gas-insulated line~~ GIL retaining the insulating gas under the ~~prescribed~~ required conditions ~~necessary to maintain safely the rated insulation level,~~ protecting the equipment against external influences and providing a high degree of protection to personnel

3.104
compartment
part of ~~gas-insulated line,~~ GIL totally gastight enclosed except for openings necessary for interconnection and control

3.105
partition
~~part of gas-insulated line separating one compartment from other compartments~~
gas tight support insulator of gas-insulated metal-enclosed switchgear separating two adjacent compartments

3.106
main circuit
all the conductive parts of ~~gas-insulated line~~ GIL included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:1984, 441-13-02, modified – Replacement of “an assembly" by “GIL".]

3.107
ambient air temperature ~~(of gas-insulated line)~~
temperature, determined under ~~prescribed~~ required conditions, of the air surrounding the external GIL enclosure ~~of gas-insulated line~~ in case of installation in open air, open trenches or tunnels

[SOURCE: IEC 60050-441:1984, 441-11-13, modified – Replacement of “complete switching device or fuse" by “external GIL enclosure in case of installation in open air, open trenches or tunnels".]

3.108
design temperature ~~(~~**of the enclosure**~~)~~
~~highest~~ maximum temperature which can be reached ~~by the~~ on a GIL enclosure under service conditions

3.109
design pressure (of the enclosure)
relative pressure used to determine the design of the enclosure

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

3.110
design pressure (of the partitions)
relative pressure used to determine the design of across the partition

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

3.111
disconnecting unit
unit to separate gas compartments electrically isolate one side from another of the main circuit, mainly for site testing or maintenance

3.112
disruptive discharge
phenomenon 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

Note 1 to entry: The term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss may can be only temporary (self-restoring insulation).

Note 3 to entry: The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term "flashover" is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

3.113
GIL section
a GIL section part of GIL which is defined by operational or other requirements such as maximum length for dielectric testing or installation sequence

Note 1 to entry: A GIL can consist on the assembly of several GIL sections.

Note 1 2 to entry: It may can consist of one or more compartments.

Note 2 3 to entry: Sections may can be segregated by disconnecting units.

4 Normal and special service conditions

4.1 Normal service conditions

4.1.1 General

Subclause 4.1.1 of IEC 62271-1:2017 is applicable with the following addition.

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

The normal service conditions which apply to a GIL depending on the installation conditions are given in 4.101, 4.102 and 4.103. When more than one of these installation conditions apply, the relevant subclause shall apply to each section of the GIL.

4.1.2 Indoor switchgear and controlgear

Subclause 4.1.2 of IEC 62271-1:2017 is applicable.

4.1.3 Outdoor switchgear and controlgear

Subclause 4.1.3 of IEC 62271-1:2017 is applicable.

4.2 Special service conditions

Subclause 4.2 of IEC 62271-1:2017 is applicable.

4.101 Installation in open air

For determining the ratings of GIL for open air installation, the normal service conditions of IEC 62271-1:2017 shall apply. Typical rating conditions These are also valid for open trenches.

If the actual service conditions differ from the normal service conditions, the ratings shall be adapted accordingly.

~~Unless otherwise specified by the user, the special service conditions given in the IEC 62271-1 shall apply.~~

4.102 Buried installation

~~Typical~~ General values for thermal resistivity and soil temperature are:

– 1,2 K · m/W, and 20 °C in summer;
– 0,85 K · m/W, and 10 °C in winter.

For guidance, values given in IEC 60287-3-1 ~~may~~ can be considered.

~~NOTE 1~~ For long distance transmission lines (several kilometres), site measurement of soil resistivity should also be considered.

NOTE ~~2~~ 1 The use of controlled backfill with a given soil thermal resistivity ~~may~~ can also be considered.

NOTE ~~3~~ 2 A risk of thermal runaway exists if the soil surrounding the buried GIL becomes dry. In order not to dry out the soil, a maximum service temperature of the enclosure in the range of 50 °C to 60 °C is generally considered acceptable.

The depth of laying ~~shall~~ should be agreed between manufacturer and user. The determination of depth of laying shall take into account thermo mechanical stresses, safety requirements and local regulations.

4.103 Installation in tunnel, shaft or similar situation

Forced cooling is an adequate method to handle with the waste heat and can be used in case of tunnel, shaft or similar installations.

In the case of long vertical shafts and ~~inclinated~~ inclined tunnels or sections thereof, attention shall be paid to thermal and density gradients~~, especially if a gas mixture is used~~.

5 Ratings

5.1 General

Subclause 5.1 of IEC 62271-1:2017 is not applicable~~, except~~ and is replaced as follows.

The rating of a GIL consists of the following:

a) rated voltage (U_r) ~~and number of phases~~;

b) rated insulation level (U_d, U_p, U_s);

c) rated frequency (f_r);

d) rated ~~normal~~ continuous current (I_r) ~~(for main circuits)~~;

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);

g) rated duration of short-circuit (t_k);

~~h) rated values of the components forming part of a GIL, including auxiliary equipment;~~

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

~~i) rated filling pressure of insulating gas.~~

i) rated supply frequency of auxiliary and control circuits.

5.2 Rated voltage (U_r)

Subclause ~~4.1 of IEC 62271-203~~ 5.2 of IEC 62271-1:2017 is applicable.

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:

Rated insulation levels shall be chosen from IEC 62271-203 on the basis of insulation coordination study for the specific installation in order to consider parameters like overvoltages, voltage reflections, etc. Specific insulation coordination studies are recommended for each installation. For more information, see [1][2].

Although internal arcing faults can largely be avoided by the choice of a suitable insulation level, measures to limit external overvoltages at each end of the installation (e.g. surge arresters) should be considered.

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:

The rated ~~normal~~ continuous current is defined for a single~~,~~ or a three-phase ~~circuit~~ GIL installed above ground with an ambient air temperature at 40 °C. For other installation conditions, the maximum allowable continuous current can differ from the rated continuous current. See Annex A.

~~4.4.2 Temperature rise~~

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

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

~~The temperature of the enclosure shall not exceed the maximum allowable temperature of the anti-corrosion coating if applicable.~~

~~The temperature rise of components contained in the GIL 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.~~

~~For open air, tunnel and shaft installations, the maximum temperature of the enclosure shall not exceed 80 °C. Parts normally touched during operation not to exceed 70 °C. Reference is made to Clause 11 of this standard.~~

~~For direct buried installation, the maximum temperature of the enclosure shall be limited to minimise soil drying. A temperature in the 50 °C and 60 °C range is generally considered applicable.~~

~~**4.4.3 Particular points of Table 3**~~

~~Subclause 4.4.3 of IEC 62271-1 is applicable.~~

~~**4.4.101 Particular requirements for temperature rise**~~

~~Where a non-oxidizing gas is used as the dielectric, the limits of the temperature and temperature rise shall be as specified for SF_6 in Table 3 of IEC 62271-1.~~

~~Where compressed air is used as the dielectric, the limits of the temperature and temperature rise shall be as specified for air in Table 3 of IEC 62271-1.~~

~~Where an oxidizing gas (other than air) is used as the dielectric, lower limits of temperature and temperature rise shall be agreed between manufacturer and user.~~

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 is applicable~~, with the following addition~~.

~~In selecting a rated short-time withstand current for an installation, or part of an installation, consideration may be given to the fact that the maximum fault current in a circuit reduces as the distance from the substation increases.~~

5.7 Rated peak withstand current (I_p)

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

5.8 Rated duration of short-circuit (t_k)

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

5.9 Rated supply voltage ~~of 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~~ with the following addition:~~.

~~The rated supply frequency of auxiliary circuits is the frequency at which the conditions of operation and temperature rise of these devices and circuits are determined.~~

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is not applicable.

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

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

6 Design and construction

Clause 6 of IEC 62271-1:2017 is ~~not~~ applicable, except as follows.

Any ~~component~~ GIL equipment which requires routine preventive maintenance or diagnostic testing ~~shall~~ should be easily accessible.

GIL ~~shall~~ should be designed so that normal service, inspection and maintenance operations can be carried out safely, including the checking of phase sequence after erection and extension.

The equipment ~~shall~~ should be designed such that the mechanical stress caused by all relevant loads, for example thermal expansion, agreed permitted movement of foundations, external vibration, earthquakes, soil loading, wind and ice, 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.~~

6.1 Requirements for liquids in GIL

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

6.2 Requirements for gases in GIL

Subclause 6.2 of IEC 62271-1:2017 is applicable. In case a gas mixture is used, the manufacturer should provide information about the gas characteristics such as dielectric strength, mixing ratio, process of mixing and filling pressure.

NOTE See references [2], [3] and [4].

6.3 Earthing

Subclause 6.3 of IEC 62271-1:2017 is applicable, ~~except as follows~~ with the following additions.

6.3.101 Earthing of the main circuits

To ensure safety during maintenance work, all parts of the main circuits to which access is required or provided shall be capable of being earthed. In addition, it shall be possible, after the opening of the enclosure, to connect earth electrodes to the conductor for the duration of the work.

Earthing ~~may~~ can be made by

a) earthing switches with a making ~~current~~ capacity equal to the rated peak withstand current, if there is ~~no certainty~~ still a possibility that the circuit connected is ~~not~~ live;

b) earthing switches without a short-circuit making ~~current capacity~~ capability or with a short-circuit making ~~capacity~~ capability lower than the rated peak withstand current, if there is a certainty that the circuit connected is not live, or

c) removable earthing devices, only by agreement between manufacturer and user.

Each part being capable of being disconnected shall be capable of being earthed.

Consideration ~~shall~~ should be given to the ability of the first operated earthing device to dissipate the maximum level of trapped charge on the isolated circuit.

Where the earthing switches form part of the plant connected to the transmission line, the user shall ensure that they comply with the above items a) to c).

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

6.3.102 Earthing of the enclosure

The enclosures shall be capable of being connected to earth. All metal parts intended to be earthed, which do not belong to a main or an auxiliary circuit, shall be connected to earth. For the interconnection of enclosures, frames, etc., fastening (e.g. bolting or welding) is generally acceptable for providing electrical continuity. If the fastening is done by bolting, provisions shall be given in order that a proper electrical contact is provided. If not, the mechanical joint shall be by-passed by a proper electrical connection such as copper or aluminum leads of proper cross section.

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

It is envisaged that most GIL installation will be solidly bonded and earthed at both ends. The particular design has an influence on heat dissipation, ~~standing~~ step and touch voltages and the external magnetic field. These are discussed in Annex B.

The design of the earthing of the enclosure shall be compatible with the measures for corrosion protection when the GIL is buried.

6.4 Auxiliary and control equipment

Subclause 6.4 of IEC 62271-1:2017 is applicable.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is not applicable.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is not applicable.

6.7 Independent manual or power operation (independent unlatched operation)

Subclause 6.7 of IEC 62271-1:2017 is not applicable.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is not applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is not applicable.

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

Subclause 6.10 of IEC 62271-1:2017 is applicable~~, except as follows~~.

~~Means shall be provided for monitoring gas pressure or gas density, taking into account the relevant IEC standards. It is recommended that signals be provided when the gas pressure for insulation has fallen to the alarm pressure for insulation and to the minimum functional pressure for insulation, or risen to the maximum value in the case of controlled pressure system, as defined by the manufacturer.~~

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is not applicable and is replaced as follows:

6.11.1 General

~~5.10.101 Nameplates~~

For outdoor installation, the nameplates and their fixings shall be weather-proof and corrosion proof. ~~Reference is made to IEC 62271-1 subclause 5.10.~~

A complete nameplate shall be provided at each end of the installation, and at each point where service is needed. These nameplates shall contain the following information:

- manufacturer's name or trademark
- type designation ~~or~~ and serial number
- rated voltage U_r
- rated lightning impulse withstand voltage[3] U_p
- rated switching impulse withstand voltage[4] U_s
- rated short-duration power-frequency withstand voltage[4] U_d
- rated ~~normal~~ continuous current I_r
- rated short-time withstand current I_k
- rated peak withstand current I_p
- rated frequency f_r
- rated duration of short-circuit t_k
- ~~rated~~ filling pressure for insulation; minimum functional pressure for insulation; design pressure for enclosures
- type of gas
- mass of gas ~~contained~~ ~~kg~~

NOTE The word "rated" ~~need not appear~~ is optional on the nameplates.

~~3 The values to be used for nameplates are phase-to-earth values.~~

~~**5.10.102 Equipment identification**~~

6.11.2 Application

Subclause 6.11.2 of IEC 62271-1:2017 is not applicable and is replaced as follows:

Since characteristics of different sections ~~may~~ can be different, a marking shall be provided on the enclosure for equipment identification, or on the coating of the enclosure, if any. The maximum distance between two identification markings ~~shall~~ should be agreed between manufacturer and user.

Markings shall be durable and clearly legible and shall contain the following information:

– manufacturer's name or trademark;
– type designation;
– rated voltage;
– type of gas and ~~rated~~ filling pressure for insulation.

6.12 ~~Interlocking~~ Locking devices

Subclause 6.12 of IEC 62271-1:2017 is ~~not~~ applicable.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is ~~not~~ applicable.

6.14 Degree of protection provided by enclosures

6.14.1 General

Subclause 6.14.1 of IEC 62271-1:2017 is applicable with the following additions.

No specification applies to the main circuit and parts directly connected thereto, because of the gas tightness of the enclosure.

Degrees of protection according to IEC 60529 shall be specified for all enclosures of appropriate low-voltage control and/or auxiliary circuits.

The degrees of protection apply to the service conditions of the equipment.

6.14.2 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)

Subclause 6.14.2 of IEC 62271-1:2017 is applicable with the following additions:

Protection means are applicable only for control and/or auxiliary circuits. The first characteristic numeral shall be 3 or higher.

6.14.3 Protection against ingress of water (IP coding)

Subclause 6.14.3 of IEC 62271-1:2017 is applicable with the following additions:

For installations where the laying conditions impose a risk of ingress of water (buried installations, installations in trenches, ducts, etc.), the second characteristic numeral shall be specified~~. In this case the letter X in the second position of the designation in Table 7 of IEC 62271-1 is replaced by a numeral~~ as shown in Table 1 below.

Table 1 – Second characteristic numeral of IP coding

Second characteristic numeral	Brief description	Definition
7	Protected against the effects of temporary immersion in water	Ingress of water causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
NOTE For more severe situations than those corresponding to the second characteristic numeral 7, the protection should be agreed between manufacturer and user.		

Equipment for outdoor installation, provided with additional features against rain and other weather conditions shall be specified by means of the supplementary letter W placed after the second characteristic numeral, or after the additional letter, if any.

6.14.4 Protection against mechanical impact under normal service conditions (IK coding)

Subclause 6.14.4 of IEC 62271-1:2017 is applicable.

5.13.101 Degree of protection for the main circuits

No specification applies to the main circuit and parts directly connected thereto, because of the gas tightness of the enclosure.

5.13.102 Degree of protection for auxiliary circuits

Degrees of protection according to IEC 60529 shall be specified for all enclosures of appropriate low-voltage control and/or auxiliary circuits.

The degrees of protection apply to the service conditions of the equipment.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is not applicable.

6.16 Gas and vacuum tightness

6.16.1 General

Subclause 6.16.1 of IEC 62271-1:2017 is not applicable.

6.16.2 Controlled pressure systems for gas

Not applicable for GIL.

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 62271-203:2022 is applicable with the following additions:

The tightness characteristic of a closed pressure system and the time between replenishment under normal service condition shall be stated by the manufacturer and shall be consistent with a minimum maintenance and inspection philosophy.

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment; standardized values are:

~~– for SF_6 and SF_6 mixtures, the standardized value is 0,5 % per year per compartment;~~

~~– for other gases, the standardized value is 0,5 % per year per compartment.~~

The value for the time between replenishment shall be at least 10 years for SF_6 systems and for other gases should be consistent with the tightness values. The possible leakages between subassemblies having different pressures shall also be taken into account. ~~In the particular case of maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage rate across partitions should also be stated by the manufacturer, and the time between replenishments shall be not less than one month. Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.~~

6.16.4 Sealed pressure systems

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

~~The tightness of sealed pressure systems is specified by their expected operating life. The expected operating life with regard to leakage performance shall be specified by the manufacturer. Preferred values are 20 years, 30 years and 40 years.~~

~~NOTE To fulfil the expected operating life requirement, the leakage rate for SF_6 systems is considered to be 0,1 % per year.~~

6.16.5 Internal partitions

~~If requested by the user, in order to permit maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage across partitions should also be stated by the manufacturer.~~

In the particular case of maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage rate across partitions should also be stated by the manufacturer, and the time between replenishments shall be not less than one month. Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.

Handling for repair and maintenance shall be carried out according to local regulation, see IEC 62271-4.

6.17 ~~Liquid tightness~~ Tightness of 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 not applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is not applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is not applicable.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 is applicable, ~~except as follows~~ with the following additions:

6.21.101 Corrosion protection for buried installations

Corrosion protection, i.e. both the external coating and any active protection system, shall take into account special considerations such as: the location, the soil/backfill material and conditions, the enclosure material and the type of earthing adopted.

In general, the corrosion protection for GIL is similar to the protection means of normal pipeline or power cables. The enclosure is coated with rubber or plastic in one or more layers. The coating acts as a passive corrosion protection system by keeping humidity or water away from the metal enclosure of the electrical equipment.

In addition to the passive corrosion protection, an active system can be installed in case the passive system fails. The active corrosion protection system keeps the metal enclosure at a defined electrical potential, depending on the enclosure material (steel, aluminium). The soil condition around the GIL shall be taken into account for the design of the active corrosion protection system.

Passive corrosion protection is required and any active corrosion system, if requested and installed by mutual agreement between operator and supplier, shall be laid out in accordance with environmental conditions along the GIL.

6.21.102 Corrosion protection for not buried installations

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, switching and/or operation

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

6.101 Minimizing of internal fault effects

6.101.1 General

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

Examples of measures to avoid arcing due to an internal arc fault and to limit duration and consequences are

– insulation coordination,
– gas-leakage limitation and control,
– high-speed protection,
– high-speed arc short-circuiting devices,
– interlocking of switching devices,
– remote control,
– internal and/or external pressure reliefs, and
– checking of workmanship on site.

Arrangements should also be made to minimize the effects of internal arc faults leading to arcing on the continued service capability of the GIL. The effect of an arc should be confined to the compartment in which the arc has been initiated.

If, in spite of the measures taken, a test is agreed between manufacturer and user to verify the effect of arcing due to an internal arc faults, this test should be in accordance with 6.105 7.105 of IEC 62271-203:2022.

Tests would normally not be necessary in the case of single-phase enclosed GIL installed in isolated neutral or resonant earthed systems and equipped with a protection to limit the duration of internal earth faults.

~~NOTE In resonant earthed or isolated neutral systems, protection to limit the duration of an internal fault is strongly recommended.~~

6.101.2 External effects of the arc

Adequate installation precautions shall be taken in order to reduce the hazards to a tolerable risk~~, refer to ISO/IEC Guide 51~~. For more information, see [4].

In order to provide a high protection to personnel, the external effects of an arc shall be limited (by taking adequate precautions) to the appearance of a hole or tear in the enclosure without any fragmentation.

The manufacturer shall provide sufficient information to allow the user to take these precautions.

Manufacturer and user ~~may~~ can agree upon 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 (refer also to 6.102.2).

6.101.3 Internal fault location

Appropriate devices shall be available to enable determination of the faults location.

6.102 Enclosures

6.102.1 General

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

~~While~~ The enclosures of gas-filled equipment conforming to this document are permanently pressurized in service ~~they~~ and are subjected to particular service conditions which distinguish them from compressed air receivers and similar storage vessels. These conditions are as follows:

– ~~enclosures envelop~~ the main circuit ~~in order~~ is enclose to prevent hazardous approach to live parts and are so shaped that, when filled at or above the minimum functional gas pressure for insulation (see 5.11), they ~~ensure that~~ meet the rated insulation level (see 5.3) for the equipment ~~is achieved~~ (electrical rather than mechanical considerations predominate in determining the shape and materials employed);

– enclosures are normally filled with a non-corrosive, dry, stable and inert gas, ~~thoroughly dried, stable and inert; since measures to maintain the gas in this condition with only small fluctuations in pressure are fundamental to the operation of the installation, and since the enclosures will not be subject to internal corrosion, there is no need to make allowances for these factors in determining the design of the enclosures~~ and the gas shall remain in this condition (with only small fluctuations in pressure) in order to ensure correct operation of the installation. However, since the enclosures will not be subject to internal corrosion, there is no need to make allowances for these factors in determining the design of the enclosures (but, the effect of possible transmitted vibrations should be taken into account).

~~– the service pressure employed is relatively low.~~

For outdoor installation, the manufacturer shall take into account the influence of climatic conditions (see Clause 4).

For buried installation, environment conditions shall be taken into account. Concerning the prevention of external corrosion, see 6.21.

6.102.2 Design of enclosures

The wall thickness of the enclosure shall be based on the design pressure as well as the following minimum withstand durations in case of an internal arc without burn-through:

- 0,1 s for short-circuit currents of 40 kA and above;
- 0,2 s for lower short-circuit currents.

In order to minimize the risk of burn-through, the level and duration of the fault current, the enclosure design and the size of the compartments shall be carefully coordinated. ~~The minimum volume should be such that pressure relief devices will not operate within the minimum withstand durations given above.~~

In the absence of an international agreement on a standard procedure, methods for ~~the calculation of~~ calculating the thickness and the construction of enclosures, either by welding or casting, ~~may~~ can be chosen from established relevant pressure vessel and pipeline codes, based on the design temperature and design pressure defined in this document.

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

- the possible evacuation of the enclosure as part of the normal filling process;
- the full differential pressure that is possible across the enclosure walls or partitions;
- the resulting pressure ~~in the event of an accidental leak between the compartments in the case of adjacent compartments having different service pressures~~ between compartments in the event of an abnormal leak in the case adjacent compartments have different filling pressures;
- the possibility of the occurrence of an internal fault (see 6.101).

The design temperature of the enclosure is generally the upper limit of the ambient temperature ~~increased by~~ taking into consideration the increase in temperature rise due to the flow of rated ~~normal~~ continuous current. Solar radiations should be ~~taken into account~~ considered when they have a significant effect.

The design pressure of the enclosure is at least the upper limit of the pressure reached within the enclosure at the design temperature.

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

When designing the enclosure, mechanical loads other than those caused by internal overpressure shall be taken into account, for instance forces caused by thermal expansion (see 6.106), external vibrations (see 6.107), soil loading for buried installations, other external loads, earthquakes, wind, snow and ice, etc.

~~For~~ If the strength of any enclosures and parts thereof~~, the strength of which~~ has not been fully determined by calculation, proof tests (see 7.101) shall be performed to demonstrate that they fulfill the requirements.

Materials used in the construction of enclosures shall be of known and certified minimum physical properties which are based on calculations and/or proof tests. 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.

6.103 Partitions and partitioning

GIL shall be divided into compartments in such a manner that both the normal operating conditions are met and a limitation of the effects of an arc inside the compartment is obtained (see 6.101).

The manner in which the GIL is divided into compartments influences the following:

– installation;
– site testing;
– maintenance and repair;
– gas handling.

The partitions are generally of insulating material but are not intended by themselves to provide electrical safety of personnel, for which other means such as earthing of the equipment ~~may be necessary~~ can apply; they shall, however, provide mechanical safety against the differential gas pressure with the adjacent compartments.

A partition separating a compartment filled with insulating gas from ~~a neighboring~~ an adjacent compartment filled with liquid, shall not show any abnormal leakage through the separation affecting the dielectric properties of the two media.

Consideration should be given to the partitioning of the GIL-system in order to meet the requirement of operation, limitation of the fault affected GIL part and convenience of maintenance or repairs.

6.104 Sections of a GIL system

The sectionalizing of a GIL system can be made using disconnecting units. The length of sections along the system is determined considering requirements such as access and maximum length for testing, installation progress for long projects or operational and maintenance reasons.

6.105 Pressure relief

6.105.1 General

Pressure relief devices in accordance with 6.105 shall be arranged so as to minimize the danger to ~~an operator~~ people during the time ~~he is~~ they are performing ~~his~~ their normal operating duties on the GIL, if gases or vapors ~~escape~~ are escaping under pressure.

NOTE The term "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.

6.105.2 Limitation of maximum filling pressure

For filling a gas compartment, a pressure regulator shall be fitted to the filling pipe to prevent the gas pressure from rising to more than 10 % above the design pressure. Alternatively, the regulator ~~may~~ can be fitted to the enclosure itself.

The filling pressure should be chosen to take into account the gas temperature at the time of filling, for example, checking by temperature-compensated pressure gauges.

6.105.3 Pressure relief devices to limit pressure rise in the case of an internal fault

Since, after an arc due to an internal fault, the damaged ~~part of~~ enclosures will be replaced, pressure relief devices ~~need~~ shall only be provided to limit the external effects of the arc (see 6.101.2).

In the case of an internal fault, depending on volume of gas compartment and filling pressure, short-circuit current and duration, ~~the pressure, in the case of an internal fault, may~~ not exceed the routine test pressure of the enclosure, in such a case, a pressure relief device is not mandatory. ~~This consideration is of specific interest if the installation is in a tunnel.~~

If pressure relief devices are used in confined space accessible to personnel, precautions shall be taken to ensure safety in case of release (see also Clause 12).

~~NOTE 1~~ In the case of an internal fault which causes yielding of the enclosure, the adjacent enclosures should be checked for absence of distortion.

~~NOTE 2~~ When bursting disks are used for pressure relief, due regard should be paid to their rupture pressure in relation to the design pressure of the enclosure to reduce the possibility of unintentional rupture of the disk.

6.106 Compensation of thermal expansion

Due to temperature differences between parts of the GIL, between ~~parts of~~ the GIL and their surroundings, or ~~of~~ parts of the GIL relative to the temperature during construction, parts of the ~~line~~ GIL installation experience movements relative to each other and to their surroundings.

The relative movements or forces between the parts and/or their surroundings ~~may~~ can be determined either by measurement or calculations ~~which shall be~~ based on the maximum temperature difference of the parts relative to the temperature during construction. Where compensation is necessary, the following methods shall be used:

a) compensation between ~~primary~~ current-carrying parts and enclosure shall be ~~obtained~~ achieved by sliding contacts or similar means ~~in the primary parts~~;
b) compensation between the enclosure and its surroundings (fixed supporting structure, surrounding soil) shall be ~~obtained~~ achieved by appropriate means.

~~NOTE~~ Reference should be made to appropriate standards or methods for calculations of resulting forces and relative movements between environment and enclosure, and for interpretation of the results. This is particularly important for buried GIL, which are highly affected by factors such as anchoring, compression of the soil, type of soil, geometrical configuration of the line, etc.

6.107 External vibrations

Under certain conditions, the GIL ~~may~~ could be exposed to external vibrations. A typical case is when the GIL is attached to a bridge used by pedestrians, cars, and trains. Another case is when the GIL is directly connected to power transformers ~~and~~ or reactors.

Where a transmission line is attached to a source of vibrations, it is advisable to reduce mechanical stress by means of damping arrangements installed between the source and the part of the supporting structure which is rigidly connected to the transmission line. Such means ~~may~~ can considerably reduce the mechanical dynamic stresses in the transmission line structure. The remaining dynamic stress level shall be used as a basis for the mechanical dimensioning by means of combining the loads resulting thereof with other mechanical loads acting on the GIL in order to determine the total stress levels and to ensure that these levels are below permitted levels of the materials used.

In the case of a bridge, special attention shall be paid to relative movements between the bridge and its surrounding. These movements ~~may~~ can cause additional mechanical loads which would be necessary to consider when determining the total stress levels during the mechanical dimensioning.

6.108 Supporting structures for non-buried GIL

6.108.1 General

The supporting structures for GIL have an influence on the mechanical features of the GIL. The construction of the supporting structure ~~may~~ can vary in accordance with its function, the configuration of the GIL and the construction of the foundation, the tunnel or the shaft where the GIL is installed. For this reason, 6.108 describes the design condition and the requirements of the supporting structure functions.

6.108.2 Conditions of the design

The following forces and loads should be considered for the supporting structure design:

– weight of GIL;
– forces due to the internal gas pressure;
– friction between the surfaces of the support beam and the GIL foot;
– forces due to the thermal expansion of the GIL;
– seismic force, when applicable;
– wind load, when applicable;
– force due to short-circuit current;
– ice load, when applicable;
– forces due to other external impacts such as vibrations.
– ~~SF_6~~ gas/air bushing line pull.

When the supporting structure does not form part of the earthing system, means shall be provided to avoid eddy currents in the supporting structure and to allow corrosion protection.

6.108.3 Types of supporting structures

There are two basic kinds of supporting ~~function~~ structures:

a) sliding and flexible supporting structures: these supporting structures are designed in order to support and allow a certain movement due to the thermal expansion of the GIL;
b) rigid supporting structures: these supporting structures are designed in order to fix the GIL and to withstand the forces due to the thermal expansion of the enclosure and to the expansion of the compensators in the enclosure, if any, and to the internal gas pressure.

7 Type tests

7.1 General

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

The type tests shall be made on representative assemblies or subassemblies.

Because of the variety of possible combinations of components, it is impracticable to subject all possible arrangements to type tests. The performance of any particular arrangement ~~may~~ can be substantiated by test data obtained with comparable arrangements. All the tests shall be made with the equipment filled with the specified type of gas and at rated filling pressure, except when otherwise specified in the relevant subclause.

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with this specification, and sufficient information so that the essential part of the equipment tested can be identified. General information concerning the supporting structure shall be included in the test reports.

The type tests and verifications comprise the tests listed in 7.1.101 and 7.1.102.

7.1.101 Mandatory type tests

The following mandatory type tests shall be carried out:

		Subclause
a)	Tests to verify the insulation level of the equipment including partial discharge tests and dielectric tests on auxiliary circuits	7.2
b)	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
c)	Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short-time withstand current	7.6
d)	Tests to verify the protection of persons against contact with live parts of auxiliary circuits	7.7
e)	Tests to prove the strength of enclosures	7.101
f)	Test to prove the strength of partitions	7.102
g)	Gas tightness tests	7.8

7.1.102 Special type tests

This subject applies to agreement between manufacturer and user.

a)	Anti-corrosion tests (if applicable)	7.103
b)	Mechanical tests on sliding contacts	7.104
c)	Tests to verify the protection of the equipment against external effects due to weather and atmospheric agents	7.106
d)	Tests to assess the effects of arcing due to an internal fault	7.105
e)	Long term behaviour test for buried installation	Annex C

NOTE Some of the type tests ~~may~~ can impair the suitability of the tested parts for subsequent use in service.

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is not applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is not applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is not applicable.

7.2.4 ~~Conditions of switchgear and controlgear during dielectric tests~~ Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is not applicable and is replaced as follows:

Dielectric tests shall be performed at minimum functional pressure of the insulating gas as specified by the manufacturer. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable.

7.2.6 Application of test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is not applicable and is replaced as follows.

The test voltages specified in 7.2.7 and 7.2.8 shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits ~~are to~~ shall be connected to the earthing conductor or the frame and to the earth terminal of the test supply.

When each phase is individually encased in a metallic enclosure, only tests to earth, and no test between phases, are carried out.

7.2.7 Test of switchgear and controlgear of U_r ≤ 245 kV

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-203:2022 is applicable with the following additions:

7.2.7.2 Power-frequency voltage tests

The main circuit of the GIL shall be subjected to short duration power-frequency voltage tests in accordance with IEC 60060-1. The test voltage shall be raised to the test value and maintained for 1 min. The test shall be performed in dry conditions only.

~~The equipment shall be considered to have passed the test if no disruptive discharge has occurred.~~

7.2.7.3 Lightning impulse voltage tests

During the tests, the earthed terminal of the impulse generator shall be connected to the enclosure of the GIL.

Consideration shall be given to the length of the tested object, in order to avoid overvoltage due to travelling waves.

7.2.8 Test of switchgear and controlgear of U_r > 245 kV

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-203:2022 is applicable with the following additions:

7.2.8.2 Power-frequency voltage tests

The GIL shall be subjected to short duration power-frequency voltage tests in accordance with IEC 60060-1. The test voltage shall be raised to the test value and maintained for 1 min. The test shall be performed in dry conditions only.

~~The equipment shall be considered to have passed the test if no disruptive discharge has occurred.~~

7.2.8.3 Lightning and switching impulse voltage tests

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

During the tests, the earthed terminal of the impulse generator shall be connected to the enclosure of the GIL.

Consideration shall be given to the length of the tested object, in order to avoid overvoltage due to travelling waves.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is not applicable.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-203:2022 is applicable.

~~The maximum permissible partial discharge intensity at U_q corresponding to the applied test circuit should not exceed 5 pC.~~

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 not applicable.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 of IEC 62271-1:2017 is not applicable.

7.4 Measurement of the resistance of circuits

Subclause 7.4 of IEC 62271-1:2017 is applicable with the following addition:

The current-carrying parts of the main circuit and the enclosure, and each type of contact system shall be tested before and after the ~~temperature type~~ continuous current test.

7.5 ~~Temperature-rise tests~~ Continuous current test

Subclause 7.5 of IEC 62271-1:2017 is applicable with the following addition:

Calculations ~~may~~ can be performed based upon type test results to determine the maximum permissible current in other specified service conditions. For these calculations, refer to Annex A ~~and~~ [6]. Any complementary test ~~shall~~ should be agreed between manufacturer and user.

The assembly or subassembly shall include normal enclosure with ~~corrosive~~ corrosion preventive coating, if applicable, and shall be protected against undue external heating or cooling. ~~The test shall be carried out in open air.~~

Where the design provides alternative components or arrangements, the test shall be performed with those components or arrangements for which the most severe conditions are obtained.

Except when each phase is encased 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 assembly to the terminals provided for the connection of test cables.

When a single-phase test is permitted and carried out, the current in the enclosure shall represent the most severe condition.

When testing individual subassemblies, the neighbouring subassemblies should carry the currents which produce the power loss corresponding to the rated conditions. Equivalent conditions are allowed to be simulated, by means of heaters or heat insulation, if the test cannot be made under actual conditions.

The temperature rises of the different components shall be stated with reference to the ambient air temperature. They shall not exceed the values specified for them in the relevant standards.

The temperature of the enclosure shall not exceed the maximum allowable temperature of the anti-corrosion coating if applicable.

NOTE 1 The data on power losses and electrical resistance of the current-carrying parts of the GIL will be used to carry out calculations according to Annex A.

NOTE 2 The time constant of the GIL during the test will serve as a basis to evaluate the temporary overload capability of the GIL.

For open air, tunnel and shaft installations, the maximum temperature of the enclosure shall not exceed 80 °C. Parts normally touched during operation shall not exceed 70 °C. Reference is made to Clause 12.

For direct buried installation, the maximum temperature of the enclosure shall be limited to minimise soil drying. A temperature in the 50 °C to 60 °C range is generally considered as applicable limit. Higher temperatures can be accepted below the thermal stabilizing backfill only. A project related thermal rating calculation shall be done.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause ~~6.6 of IEC 62271-203~~ 7.6.1 of IEC 62271-1:2017 is applicable with the following addition:

Where the design provides alternative components or arrangements, the tests shall be performed with those representative components or arrangements for which the most severe conditions are obtained.

7.6.2 Arrangements of the GIL and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is not applicable and is replaced as follows:

The test arrangement shall be fitted with clean contacts in new condition.

A GIL with three-phase enclosure shall be tested three-phase.

A GIL with single-phase enclosure shall be tested according to the return current in the enclosure, dependent on the grounding system:

a) if the enclosure carries the full return current in service, the GIL shall be tested single phase, with the full return current in the enclosure;

b) if the enclosure does not carry the full return current in service, the GIL shall be tested three-phase. The tests shall be made at the minimum distance between phases indicated by the manufacturer.

7.6.3 Test current and duration

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

~~**6.6.3 Behaviour of the GIL during test**~~

~~Subclause 6.6.3 of IEC 62271-1 is not applicable.~~

~~It is recognized that, during the test, the temperature rise of current-carrying and adjacent parts of the GIL may exceed the limits specified in Table 3 of IEC 62271-1. No temperature-rise limits are specified for the short-time current withstand test, but the maximum temperature reached should not be sufficient to cause significant damage to the adjacent parts.~~

7.6.4 Conditions of the GIL after test

Subclause 7.6.4 of IEC 62271-1:2017 is not applicable and is replaced as follows:

After the test, there shall be no deformation or damage to conductors or contact joints within the enclosure which ~~may~~ can impair good service.

After the test, the resistance of the main circuits shall be measured according to 7.4. If the resistance has increased by more than 20 % and if it is not possible to confirm the conditions of the contacts by visual inspection, it will be necessary to perform an additional temperature-rise test.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 is applicable with the following addition:

If the second characteristic numeral is specified, the tests shall be performed in accordance with the requirements in Clause 11 and Clause 14 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 for the appropriate numeral.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

~~**6.8.101 Flange connection**~~

~~See 6.8 of IEC 62271-1.~~

~~**6.8.102 Welded connection**~~

~~No specific tightness test is required for on site welded enclosures if a 100 % inspection of the weld by radiographice, ultrasonic or other means be performed. In this case the welds are considered to have a zero leakage rate.~~

~~NOTE The impact of a flanged connection at the beginning and/or end is negligible in case of a welded GIL.~~

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is not applicable.

7.10 Additional test on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is not applicable.

7.11 X-radiation test procedure for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is not applicable.

7.101 Proof tests for enclosures

7.101.1 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 consist of either a bursting pressure test or a non-destructive pressure test, as appropriate to the material employed.

7.101.2 Destructive pressure tests

Subclause 7.103.2 of IEC 62271-203:2022 is applicable.

~~In the case of a bursting pressure test, the pressure rise should not be faster than 400 kPa/min. The bursting pressure test requirements should be based on 3,5 times the design pressure for cast enclosures and 2,3 times the design pressure for welded enclosures. These factors are based on the minimum certified properties of the material used.~~

~~Additional factors may be required taking into account the methods of construction and the material used.~~

~~Any enclosure remaining intact after these pressures have been reached shall be discarded.~~

7.101.3 Non-destructive pressure test

Subclause 7.103.3 of IEC 62271-203:2022 is applicable.

7.102 ~~Test to prove the strength of~~ Pressure test on partitions

Subclause 7.104 of IEC 62271-203:2022 is applicable.

7.103 ~~Anti-corrosion~~ Passive corrosion protection tests for buried installation

7.103.1 Passive corrosion protection

The passive corrosion protection system is basically a synthetic coating of the metal enclosure to protect the metal from humidity. The synthetic coating is usually built up from one or more layers of synthetic material.

The following three tests shall be performed.

7.103.2 Electrical testing

To prove the quality of the synthetic coating, a high-voltage test shall be applied. An electrical conductive layer is applied over the synthetic coating. A test voltage according to the dielectric strength of the synthetic coating is then applied between the metal enclosure and the electrical conductive layer.

The voltage level is dependent on the type of synthetic coating and shall be defined by agreement between manufacturer and user. In case the test is required by the particular contract, the corrosion protection layer shall be subjected to the electrical test specified in Clause 3 of IEC 60229:2007.

The length of the test sample shall be sufficient to provide the synthetic coating with a realistic result. Therefore, the minimum length recommended is 5 D, where D is the outer diameter of the metal enclosure.

7.103.3 Mechanical testing

Mechanical type tests ~~are~~ shall be carried out at ambient temperature in accordance with IEC 60068-1. The mechanical type test ~~has to~~ shall prove the resistance of the coating to conditions on site during and after laying. Resistance to two mechanical stresses ~~needs to~~ shall be proven:

– bending of the coating;
– impact on the coating of metal objects or rocks.

The mechanical stresses are highly dependent on the laying methods and the system layout. The forces and the procedure for carrying out testing ~~shall~~ should be mutually agreed between user and manufacturer.

7.103.4 Thermal testing

Thermal type tests represent the stresses produced by the maximum temperature changes of the GIL during on site assembly and in service.

Normal service conditions are covered by IEC 62271-1:2017, where special ambient conditions ~~need to~~ shall be defined by the user. The procedure for carrying out type tests ~~shall~~ should be mutually agreed between manufacturer and user.

7.104 Special mechanical test on sliding contacts

A mechanical endurance test shall be carried out to assess the ability of basic components such as sliding contacts to perform their duty during the expected lifetime of the equipment.

NOTE 1 The test is specific to GIL because of the difficulty of measuring and maintaining the contacts.

The contact shall be identified by

– the contact arrangement and principle,
– the contact material (including the nature and thickness of the coating, if any),
– the contact pressure (minimum – maximum), and
– the lubrication (if any) as indicated in the instruction manual.

The test conditions shall indicate

– the contact stroke,
– the contact speed, and
– the number of cycles.

A motorized test rig ~~may~~ can be used to simulate the expected relative movement of the live conductor. The test is considered representative, provided that

– the worst conditions are met, considering maximum differential expansion, weight of conductor, loads, etc.,
– the frequency of operation is limited to a value in the order of six cycles an hour, and
– the number of cycles is 10 000 for general purpose of GIL.

NOTE 2 For special applications, such as feeding a pump storage plant, a larger number of operating cycles and/or an increased frequency of operation ~~may~~ can be agreed between manufacturer and user.

The following inspections and tests are performed before and after the test:

– visual check;
– dimensional check and contact pressure;

– contact resistance.

The test will be considered satisfactory if

– the visual check shows that initial surface coating is still present everywhere,
– the wear is such that contact pressure is still within allowed tolerance, and
– the contact resistance variation is less than or equal to 20 %.

7.105 Test under conditions of arcing due to internal fault

Evidence of performance according 6.102.2 shall be demonstrated by the manufacturer when required by the user.

If such a test is agreed between manufacturer and user, the procedure shall be in accordance with the methods described in IEC 62271-203:2022, Annex B.

The current duration shall not be less than the expected second stage protection fault clearance time, as determined by the protection devices.

The values of the short-circuit current should correspond to the rated short-time withstand current.

NOTE For information, the fault clearing time for the first stage protection is about 0,1 s for currents of 40 kA and above and 0,2 s for lower currents. The time for the second stage protection normally does not exceed 0,3 s for currents of 40 kA and above, and 0,5 s for lower currents.

The GIL is considered adequate if, during the test, no external effects are produced within the withstand durations specified in 6.102.2.

No fragmentation of the enclosure shall result from a fault cleared in 0,3 s for currents of 40 kA and above, and in 0,5 s for lower currents unless otherwise agreed upon between manufacturer and user.

Tests on a particular arrangement ~~may~~ can also be used to predict the performance of other arrangements with the same design, either by calculation, or inference, or a combination of both.

To extend the test results to other enclosures of similar design but of different size and shape and/or to other test parameters, calculation methods should be agreed between manufacturer and user.

7.106 Weatherproofing test

When agreed between manufacturer and user, a weatherproofing test shall be made on GIL for outdoor use. A recommended method is given in ~~Annex A of IEC 62271-203~~ Annex C of IEC 62271-1:2017. ~~This test also takes into account the effects of wind-driven snow.~~

If an examination of the design shows the test to be unnecessary, it ~~may~~ can be omitted.

8 Routine tests

8.1 ~~Dielectric tests on the main circuits~~ General

Subclause ~~7.1 of IEC 62271-203~~ 8.1 of IEC 62271-1:2017 is applicable with the following addition:

Dielectric routine tests will preferably be performed on complete subassemblies. However, because of the existence of very long parts which ~~may~~ can be shipped dismantled, the manufacturer may limit can exclude the enclosure and conductor pipes including contacts from the routine test to critical parts (insulators for example). These critical parts All other components shall be subject to a factory routine test and be tested in a dielectric configuration identical to the service condition. The dielectric test on the fully assembled section will then be made at site (see 11.4.101).

The short-duration power-frequency voltage tests on the main circuit of the GIL shall be performed according to the requirements of 7.2.6 phase to earth and between phases (if applicable). The test voltages for routine tests shall be chosen from IEC 62271-203:2022, column (2) of Table 2 or Table 3.

The tests shall be performed at minimum functional pressure of the insulating gas.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable.

8.3 Dielectric Tests on auxiliary and control circuits

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

8.4 Measurement of the resistance of the main circuit

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

Overall measurements are made on transport units in the factory. The overall resistance measured shall not exceed 1,2 R_u, where R_u is the sum of the corresponding resistances measured during the type test.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 is applicable, with the following addition:

Attention shall be paid to the fact that external coating of the enclosure (if any) may can hide a leak. The tightness test procedure shall be adapted accordingly.

NOTE This test applies for factory made enclosures; for site welded enclosures, refer to 11.4.104.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable.

8.101 Partial discharge measurement

Partial discharge measurements (PD) shall be applied to critical parts such as insulators. Refer to 7.2.10 for the voltage levels and the partial discharge acceptance value.

The detection of PD on subassemblies and/or sections of the GIL is recommended.

8.102 Pressure tests of factory made enclosures

A pressure test shall be made on each individual enclosure after manufacture.

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

– 1,3 for welded enclosures;

– 2,0 for cast enclosures.

Subclause 8.101 of IEC 62271-203:2022 is applicable.

9 Guide to the selection of GIL (informative)

Clause 9 of IEC 62271-1:2017 is ~~not~~ applicable.

9.1 General

Subclause 9.1 of IEC 62271-1:2017 is not applicable and is replaced as follows:

For a given duty in service, GIL is selected by considering the individual rated values required under normal load conditions and in case of fault conditions.

The rated values should be chosen, as suggested in this document, with regard to the characteristics of the system as well as its expected future development.

In selecting a rated short-time withstand current for an installation, or part of an installation, consideration can be given to the fact that the maximum fault current in a circuit reduces as the distance from the substation increases. ~~The duty imposed by~~ These fault conditions should be determined by calculating the fault currents at the place where the transmission line is to be located in the system.

When applicable, temporary overload and ~~coincident~~ ambient temperature ~~shall~~ should be agreed between manufacturer and user. It is recommended to develop a temperature study on the project specific installation to confirm that temperature limits will not be exceeded.

9.101 Short time overload capability

The conditions of temporary overload ~~shall~~ should be agreed between manufacturer and user under consideration of the special circumstances (overload factor and duration, ambient temperature, initial conditions, increase in temperature limits for overload condition, laying conditions etc.). A typical overload figure is for example 20 % above the rated current for 30 min taking into account the particular load and temperatures at the beginning of the overload period.

9.102 Forced cooling

~~It shall take into account the total losses in the tunnel. Losses shall be those at rated current for the GIL and rated conditions for other sources.~~

Dimensioning of the forced cooling should take into account the total thermal losses in the tunnel. Thermal losses should be those at rated current for the GIL at maximum ambient temperature and thermal losses from other heat sources.

NOTE Access to the tunnel for service ~~should~~ can be restricted under the following conditions:

– in case of temporary overload;
– in case of loss of ventilation;
– in case of excessive temperature within the tunnel;
– when gas concentration exceeds levels stated in local regulations.

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

Clause 10 of IEC 62271-1:2017 is not applicable.

10.101 Information with enquiries and orders

10.101.1 General

When enquiring for, or ordering the installation of a GIL, the information listed in 10.101.2 to 10.101.7 should be supplied by the enquirer.

10.101.2 Particulars of the system

Nominal and highest voltage, frequency, type of system neutral earthing.

10.101.3 Environmental conditions

Details of environmental conditions ~~shall~~ should be given such as the following:

a) location inside electrical plant with restricted accessibility or outside, accessible to the public;
b) buried or non-buried installation;
c) installation in trenches, tunnels, or in open air with structures to be provided;
d) geological section and, in the case of a buried installation, geological and physical structure of soil;
e) depth of laying (if buried);
f) thermal conductivity of soil (if buried);
g) ventilation of trenches or tunnels;
h) seismic requirements.

10.101.4 Service conditions

Minimum and maximum ambient air or soil temperature; any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment. For example, unusual exposure to vapour, moisture, fluids, fumes, explosive gases, excessive dust or salt, the risk of earth tremors or other vibrations due to causes external to the equipment to be delivered, as well as possible movement of foundation, and possible mechanical impact.

10.101.5 Particulars of the installation

Details of the particulars of the installation ~~shall~~ should be given, such as the following:

a) system length and geographical routing;
b) number of phases (~~individually encased or in a common enclosure~~ single-phase enclosed or three-phase enclosed);
c) number of lines located in the same trench or tunnel;
d) rated voltage;
e) rated insulation level;
f) rated frequency (f_r);
g) rated normal current;
h) rated short-time withstand current;
i) rated duration of short-circuit (if different from 1 s);
j) rated peak withstand current;
k) maximum fault clearing time in case of internal fault;
l) degree of protection for auxiliary circuits;
m) crossing other utilities and or heat sources.

10.101.6 Particulars of the auxiliary devices

Details of the particulars of the auxiliary devices ~~shall~~ should be given, such as the following:

a) requirements of auxiliary devices and monitoring system (e.g. interlocking, gas supervision, signals etc.);
b) rated auxiliary voltage (if any);
c) rated auxiliary frequency (if any).

10.101.7 Specific conditions

In addition to the items listed in 10.101.2 to 10.101.6, the enquirer should indicate every condition which might influence the tender or the order, such as, for example, transport facilities and/or restrictions, special mounting or erection conditions, the locating of the external high-voltage connections or the rules for pressure vessels.

Information should be supplied if special type tests are required.

10.102 Information with tenders and contract documentation

10.102.1 General

The information listed in 10.102.2 to 10.102.6, if applicable, should be given by the manufacturer with written descriptions and drawings.

10.102.2 Rated values and characteristics

Particulars of the installation are enumerated in 10.101.5.

10.102.3 Further particulars of the transmission line and its components

Details of the line ~~shall~~ should be given, such as the following:

a) design pressure of enclosures;
b) design temperature of enclosures;
c) type and ~~rated~~ filling pressure of gas for insulation;
d) minimum functional pressure;
e) mass of gas for the different compartments;
f) length of the compartments;
g) limit values of moisture content and gas leakage;
h) details of appropriate measures for fault location.

10.102.4 Type test certificate or reports

When requested, type test certificates or reports ~~shall~~ should be transmitted as complete documents.

10.102.5 Particulars of the auxiliary devices

The tenders and contract documentation ~~shall~~ should provide at least, but not limited to, the following information:

a) types and rated values as enumerated in 10.101.6;
b) current or input power for operation.

~~9.102.6 Information about all matters to be subject to prior agreement between manufacturer and user~~

~~Void.~~

10.102.6 List of recommended essential spare parts

Spare parts should be procured by the user.

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

11.1 General

Subclause 11.1 of IEC 62271-1:2017 ~~is applicable, except as follows~~ applies.

11.2 Conditions during transport, storage and installation

Subclause 11.2 IEC 62271-1:2017 is applicable, with the following addition:

Internal cleanliness influences the function of the GIL; cleanliness therefore shall be assured by suitable precautions as ~~prescribed~~ required by the manufacturer.

~~NOTE~~ The following precautions ~~may~~ can be included:

- connecting GIL units under clean conditions (e.g. closed assembly tents with dry air, temperature regulation and with slight gauge pressure);
- openings should be covered by dust-protector or coverplates during installation;
- if necessary, the complete GIL should be cleaned inside after assembly;
- additional to precautions on site, transportation under condition of transport regulation with a prefill of dry and clean gas at an overpressure can be helpful to keep internal parts of the GIL in good condition.

The assembly unit should be as large as possible in order to reduce the assembly on site and the risk of pollution.

Connecting areas of the GIL units should be protected against damage to sealing surfaces or prepared edges for welding seams.

Where the GIL units have been welded on site, precautions should be made to avoid metal particles or polluting smoke entering the GIL.

The installation procedure should be covered by the quality assurance system.

11.3 Installation

11.3.1 General

Subclause 11.3.1 of IEC 62271-1:2017 is applicable, with the following addition.

For each type of GIL, the instructions provided by the manufacturer should at least include the items listed in 11.3.2 to 11.3.101.

11.3.2 Unpacking and lifting

Subclause 11.3.2 of IEC 62271-1:2017 is applicable.

11.3.3 Assembly

Subclause 11.3.3 of IEC 62271-1:2017 is applicable.

11.3.4 Mounting

Subclause 11.3.4 of IEC 62271-1:2017 is applicable.

11.3.5 Connections

Subclause 11.3.5 of IEC 62271-1:2017 is applicable.

11.3.6 Information about gas and gas mixtures for controlled and closed pressure systems

Subclause 11.3.6 of IEC 62271-1:2017 is applicable.

11.3.7 Final installation inspection

Subclause 11.3.7 of IEC 62271-1:2017 is not applicable and is replaced as follows:

~~10.3 Operation~~

~~Subclause 10.3 of IEC 62271-1 is not applicable.~~

After installation, before putting into service, the GIL shall be tested to check the correct operation and the dielectric strength of the equipment.

These tests and verifications comprise:

	Subclause
a) voltage tests on the main circuits	11.4.101
b) dielectric tests on auxiliary circuits	7.2.11
c) measurement of the resistance of the main circuit	11.4.103
d) gas tightness tests	7.8
e) checks and verifications	11.4.106
f) measurement of gas conditions	11.4.102
g) anti-corrosion tests for buried installations	11.4.107
h) tests on enclosures welded on site	11.4.104

To ensure minimum disturbance, and to reduce the risk of moisture and dust entering enclosures ~~so preventing~~, which secures correct operation of the GIL, no obligatory periodic inspections or pressure tests are specified or recommended when the GIL is in service.

Instructions should be provided for inspection and tests which should be made after the GIL has been installed and all connections have been completed.

The instructions should include the following:

- a schedule of recommended site tests to establish a correct functioning;
- recommendations for any relevant measurements that should be made and recorded to help future maintenance decisions;
- instructions for final inspection and putting into service.

For welded connection, the following shall apply: no specific tightness test is required for on site welded enclosure pipes (butt welds) if a 100 % inspection of the welds by radiographic, ultrasonic or other means is performed. In this case, the welds are considered to have a zero leakage rate.

NOTE The impact of a flanged connection at the beginning and/or end is negligible in case of a welded GIL.

11.3.8 Basic input data by the user

Subclause 11.3.8 of IEC 62271-1:2017 is applicable.

11.3.9 Basic input data by the manufacturer

Subclause 11.3.9 of IEC 62271-1:2017 is applicable.

11.3.101 Constructional features

The tenders and contract documentation ~~shall~~ should provide at least, but not limited to, the following information:

a) mass of the heaviest transport unit;
b) overall dimensions of the transmission line;
c) arrangement of the external connections;
d) provisions for transport to be taken by the user;
e) provisions for installation and laying ~~prescribed~~ required by the manufacturer;
f) location of the attachment points to the supports;
g) maximum forces to each attachment point;
h) maximum deflection of the enclosure at each attachment point.

11.4 Operating instructions

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

11.4.101 Voltage test on the main circuits

11.4.101.1 General

~~Since it is exceptionally important for GIL,~~ The dielectric strength shall be checked in order to eliminate causes which might give rise to an internal fault in service.

The site voltage tests are supplementary to the dielectric routine tests with the aim of checking the dielectric integrity of the completed installation and of detecting irregularities as mentioned above. Normally, the dielectric test shall be made after the GIL has been fully erected and gas-filled at the ~~rated~~ filling pressure, preferably at the end of all site tests, when newly installed. Such a dielectric test is recommended to be performed also after major dismantling for maintenance, repair or reconditioning of compartments. These tests shall be distinguished from the progressive voltage increase, performed in order to achieve a kind of electrical conditioning of the equipment before commissioning.

The execution of such site tests is not always practicable and deviations from the standards ~~may~~ can be accepted. The aim of these tests being a final check before energizing, it is very important that the chosen test procedure does not jeopardize sound parts of the GIL.

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

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

11.4.101.2 Test procedure

The GIL shall be properly erected and gas-filled at its ~~rated~~ filling pressure.

For the test, the GIL ~~may not~~ can be ~~connected to~~ disconnected from other equipment, either because of their high charging current or because of their effect on voltage limitation, such as

– high-voltage cables, overhead lines, and GIS,
– power transformers and most voltage transformers, and
– surge arresters and protective spark gaps.

Due to the possible length of a GIL it ~~may~~ can be ~~necessary~~ applicable for the site dielectric test to be carried out in sections. Due to this fact, provisions shall be made within the design of the GIL to incorporate positions where test equipment can be mounted without having to dismantle the GIL.

The conductors of the GIL section not under test shall be grounded.

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

NOTE 2 In order to test as much as possible of the GIL, removable links ~~may~~ can be included in the design in each of the above-mentioned cases. Here a "link" is understood to be a part of the conductor which can easily be removed in order to isolate two parts of the GIL from each other. This type of separation is preferable rather than dismantling.

Every newly erected part of a GIL shall be subjected to a dielectric test on site.

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

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

For the choice of an appropriate voltage waveform, IEC 60060-1 should be taken into consideration; however, similar waveforms are also permissible. AC is preferred, and DC should not be used. Partial discharge monitoring shall be performed during application of the test voltage. Conventional partial discharge measurement in accordance with IEC 60270 ~~may~~ is possibly ~~not be~~ appropriate. Other methods, such as UHF method should be considered. At the present time, no level has been ~~prescribed~~ required.

A voltage level equal to 80 % of the AC voltage applied during the routine test is recommended. For long GIL, the test is performed on sections as long as possible.

When the sections are fully assembled to form the complete installation, a test is performed at a lower voltage because of the capacity of the testing facility.

Impulse test voltage ~~may~~ can be additionally performed (lightning impulse wave shape, possibly oscillating, with an extended front time ~~may~~ can be used). The voltage level ~~shall~~ should be agreed between manufacturer and user.

11.4.102 Measurement of gas conditions

The ~~moisture~~ humidity content of the ~~insulation~~ insulating gas shall be determined. This ~~moisture~~ humidity content shall be in accordance with ~~5.1~~ 11.101.7 of IEC 62271-203:2022.

The measurement shall be performed on all compartments of the GIL, assembled and filled with gas at the ~~rated~~ filling pressure.

If the GIL is filled with sulphur hexafluoride, refer to IEC 60376 and IEC 60480 for checking the conditions of the gas during service. For other gases, see instruction manual from GIL manufacturer.

11.4.103 Measurement of the resistance of the main circuit

The measurement shall be performed on assembled sections of the GIL. The conditions of the measurement should be as close as possible to those of routine tests performed where possible on transport units.

Nevertheless, the measurement method and the adequate length for the assembled sections shall be chosen considering the following requirements:

– the measurement shall be done in such a way as to verify the integrity of the main circuit, including joints;
– the accuracy of the measurement shall allow the detection of all possible bad joints.
– The resistance measured shall not exceed 120 % of the maximum values measured during type tests (before temperature rise test), taking into account the differences of the two test arrangements (number of devices, contacts and connections, length of conductors, etc.).

11.4.104 Tests on enclosures welded on site

11.4.104.1 General

Where enclosures are welded on site, two types of tests shall be performed to verify the weld quality and integrity: testing of the welds and pressure tests.

11.4.104.2 Testing of site welding

~~The absence of unacceptable defects in all welds prepared on site shall be confirmed by suitable radiographic, ultrasonic or other equivalent techniques, by agreement between manufacturer and user.~~

The welding of the enclosure on site 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.

Imperfection assessment on a basis of welding procedure and welders qualification shall be made in agreement between manufacturer and user. For further information, consult the Bibliography and Annex D.

11.4.104.3 Pressure test

Site-welded enclosures shall withstand a pressure test, preferably pneumatic. In this case, the factor k ~~may~~ can be limited to 1,1, the test being done on the complete fully assembled compartment. In such case, additional precautions such as increased weld inspections should be made.

Where the factor k is limited to 1,1, testing of the weld in accordance with 11.4.104.1 shall be performed over 100 % of the weld length.

Provision shall be taken during the test to make sure that the pressure relief device will not operate. If a pneumatic test is not in compliance with local regulations, an alternative method ~~shall~~ should be agreed between manufacturer and user.

~~NOTE~~ Hydraulic testing of the assembled compartment should be avoided.

11.4.105 Periodic testing of the enclosure

No periodic testing of the enclosure is required if

– enclosures are filled with a non-corrosive gas, dried, stable and inert, or
– anti-corrosion external coating is monitored.

11.4.106 Checks and verifications

The following shall be verified:

a) conformity of the assembly with the manufacturer's drawings and instructions.
b) sealing of all pipe junctions, and tightness of bolts and connections;
c) conformity of the wiring with the diagrams;
d) proper functioning of the monitoring and regulating equipment including heating and lighting;
e) check of the correct connection of the bonding system.

~~NOTE~~ If, for whatever reason, one or more routine tests are not performed at the manufacturer's works, they should be carried out on site combined with the tests after erection.

11.4.107 Tests on corrosion protection for directly buried GIL

11.4.107.1 Passive corrosion protection

The voltage level and duration specified in Clause 5 of IEC 60229:2007 shall be applied between the metallic enclosure and the ground.

For the test to be effective, it is necessary that the ground makes good contact with all of the outer surface of the oversheath. A conductive layer on the oversheath can assist in this respect.

11.4.107.2 Active corrosion protection

The active corrosion protection system is laid out in accordance with the environmental conditions along the GIL. The protection current and protection potentials are calculated from data on soil electrical resistivity and acidity.

These values shall be measured after the GIL goes into service.

11.5 Maintenance

11.5.1 General

Subclause 11.5.1 of IEC 62271-1:2017 is applicable.

11.5.2 Information about fluids and gas to be included in maintenance manual

Subclause 11.5.2 of IEC 62271-1:2017 is applicable.

11.5.3 Recommendations for the manufacturer

Subclause 11.5.3 of IEC 62271-1:2017 is applicable.

11.5.4 Recommendations for the user

Subclause 11.5.4 of IEC 62271-1:2017 is applicable.

11.5.5 Failure report

Subclause 11.5.5 of IEC 62271-1:2017 is applicable.

11.5.101 Maintenance of GIL

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

It is important to think through the requirements of a possible post-fault or other repair and make provisions for gas handling and storage, access for replacement section, in-situ welding, fume extraction and weld inspection, and consider how a high-voltage test can be performed post-repair.

11.5.102 Gas handling

The following applies to GIL filled with gases which might have an environmental impact or might impose a hazard to the operating personnel.

For GIL ~~utilizing SF_6 gas or mixtures thereof, IEC 62271-303 applies,~~ using SF_6 gas, SF_6 mixtures or other gas mixtures included in IEC 62271-4, the requirements therein shall be applied in addition to the recommendations below.

In general, insulating gas shall be handled in such a way as not to cause harmful effects to the environment or persons. If the gas, or its decomposition products, which might be generated under certain service conditions (e.g. due to internal arcing), impose a hazard to personnel, appropriate precautions shall be taken in order to ensure safe handling, including decontamination after accidental release of hazardous products.

Regulations concerning the maximum permitted concentration of gas in those work areas using the gas shall be observed. This might call for installation of devices for measurement of the gas concentration, and for ventilation arrangements. This is particularly important when working in trenches, tunnels and similar locations with restricted space close to the installation. In the case of nitrogen and other gases which can be inhaled without risk, similar precautions shall be taken in order to prevent suffocation.

If the gas used has an environmental impact, it shall not under normal conditions (e.g. maintenance, repair) be released into the atmosphere. This means reclaiming by means of a gas handling unit with a storing capacity corresponding to the largest gas volume of the installation. Abnormal leaks shall be rectified. Contaminated gas shall either be ~~reprocessed~~ reclaimed by means of the gas handling unit and reused, or, if not possible, be sent to a company specialized in decontamination/reprocessing of waste. If the waste is considered to be hazardous, relevant rules for safety during handling and transportation shall be observed (see IEC 62271-4).

12 Safety

12.1 General

Subclause 12.1 of IEC 62271-1:2017 is applicable~~, except as follows~~ with the following additions:

High-voltage, ~~gas-insulated transmission lines~~ GIL can be safe only when installed in accordance with the relevant installation rules, and used and maintained in accordance with the manufacturer's instructions. It shall be operated and maintained by qualified personnel.

Due to the fact that it is completely impossible to touch any live part, a GIL provides a maximum degree of safety. However, it is normally only accessible by instructed or authorized persons.

When it is installed in an area accessible to the public, additional safety features shall be required. Two types of installation ~~are to~~ shall be considered.

– In the case of buried installations, there is no direct access but visible markings and a buried marker tape inform persons that an electrical device is buried at this location. These dispositions, combined with a sufficient thickness of earth (typically 1 m, see 4.102) should avoid any accidental contact. Potential load limits of the area above the trench shall be clearly visible installed along the route.
– In the case of above ground installations, fences or equivalent means shall be located along the GIL in such a way that no unintentional contact with the GIL or its accessories is possible.

The specifications in 12.2 to 12.103 are particularly important in order to ensure personal safety.

12.2 Precautions by manufacturers

Subclause 12.2 of IEC 62271-1:2017 is applicable.

12.3 Precautions by users

Subclause 12.3 of IEC 62271-1:2017 is applicable.

~~11.3 Electrical aspects~~

~~Subclause 11.3 of IEC 62271-1 is applicable with the following addition:~~

~~– Effect of an internal fault(see 5.101)~~

12.101 Mechanical aspects

– Mechanical stress due to the action of the external environment, or interaction between GIL and the environment:
  - movement of foundation, earthquakes, soil loading, wind, ice (see 6.102.2, 6.21)
  - thermal expansion (see 6.106)
– Pressurized components (see 6.102.2, 6.103, 6.104)
– Mechanical impact protection (see IEC 62271-1:2017)

12.102 Thermal aspects

– Maximum temperature of accessible part (see 7.5)
– Flammability (see IEC 62271-1:2017)

12.103 Maintenance aspects

– Gas handling (see 11.4.102)
– Operations of maintenance personnel in tunnels (see 6.105.3)

  Operations performed by maintenance personnel shall be strictly limited. When a maintenance operation is necessary, conditions shall be carefully defined and take into account the design of the GIL (gas volumes of the compartments, presence of pressure relief devices, etc.) and the volume of the tunnel.
– Earthing of the main circuits and the enclosure (see 6.3.101, 6.3.102)

13 Influence of the product on the environment

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

Also refer to 11.5.102.

Annex A
(informative)

Estimation of continuous current

A.1 General

The aim of Annex A is to define the continuous current of the GIL single phase when operating conditions are different from those of type tests, for example, open air GIL directly exposed to solar radiation, buried GIL or GIL in shafts or tunnels with forced cooling. Other changes might include different distances between phases or phase positions in the case of single-phase GIL or different enclosure currents due to earthing. The proposed method provides a basis for the estimation of continuous current, and refers to IEC 60287-1-1.

In contrast to the referred standards, the estimation of the continuous current ~~may not solely~~ can be based on more than one calculation, but be deduced from reference values to be obtained from type test results. The given standards ~~may~~ can be used for calculation. If other appropriate calculation methods are used, these ~~may~~ can be mentioned. The calculation is allowed if the temperature rise of the conductor is not more than 15 K with respect to the performed type test.

NOTE Although the scope of ~~IEC 60287-3-1~~ IEC 60287-1-1 refers to cables, the given calculations are also valid for GIL, unless the premises for certain relations (mainly concerning dimensions) define otherwise.

A.2 Symbols

D_c	diameter of conductor	(m)
D_e	diameter of enclosure	(m)
L	length of GIL	(m)
n	number of phases in one enclosure	
$\Delta\theta_c$	average temperature rise of the conductor	(K)
$\Delta\theta_{mc}$	maximum temperature rise of the conductor	(K)
$\Delta\theta_e$	average temperature rise of the enclosure	(K)
$\Delta\theta_{me}$	maximum temperature rise of the enclosure	(K)
$\Delta\theta_{ce}$	average temperature difference between conductor and enclosure	(K)
I_s	estimated continuous current	(kA)
K	thermal coefficient for heat exchange	
α	temperature coefficient of electrical resistivity	(1/K)
α_c	temperature coefficient of electrical resistivity for conductor	(1/K)
α_e	temperature coefficient of electrical resistivity for enclosure	(1/K)

A.3 Reference values

A.3.1 General

The following reference values ~~may~~ can be deduced from the type test results:

a) general type test values;

b) AC resistances;

c) dissipation;

d) thermal resistances;

e) thermal coefficients.

A.3.2 General type test values

The following values ~~have to~~ shall be derived from or given by the performed type test:

I_r	rated current	(kA)
$\Delta\theta_{co}$	average temperature rise of the conductor	(K)
$\Delta\theta_{mco}$	maximum temperature rise of the conductor	(K)
R_{dco}	DC resistance of conductor at ambient temperature	(μΩ)
I_{eo}	enclosure current	(kA)
$\Delta\theta_{eo}$	average temperature rise of the enclosure	(K)
$\Delta\theta_{meo}$	maximum temperature rise of the enclosure	(K)
R_{deo}	DC resistance of enclosure at ambient temperature	(μΩ)
$\Delta\theta_{ceo}$	average temperature difference between conductor and enclosure	(K)

NOTE The average temperature is determined from the temperature profile over the (tested) length.

A.3.3 AC resistances

The AC resistance of the conductor at average conductor temperature R_{co} ~~may~~ can either be deduced from the measured DC resistance R_{dco} and IEC 60287-3-1 or by appropriate calculation.

The AC resistance of the enclosure at the average enclosure temperature R_{eo} ~~may~~ can either be deduced from the measured DC resistance R_{deo} and IEC 60287-3-1 or by appropriate calculation.

~~NOTE 1~~ Contact resistance should also be taken into account.

~~NOTE 2~~ Such resistance value of the GIL should be defined in relation to the length of the GIL under consideration.

~~NOTE 3~~ Proximity effect should be considered; reference ~~may~~ can be made to ~~IEC 60287-3-1~~ IEC 60287-1-1 or the appropriate literature.

A.3.4 Dissipation

The dissipation in the conductor P_{co} at average conductor temperature ~~may~~ can be determined by:

$$P_{co} = I_r^2 \times R_{co}$$

The dissipation in the enclosure at P_{eo} average enclosure temperature ~~may~~ can be determined in case of known amplitude by:

$$P_{eo} = I_{eo}^2 \times R_{eo}$$

Otherwise, the dissipation in the enclosure due to eddy currents ~~may~~ can be determined by calculation (refer ~~IEC 60287-3-1~~ IEC 60287-1-1 or appropriate literature).

A.3.5 Thermal resistances

The thermal resistance T_{ceo} between conductor and enclosure is given by:

$$T_{ceo} = \Delta\theta_{ceo} / P_{co}$$

The thermal resistance T_{eo} between enclosure and the environment is given by:

$$T_{eo} = \Delta\theta_{eo} / [n \times P_{co} + P_{eo}]$$

A.3.6 Thermal coefficient

The thermal resistance T is given in IEC 60287-3-1 (thermal resistance in air (gaseous medium)) as:

$$T = 1 / [\pi \times D \times K \times \theta^{0,25}]$$

where

K is the thermal coefficient;

D is the diameter;

θ is the temperature difference.

The thermal coefficients K_{ce} and K_e for respectively T_{ce} and T_e are therefore given by:

$$K_{ce} = 1 / [T_{ceo} \times \pi \times D_c \times \Delta\theta_{ceo}{}^{0,25}]$$

$$K_e = 1 / [T_{eo} \times \pi \times D_e \times \Delta\theta_{eo}{}^{0,25}]$$

NOTE According to IEC TR 60943, the relationship between current and temperature rise is:

$$I^{1,67} = K' \Delta\theta.$$

Therefore, the thermal resistance according to IEC TR 60943 would be given by:

$$T = 1 / [\pi \times D \times K' \theta^{0,2}]$$

A.4 Estimation of current rating

A.4.1 General

In establishing the estimated continuous current, the following should be taken into consideration.

A.4.2 Maximum temperature rise

Since the calculations are based on the average temperature rise, the following relation is used to determine the maximum temperature rise of the conductor relative to the average conductor temperature rise:

~~$$\delta\theta_{mc} = (I_s/I_r)^2 \times (\Delta\theta_{mco} - \Delta\theta_{co})$$~~

$$\Delta\theta_{mc} = (I_s/I_r)^2 \times (\Delta\theta_{mco} - \Delta\theta_{co})$$

Therefore, the maximum temperature rise $\Delta\theta_{mc}$ of the conductor is given by:

$$\Delta\theta_{mc} = \Delta\theta_c + \delta\theta_{mc}$$

The maximum temperature rise ~~$\delta\theta_{me}$~~ $\Delta\theta_{me}$ of the enclosure is found in exactly the same way.

A.4.3 Heat input

A.4.3.1 General

The influence of the adjacent phases ~~may~~ can be taken into account for the evaluation of external heat input.

A.4.3.2 Estimated internal dissipation

The internal dissipation of the conductor for the required situation is given by:

$$P_c = (I_s/I_r)^2 \times P_{co}\,[1 + \alpha_c \times (\Delta\theta_c - \Delta\theta_{co})]$$

The dissipation of the enclosure for the required situation is given by:

$$P_e = (I_s/I_r)^2 \times P_{eo}\,[1 + \alpha_e \times (\Delta\theta_e - \Delta\theta_{eo})]$$

NOTE When the layout of the installation is different (e.g. different phase distance of single-phase equipment or different earthing), the calculation of the dissipation is adjusted accordingly.

A.4.3.3 External heat input

Other external heat sources should be taken into account such as solar radiation, influence of adjacent phases, etc. In the following, their effect is designated by the symbol P_s.

A.4.4 Thermal resistances

A.4.4.1 Internal thermal resistance

The internal thermal resistance ~~T_{ce}~~ T_{ceo} between conductor and enclosure ~~may~~ can be calculated according to the formula given in A.4.5. The calculated thermal coefficient ~~may~~ can be used.

A.4.4.2 External thermal resistance

The external thermal resistance ~~T_e~~ T_{eo} of the enclosure to the environment, for an installation in free air, the formula is given in A.4.5, including the thermal coefficient. In this case, the influence of wind, etc., is neglected.

The external thermal resistance T_e for other situations ~~may~~ can be determined according to ~~IEC 60287-3-1~~ IEC 60287-1-1 or other relevant literature.

NOTE The external thermal resistance is the total thermal resistivity of the enclosure to the environment.

A.4.5 Estimated maximum temperature rise

The estimated average temperature rise of the enclosure is defined as follows:

$$\Delta\theta_e = T_e \times (n \times P_c + P_e + P_s)$$

The maximum temperature rise of the enclosure is then given by:

$$\Delta\theta_{me} = \Delta\theta_e + \delta\theta_{me}$$

and the maximum temperature rise of the conductor is given by the following:

$$\Delta\theta_{mc} = \Delta\theta_e + \delta\theta_{mc} + T_{ce} \times P_c$$

$$\Delta\theta_{mc} = \Delta\theta_e + \delta\theta_{mc} + T_{ceo} \times P_c$$

A.4.6 Permissible temperature rises

The temperature rise of any point of the GIL (conductor, enclosure, tunnel, etc.) may can be in accordance with the allowed temperature rise of the relevant IEC standard.

A.4.7 Estimated continuous current

The estimated continuous current is defined by the simultaneous solution of the relations and premises given in Annex A.

A.4.8 Informal documents

For more information, see [7].

Annex B
(informative)

Earthing

B.1 General

The earthing system is designed to ensure that no danger to persons or damage to equipment occurs under normal or abnormal operating conditions due to hazardous potential differences.

B.2 Safe limits on potential rise

The design of the earthing system should take into account potential rises due to fault currents, high-frequency currents associated with transient enclosure voltage and, for some types of bonding, ~~standing~~ step and touch voltages.

Acceptable values for touch potentials, step potentials and transferred potentials for the safety of persons should be determined with reference to IEC TS 60479-1 and IEC TS 60479-2. Attention is drawn to further limits on potential rise (~~standing~~ step and touch voltages, induced voltages) that ~~may~~ can be imposed by local regulations.

B.3 Enclosures

A GIL is contained within a conducting enclosure nominally at, or near, ground potential.

B.4 Earth electrodes

An earth electrode provides a low-impedance path to earth for both fault currents and high-frequency currents associated with transient enclosure voltage.

The earth electrode design should take into account the maximum ground fault current and duration at that position in the system and the soil resistivity so that hazardous potential differences do not occur.

The earth electrode cross-sectional area should be chosen to accommodate the maximum ground fault current and duration at that position in the system within an acceptable temperature rise.

The design of any joints should take into account the maximum ground fault current and duration at that position in the system.

The earth electrode design should take into account the mechanical stresses that ~~may~~ can occur during installation and during fault conditions.

The earth electrode material should be resistant to corrosion.

B.5 Conductors of earthing system

The conductors of the earthing system ~~may be required~~ need to carry both fault currents and possible high-frequency currents associated with transient enclosure voltages. In some cases, conductors will carry zero sequence currents or circulating power-frequency currents.

The conductor design should take into account all currents to be carried so that hazardous potential differences do not occur.

The conductors should be wide (typically greater than 50 mm in width), kept as short as possible and as free from changes in direction as possible to achieve a low inductance. Sharp bends in the conductors should be avoided.

The conductor cross-sectional area should be chosen to accommodate any current to be carried within an acceptable temperature rise.

The design of any joint should take into account all currents to be carried.

The conductor design should take into account the mechanical stresses that ~~may~~ can occur during fault conditions.

B.6 Earth continuity

Electrical continuity between the earthing systems at either end of the transmission line route is necessary to provide a low impedance path for zero sequence currents.

Where it is not possible to use the enclosures to provide adequate earth continuity, a separate earth continuity conductor will be necessary.

B.7 Induced voltages

The earthing system should be designed to avoid large ground currents (which is not the enclosure current during normal operation) flowing as these ~~may~~ can induce hazardous voltages in neighbouring communications circuits, pipelines, etc., possibly belonging to other authorities.

B.8 Transient enclosure voltage

Events such as switching (particularly disconnector operation), fault conditions, lightning strokes and operation of surge arresters generate fast fronted transients. Under such conditions, discontinuities in enclosures (e.g. where an insulating flange forms an essential part of the structure, or at gas to air bushings) will allow high-frequency currents to couple out and propagate on the outside of the enclosures giving rise to transient enclosure voltages. Precautions are taken in the design of the earthing system to limit the effects of transient enclosure voltages.

B.9 Non-linear resistors

To protect against the effects of transient enclosure voltages, protective devices (non-linear resistors) should be installed where the ends of enclosures are not connected to earth.

The rated voltage of the devices should be coordinated with ~~standing~~ step and touch voltages induced by rated and short-circuit current (see Clause B.10). The devices should have adequate energy absorption and high-frequency response.

They should be arranged to give a low-inductance connection by minimizing the length of the connecting leads and connecting a number of devices in parallel.

B.10 Bonding and earthing

B.10.1 General

It is envisaged that most GIL installations will be solidly bonded and earthed at both ends. However, where other bonding methods are used such as single point bonding or cross-bonding, additional precautions ~~will need to~~ shall be taken in the design of the earthing system in order to manage the effects of ~~standing~~ step and touch voltages and induced voltages and currents, as well as mechanical forces resulting from short-circuit currents.

The enclosure may need to be earthed at additional positions along the route to reduce the earth potential rise under internal fault conditions.

Where the three phases of a transmission line are contained within a single enclosure, the enclosure ~~may~~ can be earthed at both ends of the transmission line route. The enclosure will normally provide adequate earth continuity between the two ends of the route and a separate earth continuity conductor will be unnecessary.

The enclosures ~~may~~ can be bonded and earthed at one end and insulated from earth at the other (end point bonding) or bonded and earthed at the mid-point and insulated from earth at the two ends (mid-point bonding). The transmission line ~~may~~ can consist of a number of elementary sections, each single-point bonded.

To protect against the effects of transient voltages, protective devices (non-linear resistors) are connected at the ends of elementary sections where the enclosures are insulated from earth.

B.10.2 Cross-bonding

In a cross-bonded system, the enclosures are connected in series at the end of each elementary section in phase rotation, so that the e.m.f. induced along the enclosures tend to sum to zero after three elementary sections. The enclosure voltage is therefore controlled and circulating currents are virtually eliminated. However, eddy currents will generally be induced in the enclosure walls and these will contribute to the total heat dissipation of the transmission line.

The enclosures ~~may~~ can be solidly bonded and earthed at the ends of a transmission line and continuously cross-bonded throughout its length (continuous cross-bonding) or solidly bonded and earthed at the ends of a number of major sections, each consisting of three cross-bonded minor sections (sectionalized cross-bonding).

To protect against the effects of transient voltages, protective devices (non-linear resistors) are connected at the ends of elementary sections where the enclosures are insulated from earth.

Where the earth resistance at solidly bonded positions is high, a separate earth continuity conductor ~~may~~ can be ~~necessary~~ applicable in order to prevent the ratings of protective devices being exceeded under internal fault conditions.

B.11 Application to directly buried installations

Where an installation is directly buried, the design of the earthing system shall accommodate the requirements of corrosion protection as stated under 6.21 (see Figure B.1).

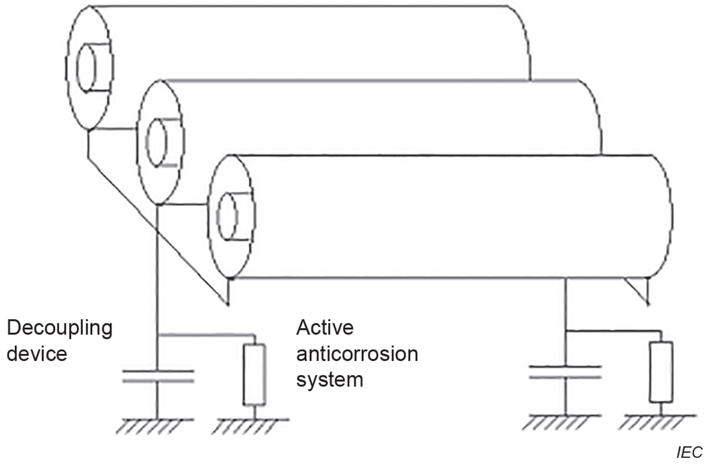

Figure B.1 – Example of earthing system together with active anti-corrosion system in the case of solid bonding of the enclosure at both ends

The design of the earthing system should be coordinated with the insulation level of the corrosion protection coating.

Removable links should be provided to allow electrical testing of the passive corrosion protection as stated under 7.103.

The design of the earthing system and the active corrosion protection should be coordinated so that no damage results to the active corrosion system from currents flowing from the enclosures to earth.

B.12 Informal documents

For more information, see [7] and [9].

Annex C
(~~normative~~ informative)

Long-term testing of buried installations

C.1 Assessment of long-term behaviour

C.1.1 General

The points that ~~need to~~ shall be considered to assess long-term behaviour are

– the thermomechanical performance of the assembly, and
– the corrosion protection of the enclosures.

C.1.2 Thermomechanical performance

Thermomechanical forces, unless properly accounted for, can result in mechanical damage to the GIL and possible rupture of the enclosure. Therefore, whichever device is employed for counteracting the effects of thermal expansion and contraction, especially for the enclosures, it ~~needs to~~ shall be evaluated under buried condition. The length of the test installation ~~needs to~~ shall be sufficient to ensure that any thermomechanical movement is representative of what might occur in service.

NOTE ~~Performance of the backfill material~~

Evaluation of the soil over the complete GIL installation could prove difficult unless a backfill material with known properties is used. It is assumed that normal ground materials will have a dried-out thermal resistivity value at a temperature between 50 °C and 60 °C and a non-dried out value if the temperature is below this. These figures are used in the rating calculations detailed in Annex A. Provided that the thermal resistivity values are known, the ground temperatures and hence system rating can be calculated allowing for dried out values where applicable.

C.1.3 Corrosion protection of the enclosures

It is important that the enclosure protective coating is not penetrated during service. The performance of the coating can be evaluated by either long-term water immersion tests or by long-term burial test in a wet soil condition. During this time, the GIL should undergo heat cycles to see the effect of temperature cycles on the migration of water. Deterioration in the coating can be detected by regular application of a test voltage and measurement of the leakage current that flows.

C.2 Summary of long-term tests

Development tests shall be completed by the manufacturer before long-term tests are undertaken. The purpose of these tests is to identify the long-term performance of the complete GIL system and ~~need~~ shall only be carried out once, unless there is a substantial change in the GIL system concerning material, process and design. The test arrangement should consist of between 50 m and 100 m of GIL including auxiliary equipment (gas monitoring, partial discharge detection and pressure relief devices). At least one type of each component to be used in the system should be tested and the test arrangement should be representative of an installation design. The long-term tests should be undertaken over a twelve-month period.

The definition of the test procedure is under consideration. The following is proposed for guidance.

The following test should be carried out before starting and after the long duration tests:

a) temperature rise measurement (in accordance with ~~4.4.2~~ 7.5.3.1 of IEC 62271-1:2017) of external enclosure walls and at set distances within the backfill material;
b) measurement of the main circuit resistance;

c) partial discharge levels within the GIL;
d) dielectric withstand test;
e) gas leakage rate;
f) on completion of the tests, a voltage test to breakdown ~~may~~ can be performed.

Long duration tests ~~may~~ can include:

- long-term thermal cycling;

  Subject the busbars and any expansion device to thermomechanical forces.
- corrosion protection performance;

  This ~~is to~~ shall be evaluated under thermal cycling and will include the complete arrangement and all the auxiliary equipment.
- backfill performance;

  This shall be carried out if the performance of the backfill is not known or cannot be guaranteed.

Annex D
(normative)

Requirements for welds on pressurized parts

D.1 General

Weld seams shall be produced and assessed according to defined requirements. During the production of a GIL, welding seams are made in the factories and on site.

D.2 Process and personal qualifications

All welding processes shall be checked and documented in accordance with international standards. Welding and subsequent testing personnel shall be certified in accordance with international standards.

- Definition of the welding procedures (WPS) according to ISO 15609 (all parts)
- Welding process qualification (WPQR) according to ISO 15614 (all parts)
- Qualification of welders and operators according to ISO 9606 (all parts) and ISO 14732
- Non-destructive test (NDT) personnel according to ISO 9712

D.3 Non-destructive tests of welding

For non-destructive testing of factory and on site welds, the items of Table D.1 applies:

Table D.1 – Quantity of NDTs

Tests type	Factory welds	On site welds
Visual (VT) 8.6 of IEC 62271-1:2017	100 %	100 %
Radiography (RT) or ultrasonic (UT) 7.103 of IEC 62271-203:2022	min. 10 %, 100 % of cross sections; welding factor ν = 1	min. 10 % to 100 % 11.3.7 and 11.4.104

For imperfections defined and classified according to ISO 6520 (all parts), refer to Table D.2.

Table D.2 – Acceptance criteria of imperfections

Test type	Applicable standard		Acceptance level	
	Steel	**Aluminum**	**Steel**	**Aluminum**
VT	ISO 5817	ISO 10042	EN 50068	EN 50064
RT	ISO 10675-1	ISO 10675-2		
UT	Recommended applicable standards			
	ISO 11666, ISO 17640	[a]		
	ISO 22825, ISO 23279			
	ISO 10893-8, ISO 10893-9, ISO 10893-10 and ISO 10893-11			

[a] UT testing of aluminium welds should be performed according to the adapted steel standards or equivalent manufacturer specifications. For more information, see [10] and [11].

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[9] IEC TS 60479-2:2019, *Effects of current on human beings and livestock – Part 2: Special aspects*

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[11] EN 50068, *High-voltage switchgear and controlgear – Gas-filled wrought steel enclosures*

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[13] ISO 6520 (all parts), *Welding and allied processes – Classification of geometric imperfections in metallic materials*

[14] ISO 10042, *Welding – Arc-welded joints in aluminium and its alloys – Quality levels for imperfections*

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[18] ISO 10893-9, *Non-destructive testing of steel tubes – Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes*

[19] ISO 10893-10, *Non-destructive testing of steel tubes – Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

[20] ISO 10893-11, *Non-destructive testing of steel tubes – Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*

[21] ISO 11666, *Non-destructive testing of welds – Ultrasonic testing – Acceptance levels*

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IEC 62271-204

Edition 2.0 2022-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

High-voltage switchgear and controlgear –
Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV

Appareillage à haute tension –
Partie 204: Lignes de transport rigides à isolation gazeuse de tension assignée supérieure à 52 kV

IEC 62271-204:2022-05(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV

FOREWORD

IEC 62271-204 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

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

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

a) update to be in line with IEC 62271-1:2017 and alignment of the voltage ratings and the test voltages.

b) addition of new information for welds on pressurized parts and gas tightness.

The text of this document is based on the following documents:

Draft	Report on voting
17C/840/FDIS	17C/846/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.

This document is to be read in conjunction with IEC 62271-1:2017 and IEC 62271-203:2022, to which it refers and which are applicable unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1:2017 and IEC 62271-203:2022. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

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

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV

1 Scope

This part of IEC 62271 applies to rigid HV gas-insulated transmission lines (GIL) in which the insulation is obtained, at least partly, by an insulating gas or gas mixture other than air at atmospheric pressure, for alternating current of rated voltages above 52 kV, and for service frequencies up to and including 60 Hz.

This document is applicable where the provisions of IEC 62271-203 do not cover the application of GIL (see Note 3).

At each end of the HV gas-insulated transmission line, a specific element is used for the connection between the HV gas-insulated transmission line and other equipment like bushings, power transformers or reactors, cable boxes, metal-enclosed surge arresters, voltage transformers or GIS, covered by their own specification.

Unless otherwise specified, the HV gas-insulated transmission line is designed to be used under normal service conditions.

NOTE 1 In this document, the term "HV gas-insulated transmission line" is abbreviated to "GIL".

NOTE 2 In this document, the word "gas" means gas or gas mixture, as defined by the manufacturer.

NOTE 3 Examples of GIL applications:

- where all or part of the HV gas-insulated transmission line is directly buried;
- where the HV gas-insulated transmission line is located, wholly or partly, in an area accessible to public;
- where the HV gas-insulated transmission line is long (typically longer than 500 m) and the typical gas compartment length exceeds the common practice of GIS technology.

2 Normative references

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

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

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60229:2007, *Electric cables – Tests on extruded oversheaths with a special protective function*

IEC 60287-3-1:2017, *Electric cables – Calculation of the current rating – Part 3-1: Operating conditions – Site reference conditions*

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

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

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

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

IEC 62271-203:2022, *High-voltage switchgear and controlgear – Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC 62271-4:2013, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures*

ISO 9606 (all parts), *Qualification test of welders – Fusion welding*

ISO 9712, *Non-destructive testing – Qualification and certification of NDT personnel*

ISO 14732, *Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure specification*

ISO 15614 (all parts), *Specification and qualification of welding procedures for metallic materials – Welding procedure test*

3 Terms and definitions

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

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

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

3.101
area accessible to public
area accessible without restriction to any person

Note 1 to entry: A GIL installed above the ground and outside a substation is considered to be "installed in an area accessible to public".

3.102
gas-insulated transmission lines
GIL
metal-enclosed lines in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure, with the external enclosure intended to be earthed

3.103
GIL enclosure
part of GIL retaining the insulating gas under the required conditions protecting the equipment against external influences and providing a high degree of protection to personnel

3.104
compartment
part of GIL totally gastight enclosed except for openings necessary for interconnection and control

3.105
partition
gas tight support insulator of gas-insulated metal-enclosed switchgear separating two adjacent compartments

3.106
main circuit
all the conductive parts of GIL included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:1984, 441-13-02, modified – Replacement of “an assembly" by “GIL".]

3.107
ambient air temperature
temperature, determined under required conditions, of the air surrounding the external GIL enclosure in case of installation in open air, open trenches or tunnels

[SOURCE: IEC 60050-441:1984, 441-11-13, modified – Replacement of “complete switching device or fuse" by “external GIL enclosure in case of installation in open air, open trenches or tunnels".]

3.108
design temperature of the enclosure
maximum temperature which can be reached on a GIL enclosure under service conditions

3.109
design pressure of the enclosure
relative pressure used to determine the design of the enclosure

Note 1 to entry: It is at least equal to the maximum relative pressure in the enclosure at the design temperature of the enclosure.

3.110
design pressure of the partitions
relative pressure across the partition

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

3.111
disconnecting unit
unit to electrically isolate one side from another of the main circuit, mainly for site testing or maintenance

3.112
disruptive discharge
phenomenon associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation, reducing the voltage between the electrodes to zero or almost zero

Note 1 to entry: The term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric, the loss can be only temporary (self-restoring insulation).

Note 3 to entry: The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric. The term "flashover" is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium. The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

3.113
GIL section
part of GIL which is defined by operational or other requirements such as maximum length for dielectric testing or installation sequence

Note 1 to entry: A GIL can consist on the assembly of several GIL sections.

Note 2 to entry: It can consist of one or more compartments.

Note 3 to entry: Sections can be segregated by disconnecting units.

4 Normal and special service conditions

4.1 Normal service conditions

4.1.1 General

Subclause 4.1.1 of IEC 62271-1:2017 is applicable with the following addition.

The normal service conditions which apply to a GIL depending on the installation conditions are given in 4.101, 4.102 and 4.103. When more than one of these installation conditions apply, the relevant subclause shall apply to each section of the GIL.

4.1.2 Indoor switchgear and controlgear

Subclause 4.1.2 of IEC 62271-1:2017 is applicable.

4.1.3 Outdoor switchgear and controlgear

Subclause 4.1.3 of IEC 62271-1:2017 is applicable.

4.2 Special service conditions

Subclause 4.2 of IEC 62271-1:2017 is applicable.

4.101 Installation in open air

For determining the ratings of GIL for open air installation, the normal service conditions of IEC 62271-1:2017 shall apply. These are also valid for open trenches.

If the actual service conditions differ from the normal service conditions, the ratings shall be adapted accordingly.

4.102 Buried installation

General values for thermal resistivity and soil temperature are:

– 1,2 K · m/W, and 20 °C in summer;
– 0,85 K · m/W, and 10 °C in winter.

For guidance, values given in IEC 60287-3-1 can be considered.

For long distance transmission lines (several kilometres), site measurement of soil resistivity should also be considered.

NOTE 1 The use of controlled backfill with a given soil thermal resistivity can also be considered.

NOTE 2 A risk of thermal runaway exists if the soil surrounding the buried GIL becomes dry. In order not to dry out the soil, a maximum service temperature of the enclosure in the range of 50 °C to 60 °C is generally considered acceptable.

The depth of laying should be agreed between manufacturer and user. The determination of depth of laying shall take into account thermo mechanical stresses, safety requirements and local regulations.

4.103 Installation in tunnel, shaft or similar situation

Forced cooling is an adequate method to handle with the waste heat and can be used in case of tunnel, shaft or similar installations.

In the case of long vertical shafts and inclined tunnels or sections thereof, attention shall be paid to thermal and density gradients.

5 Ratings

5.1 General

Subclause 5.1 of IEC 62271-1:2017 is not applicable and is replaced as follows.

The rating of a GIL consists of the following:

a) rated voltage (U_r);
b) rated insulation level (U_d, U_p, U_s);
c) rated frequency (f_r);
d) rated continuous current (I_r);
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);
g) rated duration of short-circuit (t_k);
h) rated supply voltage of auxiliary and control circuits (U_a);
i) rated supply frequency of auxiliary and control circuits.

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1:2017 is applicable.

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:

Rated insulation levels shall be chosen from IEC 62271-203 on the basis of insulation coordination study for the specific installation in order to consider parameters like overvoltages, voltage reflections, etc. Specific insulation coordination studies are recommended for each installation. For more information, see [1][1].

Although internal arcing faults can largely be avoided by the choice of a suitable insulation level, measures to limit external overvoltages at each end of the installation (e.g. surge arresters) should be considered.

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

5.4 Rated frequency (f_r)

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

5.5 Rated continuous current (I_r)

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

The rated continuous current is defined for a single or a three-phase GIL installed above ground with an ambient air temperature at 40 °C. For other installation conditions, the maximum allowable continuous current can differ from the rated continuous current. See Annex A.

5.6 Rated short-time withstand current (I_k)

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

5.7 Rated peak withstand current (I_p)

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

5.8 Rated duration of short-circuit (t_k)

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

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

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

5.10 Rated supply frequency of auxiliary and control circuits

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

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 is not applicable.

6 Design and construction

Clause 6 of IEC 62271-1:2017 is applicable, except as follows.

Any GIL equipment which requires routine preventive maintenance or diagnostic testing should be easily accessible.

GIL should be designed so that normal service, inspection and maintenance operations can be carried out safely, including the checking of phase sequence after erection and extension.

The equipment should be designed such that the mechanical stress caused by all relevant loads, for example thermal expansion, agreed permitted movement of foundations, external vibration, earthquakes, soil loading, wind and ice, do not impair the assigned performance of the equipment.

6.1 Requirements for liquids in GIL

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

6.2 Requirements for gases in GIL

Subclause 6.2 of IEC 62271-1:2017 is applicable. In case a gas mixture is used, the manufacturer should provide information about the gas characteristics such as dielectric strength, mixing ratio, process of mixing and filling pressure.

NOTE See references [2], [3] and [4].

6.3 Earthing

Subclause 6.3 of IEC 62271-1:2017 is applicable, with the following additions.

6.3.101 Earthing of the main circuits

To ensure safety during maintenance work, all parts of the main circuits to which access is required or provided shall be capable of being earthed. In addition, it shall be possible, after the opening of the enclosure, to connect earth electrodes to the conductor for the duration of the work.

Earthing can be made by

a) earthing switches with a making capacity equal to the rated peak withstand current, if there is still a possibility that the circuit connected is live;
b) earthing switches without a short-circuit making capability or with a short-circuit making capability lower than the rated peak withstand current, if there is a certainty that the circuit connected is not live, or
c) removable earthing devices, only by agreement between manufacturer and user.

Each part being capable of being disconnected shall be capable of being earthed.

Consideration should be given to the ability of the first operated earthing device to dissipate the maximum level of trapped charge on the isolated circuit.

Where the earthing switches form part of the plant connected to the transmission line, the user shall ensure that they comply with the above items a) to c).

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

6.3.102 Earthing of the enclosure

The enclosures shall be capable of being connected to earth. All metal parts intended to be earthed, which do not belong to a main or an auxiliary circuit, shall be connected to earth. For the interconnection of enclosures, frames, etc., fastening (e.g. bolting or welding) is generally acceptable for providing electrical continuity. If the fastening is done by bolting, provisions shall be given in order that a proper electrical contact is provided. If not, the mechanical joint shall be by-passed by a proper electrical connection such as copper or aluminum leads of proper cross section.

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

It is envisaged that most GIL installation will be solidly bonded and earthed at both ends. The particular design has an influence on heat dissipation, step and touch voltages and the external magnetic field. These are discussed in Annex B.

The design of the earthing of the enclosure shall be compatible with the measures for corrosion protection when the GIL is buried.

6.4 Auxiliary and control equipment

Subclause 6.4 of IEC 62271-1:2017 is applicable.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1:2017 is not applicable.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 is not applicable.

6.7 Independent manual or power operation (independent unlatched operation)

Subclause 6.7 of IEC 62271-1:2017 is not applicable.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 is not applicable.

6.9 Operation of releases

Subclause 6.9 of IEC 62271-1:2017 is not applicable.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 is applicable.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 is not applicable and is replaced as follows:

6.11.1 General

For outdoor installation, the nameplates and their fixings shall be weather-proof and corrosion proof.

A complete nameplate shall be provided at each end of the installation, and at each point where service is needed. These nameplates shall contain the following information:

- manufacturer's name or trademark
- type designation and serial number
- rated voltage U_r
- rated lightning impulse withstand voltage U_p
- rated switching impulse withstand voltage U_s
- rated short-duration power-frequency withstand voltage U_d
- rated continuous current I_r
- rated short-time withstand current I_k
- rated peak withstand current I_p
- rated frequency f_r
- rated duration of short-circuit t_k
- filling pressure for insulation; minimum functional pressure for insulation; design pressure for enclosures

– type of gas
– mass of gas

NOTE The word "rated" is optional on the nameplates.

6.11.2 Application

Subclause 6.11.2 of IEC 62271-1:2017 is not applicable and is replaced as follows:

Since characteristics of different sections can be different, a marking shall be provided on the enclosure for equipment identification, or on the coating of the enclosure, if any. The maximum distance between two identification markings should be agreed between manufacturer and user.

Markings shall be durable and clearly legible and shall contain the following information:

– manufacturer's name or trademark;
– type designation;
– rated voltage;
– type of gas and filling pressure for insulation.

6.12 Locking devices

Subclause 6.12 of IEC 62271-1:2017 is applicable.

6.13 Position indication

Subclause 6.13 of IEC 62271-1:2017 is applicable.

6.14 Degree of protection provided by enclosures

6.14.1 General

Subclause 6.14.1 of IEC 62271-1:2017 is applicable with the following additions.

No specification applies to the main circuit and parts directly connected thereto, because of the gas tightness of the enclosure.

Degrees of protection according to IEC 60529 shall be specified for all enclosures of appropriate low-voltage control and/or auxiliary circuits.

The degrees of protection apply to the service conditions of the equipment.

6.14.2 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)

Subclause 6.14.2 of IEC 62271-1:2017 is applicable with the following additions:

Protection means are applicable only for control and/or auxiliary circuits. The first characteristic numeral shall be 3 or higher.

6.14.3 Protection against ingress of water (IP coding)

Subclause 6.14.3 of IEC 62271-1:2017 is applicable with the following additions:

For installations where the laying conditions impose a risk of ingress of water (buried installations, installations in trenches, ducts, etc.), the second characteristic numeral shall be specified as shown in Table 1 below.

Table 1 – Second characteristic numeral of IP coding

Second characteristic numeral	Brief description	Definition
7	Protected against the effects of temporary immersion in water	Ingress of water causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
For more severe situations than those corresponding to the second characteristic numeral 7, the protection should be agreed between manufacturer and user.		

6.14.4 Protection against mechanical impact under normal service conditions (IK coding)

Subclause 6.14.4 of IEC 62271-1:2017 is applicable.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 is not applicable.

6.16 Gas and vacuum tightness

6.16.1 General

Subclause 6.16.1 of IEC 62271-1:2017 is not applicable.

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 62271-203:2022 is applicable with the following additions:

The tightness characteristic of a closed pressure system and the time between replenishment under normal service condition shall be stated by the manufacturer and shall be consistent with a minimum maintenance and inspection philosophy.

The value for the time between replenishment shall be at least 10 years for SF_6 systems and for other gases should be consistent with the tightness values. The possible leakages between subassemblies having different pressures shall also be taken into account.

6.16.4 Sealed pressure systems

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

6.16.5 Internal partitions

In the particular case of maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage rate across partitions should also be stated by the manufacturer, and the time between replenishments shall be not less than one month. Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.

Handling for repair and maintenance shall be carried out according to local regulation, see IEC 62271-4.

6.17 Tightness of 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 not applicable.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 is not applicable.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 is not applicable.

6.21 Corrosion

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

6.21.101 Corrosion protection for buried installations

Corrosion protection, i.e. both the external coating and any active protection system, shall take into account special considerations such as: the location, the soil/backfill material and conditions, the enclosure material and the type of earthing adopted.

In general, the corrosion protection for GIL is similar to the protection means of normal pipeline or power cables. The enclosure is coated with rubber or plastic in one or more layers. The coating acts as a passive corrosion protection system by keeping humidity or water away from the metal enclosure of the electrical equipment.

Passive corrosion protection is required and any active corrosion system, if requested and installed by mutual agreement between operator and supplier, shall be laid out in accordance with environmental conditions along the GIL.

6.21.102 Corrosion protection for not buried installations

Subclause 6.21 of IEC 62271-1:2017 is applicable.

6.22 Filling levels for insulation, switching and/or operation

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

6.101 Minimizing of internal fault effects

6.101.1 General

A fault leading to an internal arc fault within GIL built according to this document has a very low probability. This results from the use of an insulating gas, other than air at atmospheric pressure, which will not be affected by pollution, humidity or vermin.

Examples of measures to avoid an internal arc fault and to limit duration and consequences are

- insulation coordination,
- gas-leakage limitation and control,
- high-speed protection,
- high-speed arc short-circuiting devices,
- interlocking of switching devices,
- remote control,
- internal and/or external pressure reliefs, and
- checking of workmanship on site.

Arrangements should also be made to minimize the effects of internal arc faults on the continued service capability of the GIL. The effect of an arc should be confined to the compartment in which the arc has been initiated.

If, in spite of the measures taken, a test is agreed between manufacturer and user to verify the effect of internal arc faults, this test should be in accordance with 7.105 of IEC 62271-203:2022.

Tests would normally not be necessary in the case of single-phase enclosed GIL installed in isolated neutral or resonant earthed systems and equipped with a protection to limit the duration of internal earth faults.

6.101.2 External effects of the arc

Adequate installation precautions shall be taken in order to reduce the hazards to a tolerable risk. For more information, see [4].

In order to provide a high protection to personnel, the external effects of an arc shall be limited (by taking adequate precautions) to the appearance of a hole or tear in the enclosure without any fragmentation.

The manufacturer shall provide sufficient information to allow the user to take these precautions.

Manufacturer and user can agree upon 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 (refer also to 6.102.2).

6.101.3 Internal fault location

Appropriate devices shall be available to enable determination of the faults location.

6.102 Enclosures

6.102.1 General

The enclosure shall be of metal, permanently earthed and capable of withstanding the normal and transient service pressures.

The enclosures of gas-filled equipment conforming to this document are permanently pressurized in service and are subjected to particular service conditions which distinguish them from compressed air receivers and similar storage vessels. These conditions are as follows:

- the main circuit is enclose to prevent hazardous approach to live parts and are so shaped that, when filled at or above the minimum functional gas pressure for insulation (see 5.11), they meet the rated insulation level (see 5.3) for the equipment (electrical rather than mechanical considerations predominate in determining the shape and materials employed);
- enclosures are normally filled with a non-corrosive, dry, stable and inert gas, and the gas shall remain in this condition (with only small fluctuations in pressure) in order to ensure correct operation of the installation. However, since the enclosures will not be subject to internal corrosion, there is no need to make allowances for these factors in determining the design of the enclosures (but, the effect of possible transmitted vibrations should be taken into account).

For outdoor installation, the manufacturer shall take into account the influence of climatic conditions (see Clause 4).

For buried installation, environment conditions shall be taken into account. Concerning the prevention of external corrosion, see 6.21.

6.102.2 Design of enclosures

The wall thickness of the enclosure shall be based on the design pressure as well as the following minimum withstand durations in case of an internal arc without burn-through:

- 0,1 s for short-circuit currents of 40 kA and above;
- 0,2 s for lower short-circuit currents.

In order to minimize the risk of burn-through, the level and duration of the fault current, the enclosure design and the size of the compartments shall be carefully coordinated.

In the absence of an international agreement on a standard procedure, methods for calculating the thickness and the construction of enclosures, either by welding or casting, can be chosen from established relevant pressure vessel and pipeline codes, based on the design temperature and design pressure defined in this document.

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

- the possible evacuation of the enclosure as part of the normal filling process;
- the full differential pressure that is possible across the enclosure walls or partitions;
- the resulting pressure between compartments in the event of an abnormal leak in the case adjacent compartments have different filling pressures;
- the possibility of the occurrence of an internal fault (see 6.101).

The design temperature of the enclosure is generally the upper limit of the ambient temperature taking into consideration the increase in temperature rise due to the flow of rated continuous current. Solar radiations should be considered when they have a significant effect.

The design pressure of the enclosure is at least the upper limit of the pressure reached within the enclosure at the design temperature.

In determining the design pressure of the enclosure, the gas temperature shall be taken as the average of the upper limits of the enclosure temperature and the main circuit conductor temperature at rated normal current unless the design pressure can be established from existing temperature-rise test records.

When designing the enclosure, mechanical loads other than those caused by internal overpressure shall be taken into account, for instance forces caused by thermal expansion (see 6.106) external vibrations (see 6.107), soil loading for buried installations, other external loads, earthquakes, wind, snow and ice, etc.

If the strength of any enclosures and parts thereof has not been fully determined by calculation, proof tests (see 7.101) shall be performed to demonstrate that they fulfill the requirements.

Materials used in the construction of enclosures shall be of known and certified minimum physical properties which are based on calculations and/or proof tests. 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.

6.103 Partitions and partitioning

GIL shall be divided into compartments in such a manner that both the normal operating conditions are met and a limitation of the effects of an arc inside the compartment is obtained (see 6.101).

The manner in which the GIL is divided into compartments influences the following:

– installation;
– site testing;
– maintenance and repair;
– gas handling.

The partitions are generally of insulating material but are not intended by themselves to provide electrical safety of personnel, for which other means such as earthing of the equipment can apply; they shall, however, provide mechanical safety against the differential gas pressure with the adjacent compartments.

A partition separating a compartment filled with insulating gas from an adjacent compartment filled with liquid, shall not show any abnormal leakage through the separation affecting the dielectric properties of the two media.

Consideration should be given to the partitioning of the GIL-system in order to meet the requirement of operation, limitation of the fault affected GIL part and convenience of maintenance or repairs.

6.104 Sections of a GIL system

The sectionalizing of a GIL system can be made using disconnecting units. The length of sections along the system is determined considering requirements such as access and maximum length for testing, installation progress for long projects or operational and maintenance reasons.

6.105 Pressure relief

6.105.1 General

Pressure relief devices in accordance with 6.105 shall be arranged so as to minimize the danger to people during the time they are performing their normal operating duties on the GIL, if gases or vapors are escaping under pressure.

NOTE The term "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.

6.105.2 Limitation of maximum filling pressure

For filling a gas compartment, a pressure regulator shall be fitted to the filling pipe to prevent the gas pressure from rising to more than 10 % above the design pressure. Alternatively, the regulator can be fitted to the enclosure itself.

The filling pressure should be chosen to take into account the gas temperature at the time of filling, for example, checking by temperature-compensated pressure gauges.

6.105.3 Pressure relief devices to limit pressure rise in the case of an internal fault

Since, after an arc due to an internal fault, the damaged enclosures will be replaced, pressure relief devices shall only be provided to limit the external effects of the arc (see 6.101.2).

In the case of an internal fault, depending on volume of gas compartment and filling pressure, short-circuit current and duration, not exceed the routine test pressure of the enclosure, in such a case, a pressure relief device is not mandatory.

If pressure relief devices are used in confined space accessible to personnel, precautions shall be taken to ensure safety in case of release (see also Clause 12).

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

When bursting disks are used for pressure relief, due regard should be paid to their rupture pressure in relation to the design pressure of the enclosure to reduce the possibility of unintentional rupture of the disk.

6.106 Compensation of thermal expansion

Due to temperature differences between parts of the GIL, between the GIL and their surroundings, or parts of the GIL relative to the temperature during construction, parts of the GIL installation experience movements relative to each other and to their surroundings.

The relative movements or forces between the parts and/or their surroundings can be determined either by measurement or calculations based on the maximum temperature difference of the parts relative to the temperature during construction. Where compensation is necessary, the following methods shall be used:

a) compensation between current-carrying parts and enclosure shall be achieved by sliding contacts or similar means;
b) compensation between the enclosure and its surroundings (fixed supporting structure, surrounding soil) shall be achieved by appropriate means.

Reference should be made to appropriate standards or methods for calculations of resulting forces and relative movements between environment and enclosure, and for interpretation of the results. This is particularly important for buried GIL, which are highly affected by factors such as anchoring, compression of the soil, type of soil, geometrical configuration of the line, etc.

6.107 External vibrations

Under certain conditions, the GIL could be exposed to external vibrations. A typical case is when the GIL is attached to a bridge used by pedestrians, cars, and trains. Another case is when the GIL is directly connected to power transformers or reactors.

Where a transmission line is attached to a source of vibrations, it is advisable to reduce mechanical stress by means of damping arrangements installed between the source and the part of the supporting structure which is rigidly connected to the transmission line. Such means can considerably reduce the mechanical dynamic stresses in the transmission line structure. The remaining dynamic stress level shall be used as a basis for the mechanical dimensioning by means of combining the loads resulting thereof with other mechanical loads acting on the GIL in order to determine the total stress levels and to ensure that these levels are below permitted levels of the materials used.

In the case of a bridge, special attention shall be paid to relative movements between the bridge and its surrounding. These movements can cause additional mechanical loads which would be necessary to consider when determining the total stress levels during the mechanical dimensioning.

6.108 Supporting structures for non-buried GIL

6.108.1 General

The supporting structures for GIL have an influence on the mechanical features of the GIL. The construction of the supporting structure can vary in accordance with its function, the configuration of the GIL and the construction of the foundation, the tunnel or the shaft where the GIL is installed. For this reason, 6.108 describes the design condition and the requirements of the supporting structure functions.

6.108.2 Conditions of the design

The following forces and loads should be considered for the supporting structure design:

– weight of GIL;
– forces due to the internal gas pressure;
– friction between the surfaces of the support beam and the GIL foot;
– forces due to the thermal expansion of the GIL;
– seismic force, when applicable;
– wind load, when applicable;
– force due to short-circuit current;
– ice load, when applicable;
– forces due to other external impacts such as vibrations.
– gas/air bushing line pull.

When the supporting structure does not form part of the earthing system, means shall be provided to avoid eddy currents in the supporting structure and to allow corrosion protection.

6.108.3 Types of supporting structures

There are two basic kinds of supporting structures:

a) sliding and flexible supporting structures: these supporting structures are designed in order to support and allow a certain movement due to the thermal expansion of the GIL;
b) rigid supporting structures: these supporting structures are designed in order to fix the GIL and to withstand the forces due to the thermal expansion of the enclosure and to the expansion of the compensators in the enclosure, if any, and to the internal gas pressure.

7 Type tests

7.1 General

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

The type tests shall be made on representative assemblies or subassemblies.

Because of the variety of possible combinations of components, it is impracticable to subject all possible arrangements to type tests. The performance of any particular arrangement can be substantiated by test data obtained with comparable arrangements. All the tests shall be made with the equipment filled with the specified type of gas and at rated filling pressure, except when otherwise specified in the relevant subclause.

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with this specification, and sufficient information so that the essential part of the equipment tested can be identified. General information concerning the supporting structure shall be included in the test reports.

The type tests and verifications comprise the tests listed in 7.1.101 and 7.1.102.

7.1.101 Mandatory type tests

The following mandatory type tests shall be carried out:

		Subclause
a)	Tests to verify the insulation level of the equipment including partial discharge tests and dielectric tests on auxiliary circuits	7.2
b)	Tests to prove the continuous current of any part of the equipment and measurement of the resistance of the main circuit	7.4 and 7.5
c)	Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short-time withstand current	7.6
d)	Tests to verify the protection of persons against contact with live parts of auxiliary circuits	7.7
e)	Tests to prove the strength of enclosures	7.101
f)	Test to prove the strength of partitions	7.102
g)	Gas tightness tests	7.8

7.1.102 Special type tests

This subject applies to agreement between manufacturer and user.

a)	Anti-corrosion tests (if applicable)	7.103
b)	Mechanical tests on sliding contacts	7.104
c)	Tests to verify the protection of the equipment against external effects due to weather and atmospheric agents	7.106
d)	Tests to assess the effects of arcing due to an internal fault	7.105
e)	Long term behaviour test for buried installation	Annex C

NOTE Some of the type tests can impair the suitability of the tested parts for subsequent use in service.

7.2 Dielectric tests

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 is not applicable.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 is not applicable.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 is not applicable.

7.2.4 Arrangement of the equipment

Subclause 7.2.4 of IEC 62271-1:2017 is not applicable and is replaced as follows:

Dielectric tests shall be performed at minimum functional pressure of the insulating gas as specified by the manufacturer. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 is applicable.

7.2.6 Application of test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 is not applicable and is replaced as follows.

The test voltages specified in 7.2.7 and 7.2.8 shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits shall be connected to the earthing conductor or the frame and to the earth terminal of the test supply.

When each phase is individually encased in a metallic enclosure, only tests to earth, and no test between phases, are carried out.

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

7.2.7.1 General

Subclause 7.2.7.1 of IEC 62271-203:2022 is applicable with the following additions:

7.2.7.2 Power-frequency voltage tests

The main circuit of the GIL shall be subjected to short duration power-frequency voltage tests in accordance with IEC 60060-1. The test voltage shall be raised to the test value and maintained for 1 min. The test shall be performed in dry conditions only.

7.2.7.3 Lightning impulse voltage tests

During the tests, the earthed terminal of the impulse generator shall be connected to the enclosure of the GIL.

Consideration shall be given to the length of the tested object, in order to avoid overvoltage due to travelling waves.

7.2.8 Test of switchgear and controlgear of U_r > 245 kV

7.2.8.1 General

Subclause 7.2.8.1 of IEC 62271-203:2022 is applicable with the following additions:

7.2.8.2 Power-frequency voltage tests

The GIL shall be subjected to short duration power-frequency voltage tests in accordance with IEC 60060-1. The test voltage shall be raised to the test value and maintained for 1 min. The test shall be performed in dry conditions only.

7.2.8.3 Lightning and switching impulse voltage tests

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

During the tests, the earthed terminal of the impulse generator shall be connected to the enclosure of the GIL.

Consideration shall be given to the length of the tested object, in order to avoid overvoltage due to travelling waves.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 is not applicable.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-203:2022 is applicable.

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 not applicable.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 of IEC 62271-1:2017 is not applicable.

7.4 Measurement of the resistance of circuits

Subclause 7.4 of IEC 62271-1:2017 is applicable with the following addition:

The current-carrying parts of the main circuit and the enclosure, and each type of contact system shall be tested before and after the continuous current test.

7.5 Continuous current test

Subclause 7.5 of IEC 62271-1:2017 is applicable with the following addition:

Calculations can be performed based upon type test results to determine the maximum permissible current in other specified service conditions. For these calculations, refer to Annex A and [6]. Any complementary test should be agreed between manufacturer and user.

The assembly or subassembly shall include normal enclosure with corrosion preventive coating, if applicable, and shall be protected against undue external heating or cooling.

Where the design provides alternative components or arrangements, the test shall be performed with those components or arrangements for which the most severe conditions are obtained.

Except when each phase is encased 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 assembly to the terminals provided for the connection of test cables.

When a single-phase test is permitted and carried out, the current in the enclosure shall represent the most severe condition.

When testing individual subassemblies, the neighbouring subassemblies should carry the currents which produce the power loss corresponding to the rated conditions. Equivalent conditions are allowed to be simulated, by means of heaters or heat insulation, if the test cannot be made under actual conditions.

The temperature rises of the different components shall be stated with reference to the ambient air temperature. They shall not exceed the values specified for them in the relevant standards.

The temperature of the enclosure shall not exceed the maximum allowable temperature of the anti-corrosion coating if applicable.

NOTE 1 The data on power losses and electrical resistance of the current-carrying parts of the GIL will be used to carry out calculations according to Annex A.

NOTE 2 The time constant of the GIL during the test will serve as a basis to evaluate the temporary overload capability of the GIL.

For open air, tunnel and shaft installations, the maximum temperature of the enclosure shall not exceed 80 °C. Parts normally touched during operation shall not exceed 70 °C. Reference is made to Clause 12.

For direct buried installation, the maximum temperature of the enclosure shall be limited to minimise soil drying. A temperature in the 50 °C to 60 °C range is generally considered as applicable limit. Higher temperatures can be accepted below the thermal stabilizing backfill only. A project related thermal rating calculation shall be done.

7.6 Short-time withstand current and peak withstand current tests

7.6.1 General

Subclause 7.6.1 of IEC 62271-1:2017 is applicable with the following addition:

Where the design provides alternative components or arrangements, the tests shall be performed with those representative components or arrangements for which the most severe conditions are obtained.

7.6.2 Arrangements of the GIL and of the test circuit

Subclause 7.6.2 of IEC 62271-1:2017 is not applicable and is replaced as follows:

The test arrangement shall be fitted with clean contacts in new condition.

A GIL with three-phase enclosure shall be tested three-phase.

A GIL with single-phase enclosure shall be tested according to the return current in the enclosure, dependent on the grounding system:

a) if the enclosure carries the full return current in service, the GIL shall be tested single phase, with the full return current in the enclosure;

b) if the enclosure does not carry the full return current in service, the GIL shall be tested three-phase. The tests shall be made at the minimum distance between phases indicated by the manufacturer.

7.6.3 Test current and duration

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

7.6.4 Conditions of the GIL after test

Subclause 7.6.4 of IEC 62271-1:2017 is not applicable and is replaced as follows:

After the test, there shall be no deformation or damage to conductors or contact joints within the enclosure which can impair good service.

After the test, the resistance of the main circuits shall be measured according to 7.4. If the resistance has increased by more than 20 % and if it is not possible to confirm the conditions of the contacts by visual inspection, it will be necessary to perform an additional temperature-rise test.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 is applicable with the following addition:

If the second characteristic numeral is specified, the tests shall be performed in accordance with the requirements in Clause 11 and Clause 14 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 for the appropriate numeral.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 is applicable.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 is not applicable.

7.10 Additional test on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 is not applicable.

7.11 X-radiation test procedure for vacuum interrupters

Subclause 7.11 of IEC 62271-1:2017 is not applicable.

7.101 Proof tests for enclosures

7.101.1 General

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

Proof tests can consist of either a bursting pressure test or a non-destructive pressure test, as appropriate to the material employed.

7.101.2 Destructive pressure tests

Subclause 7.103.2 of IEC 62271-203:2022 is applicable.

7.101.3 Non-destructive pressure test

Subclause 7.103.3 of IEC 62271-203:2022 is applicable.

7.102 Pressure test on partitions

Subclause 7.104 of IEC 62271-203:2022 is applicable.

7.103 Passive corrosion protection tests for buried installation

7.103.1 Passive corrosion protection

The passive corrosion protection system is basically a synthetic coating of the metal enclosure to protect the metal from humidity. The synthetic coating is usually built up from one or more layers of synthetic material.

The following three tests shall be performed.

7.103.2 Electrical testing

To prove the quality of the synthetic coating, a high-voltage test shall be applied. An electrical conductive layer is applied over the synthetic coating. A test voltage according to the dielectric strength of the synthetic coating is then applied between the metal enclosure and the electrical conductive layer.

The voltage level is dependent on the type of synthetic coating and shall be defined by agreement between manufacturer and user. In case the test is required by the particular contract, the corrosion protection layer shall be subjected to the electrical test specified in Clause 3 of IEC 60229:2007.

The length of the test sample shall be sufficient to provide the synthetic coating with a realistic result. Therefore, the minimum length recommended is 5 D, where D is the outer diameter of the metal enclosure.

7.103.3 Mechanical testing

Mechanical type tests shall be carried out at ambient temperature in accordance with IEC 60068-1. The mechanical type test shall prove the resistance of the coating to conditions on site during and after laying. Resistance to two mechanical stresses shall be proven:

– bending of the coating;
– impact on the coating of metal objects or rocks.

The mechanical stresses are highly dependent on the laying methods and the system layout. The forces and the procedure for carrying out testing should be mutually agreed between user and manufacturer.

7.103.4 Thermal testing

Thermal type tests represent the stresses produced by the maximum temperature changes of the GIL during on site assembly and in service.

Normal service conditions are covered by IEC 62271-1:2017, where special ambient conditions shall be defined by the user. The procedure for carrying out type tests should be mutually agreed between manufacturer and user.

7.104 Special mechanical test on sliding contacts

A mechanical endurance test shall be carried out to assess the ability of basic components such as sliding contacts to perform their duty during the expected lifetime of the equipment.

NOTE 1 The test is specific to GIL because of the difficulty of measuring and maintaining the contacts.

The contact shall be identified by

– the contact arrangement and principle,
– the contact material (including the nature and thickness of the coating, if any),
– the contact pressure (minimum – maximum), and
– the lubrication (if any) as indicated in the instruction manual.

The test conditions shall indicate

– the contact stroke,
– the contact speed, and
– the number of cycles.

A motorized test rig can be used to simulate the expected relative movement of the live conductor. The test is considered representative, provided that

– the worst conditions are met, considering maximum differential expansion, weight of conductor, loads, etc.,
– the frequency of operation is limited to a value in the order of six cycles an hour, and
– the number of cycles is 10 000 for general purpose of GIL.

NOTE 2 For special applications, such as feeding a pump storage plant, a larger number of operating cycles and/or an increased frequency of operation can be agreed between manufacturer and user.

The following inspections and tests are performed before and after the test:

– visual check;
– dimensional check and contact pressure;
– contact resistance.

The test will be considered satisfactory if

– the visual check shows that initial surface coating is still present everywhere,
– the wear is such that contact pressure is still within allowed tolerance, and
– the contact resistance variation is less than or equal to 20 %.

7.105 Test under conditions of arcing due to internal fault

Evidence of performance according 6.102.2 shall be demonstrated by the manufacturer when required by the user.

If such a test is agreed between manufacturer and user, the procedure shall be in accordance with the methods described in IEC 62271-203:2022, Annex B.

The current duration shall not be less than the expected second stage protection fault clearance time, as determined by the protection devices.

The values of the short-circuit current should correspond to the rated short-time withstand current.

NOTE For information, the fault clearing time for the first stage protection is about 0,1 s for currents of 40 kA and above and 0,2 s for lower currents. The time for the second stage protection normally does not exceed 0,3 s for currents of 40 kA and above, and 0,5 s for lower currents.

The GIL is considered adequate if, during the test, no external effects are produced within the withstand durations specified in 6.102.2.

No fragmentation of the enclosure shall result from a fault cleared in 0,3 s for currents of 40 kA and above, and in 0,5 s for lower currents unless otherwise agreed upon between manufacturer and user.

Tests on a particular arrangement can also be used to predict the performance of other arrangements with the same design, either by calculation, or inference, or a combination of both.

To extend the test results to other enclosures of similar design but of different size and shape and/or to other test parameters, calculation methods should be agreed between manufacturer and user.

7.106 Weatherproofing test

When agreed between manufacturer and user, a weatherproofing test shall be made on GIL for outdoor use. A recommended method is given in Annex C of IEC 62271-1:2017.

If an examination of the design shows the test to be unnecessary, it can be omitted.

8 Routine tests

8.1 General

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

Dielectric routine tests will preferably be performed on complete subassemblies. However, because of the existence of very long parts which can be shipped dismantled, the manufacturer can exclude the enclosure and conductor pipes including contacts from the routine test. All other components shall be subject to a factory routine test and be tested in a dielectric configuration identical to the service condition. The dielectric test on the fully assembled section will then be made at site (see 11.4.101).

The short-duration power-frequency voltage tests on the main circuit of the GIL shall be performed according to the requirements of 7.2.6 phase to earth and between phases (if applicable). The test voltages for routine tests shall be chosen from IEC 62271-203:2022, column (2) of Table 2 or Table 3.

The tests shall be performed at minimum functional pressure of the insulating gas.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1:2017 is applicable.

8.3 Tests on auxiliary and control circuits

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

8.4 Measurement of the resistance of the main circuit

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

Overall measurements are made on transport units in the factory. The overall resistance measured shall not exceed 1,2 R_u, where R_u is the sum of the corresponding resistances measured during the type test.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1:2017 is applicable, with the following addition:

Attention shall be paid to the fact that external coating of the enclosure (if any) can hide a leak. The tightness test procedure shall be adapted accordingly.

NOTE This test applies for factory made enclosures; for site welded enclosures, refer to 11.4.104.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1:2017 is applicable.

8.101 Partial discharge measurement

Partial discharge measurements (PD) shall be applied to critical parts such as insulators. Refer to 7.2.10 for the voltage levels and the partial discharge acceptance value.

The detection of PD on subassemblies and/or sections of the GIL is recommended.

8.102 Pressure tests of factory made enclosures

Subclause 8.101 of IEC 62271-203:2022 is applicable.

9 Guide to the selection of GIL (informative)

Clause 9 of IEC 62271-1:2017 is applicable.

9.1 General

Subclause 9.1 of IEC 62271-1:2017 is not applicable and is replaced as follows:

For a given duty in service, GIL is selected by considering the individual rated values required under normal load conditions and in case of fault conditions.

The rated values should be chosen, as suggested in this document, with regard to the characteristics of the system as well as its expected future development.

In selecting a rated short-time withstand current for an installation, or part of an installation, consideration can be given to the fact that the maximum fault current in a circuit reduces as the distance from the substation increases. These fault conditions should be determined by calculating the fault currents at the place where the transmission line is to be located in the system.

When applicable, temporary overload and ambient temperature should be agreed between manufacturer and user. It is recommended to develop a temperature study on the project specific installation to confirm that temperature limits will not be exceeded.

9.101 Short time overload capability

The conditions of temporary overload should be agreed between manufacturer and user under consideration of the special circumstances (overload factor and duration, ambient temperature, initial conditions, increase in temperature limits for overload condition, laying conditions etc.). A typical overload figure is for example 20 % above the rated current for 30 min taking into account the particular load and temperatures at the beginning of the overload period.

9.102 Forced cooling

Dimensioning of the forced cooling should take into account the total thermal losses in the tunnel. Thermal losses should be those at rated current for the GIL at maximum ambient temperature and thermal losses from other heat sources.

NOTE Access to the tunnel for service can be restricted under the following conditions:

– in case of temporary overload;
– in case of loss of ventilation;
– in case of excessive temperature within the tunnel;
– when gas concentration exceeds levels stated in local regulations.

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

Clause 10 of IEC 62271-1:2017 is not applicable.

10.101 Information with enquiries and orders

10.101.1 General

When enquiring for, or ordering the installation of a GIL, the information listed in 10.101.2 to 10.101.7 should be supplied by the enquirer.

10.101.2 Particulars of the system

Nominal and highest voltage, frequency, type of system neutral earthing.

10.101.3 Environmental conditions

Details of environmental conditions should be given such as the following:

a) location inside electrical plant with restricted accessibility or outside, accessible to the public;
b) buried or non-buried installation;
c) installation in trenches, tunnels, or in open air with structures to be provided;
d) geological section and, in the case of a buried installation, geological and physical structure of soil;
e) depth of laying (if buried);
f) thermal conductivity of soil (if buried);
g) ventilation of trenches or tunnels;
h) seismic requirements.

10.101.4 Service conditions

Minimum and maximum ambient air or soil temperature; any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment. For example, unusual exposure to vapour, moisture, fluids, fumes, explosive gases, excessive dust or salt, the risk of earth tremors or other vibrations due to causes external to the equipment to be delivered, as well as possible movement of foundation, and possible mechanical impact.

10.101.5 Particulars of the installation

Details of the particulars of the installation should be given, such as the following:

a) system length and geographical routing;
b) number of phases (single-phase enclosed or three-phase enclosed);
c) number of lines located in the same trench or tunnel;
d) rated voltage;
e) rated insulation level;
f) rated frequency (f_r);
g) rated normal current;
h) rated short-time withstand current;
i) rated duration of short-circuit (if different from 1 s);
j) rated peak withstand current;
k) maximum fault clearing time in case of internal fault;
l) degree of protection for auxiliary circuits;
m) crossing other utilities and or heat sources.

10.101.6 Particulars of the auxiliary devices

Details of the particulars of the auxiliary devices should be given, such as the following:

a) requirements of auxiliary devices and monitoring system (e.g. interlocking, gas supervision, signals etc.);
b) rated auxiliary voltage (if any);
c) rated auxiliary frequency (if any).

10.101.7 Specific conditions

In addition to the items listed in 10.101.2 to 10.101.6, the enquirer should indicate every condition which might influence the tender or the order, such as, for example, transport facilities and/or restrictions, special mounting or erection conditions, the locating of the external high-voltage connections or the rules for pressure vessels.

Information should be supplied if special type tests are required.

10.102 Information with tenders and contract documentation

10.102.1 General

The information listed in 10.102.2 to 10.102.6, if applicable, should be given by the manufacturer with written descriptions and drawings.

10.102.2 Rated values and characteristics

Particulars of the installation are enumerated in 10.101.5.

10.102.3 Further particulars of the transmission line and its components

Details of the line should be given, such as the following:

a) design pressure of enclosures;
b) design temperature of enclosures;
c) type and filling pressure of gas for insulation;

d) minimum functional pressure;

e) mass of gas for the different compartments;

f) length of the compartments;

g) limit values of moisture content and gas leakage;

h) details of appropriate measures for fault location.

10.102.4 Type test certificate or reports

When requested, type test certificates or reports should be transmitted as complete documents.

10.102.5 Particulars of the auxiliary devices

The tenders and contract documentation should provide at least, but not limited to, the following information:

a) types and rated values as enumerated in 10.101.6;

b) current or input power for operation.

10.102.6 List of recommended essential spare parts

Spare parts should be procured by the user.

11 Transport, storage, installation, operating instructions and maintenance

11.1 General

Subclause 11.1 of IEC 62271-1:2017 applies.

11.2 Conditions during transport, storage and installation

Subclause 11.2 IEC 62271-1:2017 is applicable, with the following addition:

Internal cleanliness influences the function of the GIL; cleanliness therefore shall be assured by suitable precautions as required by the manufacturer.

The following precautions can be included:

– connecting GIL units under clean conditions (e.g. closed assembly tents with dry air, temperature regulation and with slight gauge pressure);

– openings should be covered by dust-protector or coverplates during installation;

– if necessary, the complete GIL should be cleaned inside after assembly;

– additional to precautions on site, transportation under condition of transport regulation with a prefill of dry and clean gas at an overpressure can be helpful to keep internal parts of the GIL in good condition.

The assembly unit should be as large as possible in order to reduce the assembly on site and the risk of pollution.

Connecting areas of the GIL units should be protected against damage to sealing surfaces or prepared edges for welding seams.

Where the GIL units have been welded on site, precautions should be made to avoid metal particles or polluting smoke entering the GIL.

The installation procedure should be covered by the quality assurance system.

11.3 Installation

11.3.1 General

Subclause 11.3.1 of IEC 62271-1:2017 is applicable, with the following addition.

For each type of GIL, the instructions provided by the manufacturer should at least include the items listed in 11.3.2 to 11.3.101.

11.3.2 Unpacking and lifting

Subclause 11.3.2 of IEC 62271-1:2017 is applicable.

11.3.3 Assembly

Subclause 11.3.3 of IEC 62271-1:2017 is applicable.

11.3.4 Mounting

Subclause 11.3.4 of IEC 62271-1:2017 is applicable.

11.3.5 Connections

Subclause 11.3.5 of IEC 62271-1:2017 is applicable.

11.3.6 Information about gas and gas mixtures for controlled and closed pressure systems

Subclause 11.3.6 of IEC 62271-1:2017 is applicable.

11.3.7 Final installation inspection

Subclause 11.3.7 of IEC 62271-1:2017 is not applicable and is replaced as follows:

After installation, before putting into service, the GIL shall be tested to check the correct operation and the dielectric strength of the equipment.

These tests and verifications comprise:

	Subclause
a) voltage tests on the main circuits	11.4.101
b) dielectric tests on auxiliary circuits	7.2.11
c) measurement of the resistance of the main circuit	11.4.103
d) gas tightness tests	7.8
e) checks and verifications	11.4.106
f) measurement of gas conditions	11.4.102
g) anti-corrosion tests for buried installations	11.4.107
h) tests on enclosures welded on site	11.4.104

To ensure minimum disturbance, and to reduce the risk of moisture and dust entering enclosures, which secures correct operation of the GIL, no obligatory periodic inspections or pressure tests are specified or recommended when the GIL is in service.

Instructions should be provided for inspection and tests which should be made after the GIL has been installed and all connections have been completed.

The instructions should include the following:

– a schedule of recommended site tests to establish a correct functioning;
– recommendations for any relevant measurements that should be made and recorded to help future maintenance decisions;
– instructions for final inspection and putting into service.

For welded connection, the following shall apply: no specific tightness test is required for on site welded enclosure pipes (butt welds) if a 100 % inspection of the welds by radiographic, ultrasonic or other means is performed. In this case, the welds are considered to have a zero leakage rate.

NOTE The impact of a flanged connection at the beginning and/or end is negligible in case of a welded GIL.

11.3.8 Basic input data by the user

Subclause 11.3.8 of IEC 62271-1:2017 is applicable.

11.3.9 Basic input data by the manufacturer

Subclause 11.3.9 of IEC 62271-1:2017 is applicable.

11.3.101 Constructional features

The tenders and contract documentation should provide at least, but not limited to, the following information:

a) mass of the heaviest transport unit;
b) overall dimensions of the transmission line;
c) arrangement of the external connections;
d) provisions for transport to be taken by the user;
e) provisions for installation and laying required by the manufacturer;
f) location of the attachment points to the supports;
g) maximum forces to each attachment point;
h) maximum deflection of the enclosure at each attachment point.

11.4 Operating instructions

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

11.4.101 Voltage test on the main circuits

11.4.101.1 General

The dielectric strength shall be checked in order to eliminate causes which might give rise to an internal fault in service.

The site voltage tests are supplementary to the dielectric routine tests with the aim of checking the dielectric integrity of the completed installation and of detecting irregularities as mentioned above. Normally, the dielectric test shall be made after the GIL has been fully erected and gas-filled at the filling pressure, preferably at the end of all site tests, when newly installed. Such a dielectric test is recommended to be performed also after major dismantling for maintenance, repair or reconditioning of compartments. These tests shall be distinguished from the progressive voltage increase, performed in order to achieve a kind of electrical conditioning of the equipment before commissioning.

The execution of such site tests is not always practicable and deviations from the standards can be accepted. The aim of these tests being a final check before energizing, it is very important that the chosen test procedure does not jeopardize sound parts of the GIL.

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

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

11.4.101.2 Test procedure

The GIL shall be properly erected and gas-filled at its filling pressure.

For the test, the GIL can be disconnected from other equipment, either because of their high charging current or because of their effect on voltage limitation, such as

– high-voltage cables, overhead lines, and GIS,
– power transformers and most voltage transformers, and
– surge arresters and protective spark gaps.

Due to the possible length of a GIL it can be applicable for the site dielectric test to be carried out in sections. Due to this fact, provisions shall be made within the design of the GIL to incorporate positions where test equipment can be mounted without having to dismantle the GIL.

The conductors of the GIL section not under test shall be grounded.

NOTE 1 In determining the parts which can be disconnected, attention is drawn to the fact that it is possible that the reconnection introduces faults after the tests are finished.

NOTE 2 In order to test as much as possible of the GIL, removable links can be included in the design in each of the above-mentioned cases. Here a "link" is understood to be a part of the conductor which can easily be removed in order to isolate two parts of the GIL from each other. This type of separation is preferable rather than dismantling.

Every newly erected part of a GIL shall be subjected to a dielectric test on site.

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

The test voltage can be applicable after repair or maintenance of major parts or after erection of extensions. The test voltage can then have to be applied to existing parts in order to test all sections involved. In those cases, the same procedure should be followed as for newly installed GIL.

For the choice of an appropriate voltage waveform, IEC 60060-1 should be taken into consideration; however, similar waveforms are also permissible. AC is preferred, and DC should not be used. Partial discharge monitoring shall be performed during application of the test voltage. Conventional partial discharge measurement in accordance with IEC 60270 is possibly not appropriate. Other methods, such as UHF method should be considered. At the present time, no level has been required.

A voltage level equal to 80 % of the AC voltage applied during the routine test is recommended. For long GIL, the test is performed on sections as long as possible.

When the sections are fully assembled to form the complete installation, a test is performed at a lower voltage because of the capacity of the testing facility.

Impulse test voltage can be additionally performed (lightning impulse wave shape, possibly oscillating, with an extended front time can be used). The voltage level should be agreed between manufacturer and user.

11.4.102 Measurement of gas conditions

The humidity content of the insulating gas shall be determined. This humidity content shall be in accordance with 11.101.7 of IEC 62271-203:2022.

The measurement shall be performed on all compartments of the GIL, assembled and filled with gas at the filling pressure.

If the GIL is filled with sulphur hexafluoride, refer to IEC 60376 and IEC 60480 for checking the conditions of the gas during service. For other gases, see instruction manual from GIL manufacturer.

11.4.103 Measurement of the resistance of the main circuit

The measurement shall be performed on assembled sections of the GIL. The conditions of the measurement should be as close as possible to those of routine tests performed where possible on transport units.

Nevertheless, the measurement method and the adequate length for the assembled sections shall be chosen considering the following requirements:

– the measurement shall be done in such a way as to verify the integrity of the main circuit, including joints;
– the accuracy of the measurement shall allow the detection of all possible bad joints.
– The resistance measured shall not exceed 120 % of the maximum values measured during type tests (before temperature rise test), taking into account the differences of the two test arrangements (number of devices, contacts and connections, length of conductors, etc.).

11.4.104 Tests on enclosures welded on site

11.4.104.1 General

Where enclosures are welded on site, two types of tests shall be performed to verify the weld quality and integrity: testing of the welds and pressure tests.

11.4.104.2 Testing of site welding

The welding of the enclosure on site 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.

Imperfection assessment on a basis of welding procedure and welders qualification shall be made in agreement between manufacturer and user. For further information, consult the Bibliography and Annex D.

11.4.104.3 Pressure test

Site-welded enclosures shall withstand a pressure test, preferably pneumatic. In this case, the factor k can be limited to 1,1, the test being done on the complete fully assembled compartment. In such case, additional precautions such as increased weld inspections should be made.

Where the factor k is limited to 1,1, testing of the weld in accordance with 11.4.104.1 shall be performed over 100 % of the weld length.

Provision shall be taken during the test to make sure that the pressure relief device will not operate. If a pneumatic test is not in compliance with local regulations, an alternative method should be agreed between manufacturer and user.

Hydraulic testing of the assembled compartment should be avoided.

11.4.105 Periodic testing of the enclosure

No periodic testing of the enclosure is required if

– enclosures are filled with a non-corrosive gas, dried, stable and inert, or
– anti-corrosion external coating is monitored.

11.4.106 Checks and verifications

The following shall be verified:

a) conformity of the assembly with the manufacturer's drawings and instructions.
b) sealing of all pipe junctions, and tightness of bolts and connections;
c) conformity of the wiring with the diagrams;
d) proper functioning of the monitoring and regulating equipment including heating and lighting;
e) check of the correct connection of the bonding system.

If, for whatever reason, one or more routine tests are not performed at the manufacturer's works, they should be carried out on site combined with the tests after erection.

11.4.107 Tests on corrosion protection for directly buried GIL

11.4.107.1 Passive corrosion protection

The voltage level and duration specified in Clause 5 of IEC 60229:2007 shall be applied between the metallic enclosure and the ground.

For the test to be effective, it is necessary that the ground makes good contact with all of the outer surface of the oversheath. A conductive layer on the oversheath can assist in this respect.

11.4.107.2 Active corrosion protection

The active corrosion protection system is laid out in accordance with the environmental conditions along the GIL. The protection current and protection potentials are calculated from data on soil electrical resistivity and acidity.

These values shall be measured after the GIL goes into service.

11.5 Maintenance

11.5.1 General

Subclause 11.5.1 of IEC 62271-1:2017 is applicable.

11.5.2 Information about fluids and gas to be included in maintenance manual

Subclause 11.5.2 of IEC 62271-1:2017 is applicable.

11.5.3 Recommendations for the manufacturer

Subclause 11.5.3 of IEC 62271-1:2017 is applicable.

11.5.4 Recommendations for the user

Subclause 11.5.4 of IEC 62271-1:2017 is applicable.

11.5.5 Failure report

Subclause 11.5.5 of IEC 62271-1:2017 is applicable.

11.5.101 Maintenance of GIL

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

It is important to think through the requirements of a possible post-fault or other repair and make provisions for gas handling and storage, access for replacement section, in-situ welding, fume extraction and weld inspection, and consider how a high-voltage test can be performed post-repair.

11.5.102 Gas handling

The following applies to GIL filled with gases which might have an environmental impact or might impose a hazard to the operating personnel.

For GIL using SF_6 gas, SF_6 mixtures or other gas mixtures included in IEC 62271-4, the requirements therein shall be applied in addition to the recommendations below.

In general, insulating gas shall be handled in such a way as not to cause harmful effects to the environment or persons. If the gas, or its decomposition products, which might be generated under certain service conditions (e.g. due to internal arcing), impose a hazard to personnel, appropriate precautions shall be taken in order to ensure safe handling, including decontamination after accidental release of hazardous products.

Regulations concerning the maximum permitted concentration of gas in those work areas using the gas shall be observed. This might call for installation of devices for measurement of the gas concentration, and for ventilation arrangements. This is particularly important when working in trenches, tunnels and similar locations with restricted space close to the installation. In the case of nitrogen and other gases which can be inhaled without risk, similar precautions shall be taken in order to prevent suffocation.

If the gas used has an environmental impact, it shall not under normal conditions (e.g. maintenance, repair) be released into the atmosphere. This means reclaiming by means of a gas handling unit with a storing capacity corresponding to the largest gas volume of the installation. Abnormal leaks shall be rectified. Contaminated gas shall either be reclaimed by means of the gas handling unit and reused, or, if not possible, be sent to a company specialized in decontamination/reprocessing of waste. If the waste is considered to be hazardous, relevant rules for safety during handling and transportation shall be observed (see IEC 62271-4).

12 Safety

12.1 General

Subclause 12.1 of IEC 62271-1:2017 is applicable with the following additions:

High-voltage, GIL can be safe only when installed in accordance with the relevant installation rules, and used and maintained in accordance with the manufacturer’s instructions. It shall be operated and maintained by qualified personnel.

Due to the fact that it is completely impossible to touch any live part, a GIL provides a maximum degree of safety. However, it is normally only accessible by instructed or authorized persons.

When it is installed in an area accessible to the public, additional safety features shall be required. Two types of installation shall be considered.

– In the case of buried installations, there is no direct access but visible markings and a buried marker tape inform persons that an electrical device is buried at this location. These dispositions, combined with a sufficient thickness of earth (typically 1 m, see 4.102) should avoid any accidental contact. Potential load limits of the area above the trench shall be clearly visible installed along the route.
– In the case of above ground installations, fences or equivalent means shall be located along the GIL in such a way that no unintentional contact with the GIL or its accessories is possible.

The specifications in 12.2 to 12.103 are particularly important in order to ensure personal safety.

12.2 Precautions by manufacturers

Subclause 12.2 of IEC 62271-1:2017 is applicable.

12.3 Precautions by users

Subclause 12.3 of IEC 62271-1:2017 is applicable.

12.101 Mechanical aspects

– Mechanical stress due to the action of the external environment, or interaction between GIL and the environment:
    - movement of foundation, earthquakes, soil loading, wind, ice (see 6.102.2, 6.21)
    - thermal expansion (see 6.106)
– Pressurized components (see 6.102.2, 6.103, 6.104)
– Mechanical impact protection (see IEC 62271-1:2017)

12.102 Thermal aspects

– Maximum temperature of accessible part (see 7.5)
– Flammability (see IEC 62271-1:2017)

12.103 Maintenance aspects

– Gas handling (see 11.4.102)
– Operations of maintenance personnel in tunnels (see 6.105.3)

  Operations performed by maintenance personnel shall be strictly limited. When a maintenance operation is necessary, conditions shall be carefully defined and take into account the design of the GIL (gas volumes of the compartments, presence of pressure relief devices, etc.) and the volume of the tunnel.
– Earthing of the main circuits and the enclosure (see 6.3.101, 6.3.102)

13 Influence of the product on the environment

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

Also refer to 11.5.102.

Annex A
(informative)

Estimation of continuous current

A.1 General

The aim of Annex A is to define the continuous current of the GIL single phase when operating conditions are different from those of type tests, for example, open air GIL directly exposed to solar radiation, buried GIL or GIL in shafts or tunnels with forced cooling. Other changes might include different distances between phases or phase positions in the case of single-phase GIL or different enclosure currents due to earthing. The proposed method provides a basis for the estimation of continuous current, and refers to IEC 60287-1-1.

In contrast to the referred standards, the estimation of the continuous current can be based on more than one calculation, but be deduced from reference values to be obtained from type test results. The given standards can be used for calculation. If other appropriate calculation methods are used, these can be mentioned. The calculation is allowed if the temperature rise of the conductor is not more than 15 K with respect to the performed type test.

NOTE Although the scope of IEC 60287-1-1 refers to cables, the given calculations are also valid for GIL, unless the premises for certain relations (mainly concerning dimensions) define otherwise.

A.2 Symbols

D_c	diameter of conductor	(m)
D_e	diameter of enclosure	(m)
L	length of GIL	(m)
n	number of phases in one enclosure	
$\Delta\theta_c$	average temperature rise of the conductor	(K)
$\Delta\theta_{mc}$	maximum temperature rise of the conductor	(K)
$\Delta\theta_e$	average temperature rise of the enclosure	(K)
$\Delta\theta_{me}$	maximum temperature rise of the enclosure	(K)
$\Delta\theta_{ce}$	average temperature difference between conductor and enclosure	(K)
I_s	estimated continuous current	(kA)
K	thermal coefficient for heat exchange	
α	temperature coefficient of electrical resistivity	(1/K)
α_c	temperature coefficient of electrical resistivity for conductor	(1/K)
α_e	temperature coefficient of electrical resistivity for enclosure	(1/K)

A.3 Reference values

A.3.1 General

The following reference values can be deduced from the type test results:

a) general type test values;

b) AC resistances;

c) dissipation;

d) thermal resistances;

e) thermal coefficients.

A.3.2 General type test values

The following values shall be derived from or given by the performed type test:

I_r	rated current	(kA)
$\Delta\theta_{co}$	average temperature rise of the conductor	(K)
$\Delta\theta_{mco}$	maximum temperature rise of the conductor	(K)
R_{dco}	DC resistance of conductor at ambient temperature	(μΩ)
I_{eo}	enclosure current	(kA)
$\Delta\theta_{eo}$	average temperature rise of the enclosure	(K)
$\Delta\theta_{meo}$	maximum temperature rise of the enclosure	(K)
R_{deo}	DC resistance of enclosure at ambient temperature	(μΩ)
$\Delta\theta_{ceo}$	average temperature difference between conductor and enclosure	(K)

NOTE The average temperature is determined from the temperature profile over the (tested) length.

A.3.3 AC resistances

The AC resistance of the conductor at average conductor temperature R_{co} can either be deduced from the measured DC resistance R_{dco} and IEC 60287-3-1 or by appropriate calculation.

The AC resistance of the enclosure at the average enclosure temperature R_{eo} can either be deduced from the measured DC resistance R_{deo} and IEC 60287-3-1 or by appropriate calculation.

Contact resistance should also be taken into account.

Such resistance value of the GIL should be defined in relation to the length of the GIL under consideration.

Proximity effect should be considered; reference can be made to IEC 60287-1-1 or the appropriate literature.

A.3.4 Dissipation

The dissipation in the conductor P_{co} at average conductor temperature can be determined by:

$$P_{co} = I_r^2 \times R_{co}$$

The dissipation in the enclosure at P_{eo} average enclosure temperature can be determined in case of known amplitude by:

$$P_{eo} = I_{eo}^2 \times R_{eo}$$

Otherwise, the dissipation in the enclosure due to eddy currents can be determined by calculation (refer IEC 60287-1-1 or appropriate literature).

A.3.5 Thermal resistances

The thermal resistance T_{ceo} between conductor and enclosure is given by:

$$T_{ceo} = \Delta\theta_{ceo} / P_{co}$$

The thermal resistance T_{eo} between enclosure and the environment is given by:

$$T_{eo} = \Delta\theta_{eo} / [n \times P_{co} + P_{eo}]$$

A.3.6 Thermal coefficient

The thermal resistance T is given in IEC 60287-3-1 (thermal resistance in air (gaseous medium)) as:

$$T = 1 / [\pi \times D \times K \times \theta^{0,25}]$$

where

K is the thermal coefficient;

D is the diameter;

θ is the temperature difference.

The thermal coefficients K_{ce} and K_{e} for respectively T_{ce} and T_{e} are therefore given by:

$$K_{ce} = 1 / [T_{ceo} \times \pi \times D_{c} \times \Delta\theta_{ceo}{}^{0,25}]$$

$$K_{e} = 1 / [T_{eo} \times \pi \times D_{e} \times \Delta\theta_{eo}{}^{0,25}]$$

NOTE According to IEC TR 60943, the relationship between current and temperature rise is:

$$I^{1,67} = K' \Delta\theta.$$

Therefore, the thermal resistance according to IEC TR 60943 would be given by:

$$T = 1 / [\pi \times D \times K' \theta^{0,2}]$$

A.4 Estimation of current rating

A.4.1 General

In establishing the estimated continuous current, the following should be taken into consideration.

A.4.2 Maximum temperature rise

Since the calculations are based on the average temperature rise, the following relation is used to determine the maximum temperature rise of the conductor relative to the average conductor temperature rise:

$$\Delta\theta_{mc} = (I_{s}/I_{r})^{2} \times (\Delta\theta_{mco} - \Delta\theta_{co})$$

Therefore, the maximum temperature rise $\Delta\theta_{mc}$ of the conductor is given by:

$$\Delta\theta_{mc} = \Delta\theta_c + \delta\theta_{mc}$$

The maximum temperature rise $\Delta\theta_{me}$ of the enclosure is found in exactly the same way.

A.4.3 Heat input

A.4.3.1 General

The influence of the adjacent phases can be taken into account for the evaluation of external heat input.

A.4.3.2 Estimated internal dissipation

The internal dissipation of the conductor for the required situation is given by:

$$P_c = (I_s/I_r)^2 \times P_{co}\,[1 + \alpha_c \times (\Delta\theta_c - \Delta\theta_{co})]$$

The dissipation of the enclosure for the required situation is given by:

$$P_e = (I_s/I_r)^2 \times P_{eo}\,[1 + \alpha_e \times (\Delta\theta_e - \Delta\theta_{eo})]$$

NOTE When the layout of the installation is different (e.g. different phase distance of single-phase equipment or different earthing), the calculation of the dissipation is adjusted accordingly.

A.4.3.3 External heat input

Other external heat sources should be taken into account such as solar radiation, influence of adjacent phases, etc. In the following, their effect is designated by the symbol P_s.

A.4.4 Thermal resistances

A.4.4.1 Internal thermal resistance

The internal thermal resistance T_{ceo} between conductor and enclosure can be calculated according to the formula given in A.4.5. The calculated thermal coefficient can be used.

A.4.4.2 External thermal resistance

The external thermal resistance T_{eo} of the enclosure to the environment, for an installation in free air, the formula is given in A.4.5, including the thermal coefficient. In this case, the influence of wind, etc., is neglected.

The external thermal resistance T_e for other situations can be determined according to IEC 60287-1-1 or other relevant literature.

NOTE The external thermal resistance is the total thermal resistivity of the enclosure to the environment.

A.4.5 Estimated maximum temperature rise

The estimated average temperature rise of the enclosure is defined as follows:

$$\Delta\theta_e = T_e \times (n \times P_c + P_e + P_s)$$

The maximum temperature rise of the enclosure is then given by:

$$\Delta\theta_{me} = \Delta\theta_{e} + \delta\theta_{me}$$

and the maximum temperature rise of the conductor is given by the following:

$$\Delta\theta_{mc} = \Delta\theta_{e} + \delta\theta_{mc} + T_{ceo} \times P_{c}$$

A.4.6 Permissible temperature rises

The temperature rise of any point of the GIL (conductor, enclosure, tunnel, etc.) can be in accordance with the allowed temperature rise of the relevant IEC standard.

A.4.7 Estimated continuous current

The estimated continuous current is defined by the simultaneous solution of the relations and premises given in Annex A.

A.4.8 Informal documents

For more information, see [7].

Annex B
(informative)

Earthing

B.1 General

The earthing system is designed to ensure that no danger to persons or damage to equipment occurs under normal or abnormal operating conditions due to hazardous potential differences.

B.2 Safe limits on potential rise

The design of the earthing system should take into account potential rises due to fault currents, high-frequency currents associated with transient enclosure voltage and, for some types of bonding, step and touch voltages.

Acceptable values for touch potentials, step potentials and transferred potentials for the safety of persons should be determined with reference to IEC TS 60479-1 and IEC TS 60479-2. Attention is drawn to further limits on potential rise (step and touch voltages, induced voltages) that can be imposed by local regulations.

B.3 Enclosures

A GIL is contained within a conducting enclosure nominally at, or near, ground potential.

B.4 Earth electrodes

An earth electrode provides a low-impedance path to earth for both fault currents and high-frequency currents associated with transient enclosure voltage.

The earth electrode design should take into account the maximum ground fault current and duration at that position in the system and the soil resistivity so that hazardous potential differences do not occur.

The earth electrode cross-sectional area should be chosen to accommodate the maximum ground fault current and duration at that position in the system within an acceptable temperature rise.

The design of any joints should take into account the maximum ground fault current and duration at that position in the system.

The earth electrode design should take into account the mechanical stresses that can occur during installation and during fault conditions.

The earth electrode material should be resistant to corrosion.

B.5 Conductors of earthing system

The conductors of the earthing system need to carry both fault currents and possible high-frequency currents associated with transient enclosure voltages. In some cases, conductors will carry zero sequence currents or circulating power-frequency currents.

The conductor design should take into account all currents to be carried so that hazardous potential differences do not occur.

The conductors should be wide (typically greater than 50 mm in width), kept as short as possible and as free from changes in direction as possible to achieve a low inductance. Sharp bends in the conductors should be avoided.

The conductor cross-sectional area should be chosen to accommodate any current to be carried within an acceptable temperature rise.

The design of any joint should take into account all currents to be carried.

The conductor design should take into account the mechanical stresses that can occur during fault conditions.

B.6 Earth continuity

Electrical continuity between the earthing systems at either end of the transmission line route is necessary to provide a low impedance path for zero sequence currents.

Where it is not possible to use the enclosures to provide adequate earth continuity, a separate earth continuity conductor will be necessary.

B.7 Induced voltages

The earthing system should be designed to avoid large ground currents (which is not the enclosure current during normal operation) flowing as these can induce hazardous voltages in neighbouring communications circuits, pipelines, etc., possibly belonging to other authorities.

B.8 Transient enclosure voltage

Events such as switching (particularly disconnector operation), fault conditions, lightning strokes and operation of surge arresters generate fast fronted transients. Under such conditions, discontinuities in enclosures (e.g. where an insulating flange forms an essential part of the structure, or at gas to air bushings) will allow high-frequency currents to couple out and propagate on the outside of the enclosures giving rise to transient enclosure voltages. Precautions are taken in the design of the earthing system to limit the effects of transient enclosure voltages.

B.9 Non-linear resistors

To protect against the effects of transient enclosure voltages, protective devices (non-linear resistors) should be installed where the ends of enclosures are not connected to earth.

The rated voltage of the devices should be coordinated with step and touch voltages induced by rated and short-circuit current (see Clause B.10). The devices should have adequate energy absorption and high-frequency response.

They should be arranged to give a low-inductance connection by minimizing the length of the connecting leads and connecting a number of devices in parallel.

B.10 Bonding and earthing

B.10.1 General

It is envisaged that most GIL installations will be solidly bonded and earthed at both ends. However, where other bonding methods are used such as single point bonding or cross-bonding, additional precautions shall be taken in the design of the earthing system in order to manage the effects of step and touch voltages and induced voltages and currents, as well as mechanical forces resulting from short-circuit currents.

The enclosure may need to be earthed at additional positions along the route to reduce the earth potential rise under internal fault conditions.

Where the three phases of a transmission line are contained within a single enclosure, the enclosure can be earthed at both ends of the transmission line route. The enclosure will normally provide adequate earth continuity between the two ends of the route and a separate earth continuity conductor will be unnecessary.

The enclosures can be bonded and earthed at one end and insulated from earth at the other (end point bonding) or bonded and earthed at the mid-point and insulated from earth at the two ends (mid-point bonding). The transmission line can consist of a number of elementary sections, each single-point bonded.

To protect against the effects of transient voltages, protective devices (non-linear resistors) are connected at the ends of elementary sections where the enclosures are insulated from earth.

B.10.2 Cross-bonding

In a cross-bonded system, the enclosures are connected in series at the end of each elementary section in phase rotation, so that the e.m.f. induced along the enclosures tend to sum to zero after three elementary sections. The enclosure voltage is therefore controlled and circulating currents are virtually eliminated. However, eddy currents will generally be induced in the enclosure walls and these will contribute to the total heat dissipation of the transmission line.

The enclosures can be solidly bonded and earthed at the ends of a transmission line and continuously cross-bonded throughout its length (continuous cross-bonding) or solidly bonded and earthed at the ends of a number of major sections, each consisting of three cross-bonded minor sections (sectionalized cross-bonding).

To protect against the effects of transient voltages, protective devices (non-linear resistors) are connected at the ends of elementary sections where the enclosures are insulated from earth.

Where the earth resistance at solidly bonded positions is high, a separate earth continuity conductor can be applicable in order to prevent the ratings of protective devices being exceeded under internal fault conditions.

B.11 Application to directly buried installations

Where an installation is directly buried, the design of the earthing system shall accommodate the requirements of corrosion protection as stated under 6.21 (see Figure B.1).

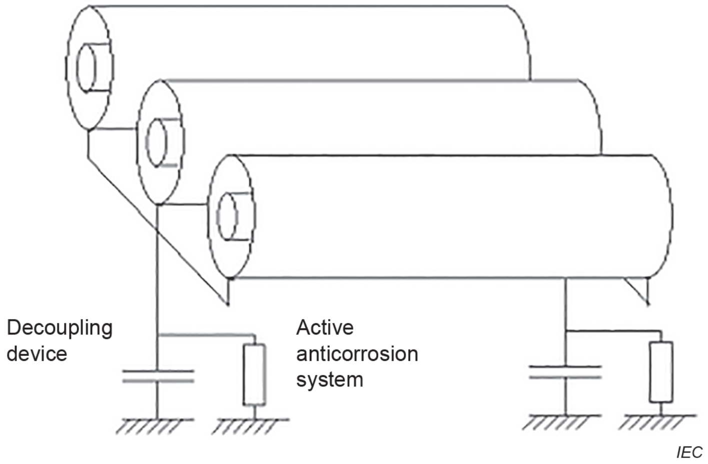

Figure B.1 – Example of earthing system together with active anti-corrosion system in the case of solid bonding of the enclosure at both ends

The design of the earthing system should be coordinated with the insulation level of the corrosion protection coating.

Removable links should be provided to allow electrical testing of the passive corrosion protection as stated under 7.103.

The design of the earthing system and the active corrosion protection should be coordinated so that no damage results to the active corrosion system from currents flowing from the enclosures to earth.

B.12 Informal documents

For more information, see [7] and [9].

Annex C
(informative)

Long-term testing of buried installations

C.1 Assessment of long-term behaviour

C.1.1 General

The points that shall be considered to assess long-term behaviour are

– the thermomechanical performance of the assembly, and
– the corrosion protection of the enclosures.

C.1.2 Thermomechanical performance

Thermomechanical forces, unless properly accounted for, can result in mechanical damage to the GIL and possible rupture of the enclosure. Therefore, whichever device is employed for counteracting the effects of thermal expansion and contraction, especially for the enclosures, it shall be evaluated under buried condition. The length of the test installation shall be sufficient to ensure that any thermomechanical movement is representative of what might occur in service.

NOTE Evaluation of the soil over the complete GIL installation could prove difficult unless a backfill material with known properties is used. It is assumed that normal ground materials will have a dried-out thermal resistivity value at a temperature between 50 °C and 60 °C and a non-dried out value if the temperature is below this. These figures are used in the rating calculations detailed in Annex A. Provided that the thermal resistivity values are known, the ground temperatures and hence system rating can be calculated allowing for dried out values where applicable.

C.1.3 Corrosion protection of the enclosures

It is important that the enclosure protective coating is not penetrated during service. The performance of the coating can be evaluated by either long-term water immersion tests or by long-term burial test in a wet soil condition. During this time, the GIL should undergo heat cycles to see the effect of temperature cycles on the migration of water. Deterioration in the coating can be detected by regular application of a test voltage and measurement of the leakage current that flows.

C.2 Summary of long-term tests

Development tests shall be completed by the manufacturer before long-term tests are undertaken. The purpose of these tests is to identify the long-term performance of the complete GIL system and shall only be carried out once, unless there is a substantial change in the GIL system concerning material, process and design. The test arrangement should consist of between 50 m and 100 m of GIL including auxiliary equipment (gas monitoring, partial discharge detection and pressure relief devices). At least one type of each component to be used in the system should be tested and the test arrangement should be representative of an installation design. The long-term tests should be undertaken over a twelve-month period.

The definition of the test procedure is under consideration. The following is proposed for guidance.

The following test should be carried out before starting and after the long duration tests:

a) temperature rise measurement (in accordance with 7.5.3.1 of IEC 62271-1:2017) of external enclosure walls and at set distances within the backfill material;
b) measurement of the main circuit resistance;
c) partial discharge levels within the GIL;
d) dielectric withstand test;

e) gas leakage rate;

f) on completion of the tests, a voltage test to breakdown can be performed.

Long duration tests can include:

- long-term thermal cycling;

  Subject the busbars and any expansion device to thermomechanical forces.
- corrosion protection performance;

  This shall be evaluated under thermal cycling and will include the complete arrangement and all the auxiliary equipment.
- backfill performance;

  This shall be carried out if the performance of the backfill is not known or cannot be guaranteed.

Annex D
(normative)

Requirements for welds on pressurized parts

D.1 General

Weld seams shall be produced and assessed according to defined requirements. During the production of a GIL, welding seams are made in the factories and on site.

D.2 Process and personal qualifications

All welding processes shall be checked and documented in accordance with international standards. Welding and subsequent testing personnel shall be certified in accordance with international standards.

- Definition of the welding procedures (WPS) according to ISO 15609 (all parts)
- Welding process qualification (WPQR) according to ISO 15614 (all parts)
- Qualification of welders and operators according to ISO 9606 (all parts) and ISO 14732
- Non-destructive test (NDT) personnel according to ISO 9712

D.3 Non-destructive tests of welding

For non-destructive testing of factory and on site welds, the items of Table D.1 applies:

Table D.1 – Quantity of NDTs

Tests type	Factory welds	On site welds
Visual (VT) 8.6 of IEC 62271-1:2017	100 %	100 %
Radiography (RT) or ultrasonic (UT) 7.103 of IEC 62271-203:2022	min. 10 %, 100 % of cross sections; welding factor v = 1	min. 10 % to 100 % 11.3.7 and 11.4.104

For imperfections defined and classified according to ISO 6520 (all parts), refer to Table D.2.

Table D.2 – Acceptance criteria of imperfections

<table>
<tr><th rowspan="2">Test type</th><th colspan="2">Applicable standard</th><th colspan="2">Acceptance level</th></tr>
<tr><th>Steel</th><th>Aluminum</th><th>Steel</th><th>Aluminum</th></tr>
<tr><td>VT</td><td>ISO 5817</td><td>ISO 10042</td><td rowspan="6">EN 50068</td><td rowspan="6">EN 50064</td></tr>
<tr><td>RT</td><td>ISO 10675-1</td><td>ISO 10675-2</td></tr>
<tr><td rowspan="4">UT</td><td colspan="2">Recommended applicable standards</td></tr>
<tr><td>ISO 11666, ISO 17640</td><td rowspan="3">a</td></tr>
<tr><td>ISO 22825, ISO 23279</td></tr>
<tr><td>ISO 10893-8,
ISO 10893-9,
ISO 10893-10 and
ISO 10893-11</td></tr>
<tr><td colspan="5">[a] UT testing of aluminium welds should be performed according to the adapted steel standards or equivalent manufacturer specifications. For more information, see [10] and [11].</td></tr>
</table>

Bibliography

[1] IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

[2] CIGRE Brochure 163:2000, *Guide for SF_6 gas mixtures*

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[8] IEC TS 60479-1:2018, *Effects of current on human beings and livestock – Part 1: General aspects*

[9] IEC TS 60479-2:2019, *Effects of current on human beings and livestock – Part 2: Special aspects*

[10] EN 50064, *Wrought aluminium and aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear*

[11] EN 50068, *High-voltage switchgear and controlgear – Gas-filled wrought steel enclosures*

[12] ISO 5817, *Welding – Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections*

[13] ISO 6520 (all parts), *Welding and allied processes – Classification of geometric imperfections in metallic materials*

[14] ISO 10042, *Welding – Arc-welded joints in aluminium and its alloys – Quality levels for imperfections*

[15] ISO 10675-1, *Non-destructive testing of welds – Acceptance levels for radiographic testing – Part 1: Steel, nickel, titanium and their alloys*

[16] ISO 10675-2, *Non-destructive testing of welds – Acceptance levels for radiographic testing – Part 2: Aluminium and its alloys*

[17] ISO 10893-8, *Non-destructive testing of steel tubes – Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*

[18] ISO 10893-9, *Non-destructive testing of steel tubes – Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes*

[19] ISO 10893-10, *Non-destructive testing of steel tubes – Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

[20] ISO 10893-11, *Non-destructive testing of steel tubes – Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*

[21] ISO 11666, *Non-destructive testing of welds – Ultrasonic testing – Acceptance levels*

[22] ISO 17640, *Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels, and assessment*

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

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

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

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[27] ISO 23279, *Non-destructive testing of welds – Ultrasonic testing – Characterization of discontinuities in welds*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À HAUTE TENSION –

Partie 204: Lignes de transport rigides à isolation gazeuse de tension assignée supérieure à 52 kV

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L'IEC 62271-204 a été établie par le sous-comité 17C: Ensembles, du comité d'études 17 de l'IEC: Appareillage haute tension. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2011. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) mise à jour par rapport à l'IEC 62271-1:2017 et alignement des caractéristiques assignées de tension et des tensions d'essai;
b) ajout de nouvelles informations relatives aux soudures sur les parties sous pression et à l'étanchéité au gaz.

Le texte du présent est issu des documents suivants:

Projet	Rapport de vote
17C/840/FDIS	17C/846/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Le présent document doit être utilisé conjointement avec l'IEC 62271-1:2017 et l'IEC 62271-203:2022, auxquelles il fait référence et qui sont applicables sauf spécification contraire. Pour faciliter le repérage des exigences correspondantes, ce document utilise une numérotation identique des articles et des paragraphes à celle de l'IEC 62271-1:2017 et de IEC 62271-203:2022. Les modifications à ces articles et paragraphes sont indiquées sous la même numérotation, alors que les paragraphes additionnels sont numérotés à partir de 101.

Une liste de toutes les parties de la série IEC 62271, publiées sous le titre général *Appareillage à haute tension*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu du présent document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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- remplacé par une édition révisée, ou
- amendé.

APPAREILLAGE À HAUTE TENSION –

Partie 204: Lignes de transport rigides à isolation gazeuse de tension assignée supérieure à 52 kV

1 Domaine d'application

La présente partie de l'IEC 62271 est applicable aux lignes de transport rigides haute tension à isolation gazeuse (LIG) dont l'isolation est réalisée, au moins partiellement, par un gaz isolant ou un mélange gazeux autre que l'air à la pression atmosphérique, pour un courant alternatif de tension assignée supérieure à 52 kV, pour des fréquences de service inférieures ou égales à 60 Hz.

Le présent document est applicable lorsque les dispositions de l'IEC 62271-203 ne couvrent pas l'application des LIG (voir la Note 3).

À chaque extrémité de la ligne de transport à isolation gazeuse HT, un élément spécifique est utilisé pour la connexion entre la ligne de transport à isolation gazeuse HT et d'autres matériels tels que les traversées, les transformateurs ou bobines d'inductance, les boîtes à câbles, les parafoudres sous enveloppe métallique, les transformateurs de tension ou les postes à isolation gazeuse, auxquels s'applique leur propre spécification.

La ligne de transport à isolation gazeuse HT est, sauf spécification contraire, conçue pour être utilisée dans les conditions normales de service.

NOTE 1 Dans le présent document, les "lignes de transport HT à isolation gazeuse" sont désignées par l'abréviation "LIG".

NOTE 2 Dans le présent document, le mot "gaz" signifie gaz ou mélange gazeux, selon la définition du constructeur.

NOTE 3 Exemples d'applications de LIG:

- lorsque tout ou partie de la ligne de transport à isolation gazeuse HT est directement enterrée;
- lorsque la ligne de transport à isolation gazeuse HT est située, entièrement ou partiellement, dans une zone accessible au public;
- lorsque la ligne de transport à isolation gazeuse HT est longue (généralement plus de 500 m) et que la longueur type du compartiment gazeux dépasse la valeur courante associée à la technologie des postes à isolation gazeuse.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1:2010, *Techniques des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60068-1:2013, *Essais d'environnement – Partie 1: Généralités et lignes directrices*

IEC 60229:2007, *Câbles électriques – Essais sur les gaines extérieures extrudées avec fonction spéciale de protection*

IEC 60287-3-1:2017, *Câbles électriques – Calcul du courant admissible – Partie 3-1: Conditions de fonctionnement – Conditions du site de référence*

IEC 60376, *Spécification de la qualité technique de l'hexafluorure de soufre (SF_6) et des gaz complémentaires à employer dans les mélanges de SF_6 pour utilisation dans les matériels électriques*

IEC 60480, *Spécifications pour la réutilisation de l'hexafluorure de soufre (SF_6) et des mélanges contenant du SF_6 dans le matériel électrique*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-203:2022, *Appareillage à haute tension – Partie 203: Appareillage sous enveloppe métallique à isolation gazeuse de tensions assignées supérieures à 52 kV*

IEC 62271-4:2013, *Appareillage à haute tension – Partie 4: Utilisation et manipulation de l'hexafluorure de soufre (SF_6) et des mélanges contenant du SF_6*

ISO 9606 (toutes les parties), *Épreuve de qualification des soudeurs – Soudage par fusion*

ISO 9712, *Essais non destructifs – Qualification et certification du personnel END*

ISO 14732, *Personnel en soudage – Épreuve de qualification des opérateurs soudeurs et des régleurs en soudage pour le soudage mécanisé et le soudage automatique des matériaux métalliques*

ISO 15609 (toutes les parties), *Descriptif et qualification d'un mode opératoire de soudage pour les matériaux métalliques – Descriptif d'un mode opératoire de soudage*

ISO 15614 (toutes les parties), *Descriptif et qualification d'un mode opératoire de soudage pour les matériaux métalliques – Épreuve de qualification d'un mode de soudage*

3 Termes et définitions

Pour les besoins du présent document, les termes et les définitions de l'IEC 62271-1:2017 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.101
zone accessible au public
zone accessible à toute personne sans restriction

Note 1 à l'article: Une LIG posée en surface à l'extérieur d'un poste électrique est réputée "installée dans une zone accessible au public".

3.102
lignes de transport à isolation gazeuse
LIG
lignes sous enveloppe métallique dans lesquelles l'isolation est obtenue, au moins partiellement, par un gaz isolant autre que l'air à la pression atmosphérique, et dont l'enveloppe externe est destinée à être mise à la terre

3.103
enveloppe LIG
partie d'une LIG contenant le gaz isolant dans les conditions exigées protégeant le matériel contre les effets extérieurs et procurant un haut degré de protection du personnel

3.104
compartiment
partie d'une LIG entièrement fermée de manière étanche au gaz à l'exception des ouvertures nécessaires à l'interconnexion et à la commande

3.105
cloison
isolateur support étanche au gaz d'un appareillage sous enveloppe métallique à isolation gazeuse séparant deux compartiments adjacents

3.106
circuit principal
toutes les pièces conductrices d'une LIG qui font partie d'un circuit destiné à transporter l'énergie électrique

[SOURCE: IEC 60050-441:1984, 441-13-02, modifié – Remplacement de "un ensemble" par "une LIG".]

3.107
température de l'air ambiant
température déterminée dans des conditions exigées de l'air qui entoure l'enveloppe LIG externe dans le cas de la pose en surface, tranchées ouvertes ou tunnels

[SOURCE: IEC 60050-441:1984, 441-11-13, modifié – Remplacement de "totalité de l'appareil de connexion ou du fusible" par "enveloppe LIG externe dans le cas de la pose en surface, tranchées ouvertes ou tunnels".]

3.108
température de calcul de l'enveloppe
température maximale d'une enveloppe LIG qui peut être atteinte dans les conditions de service

3.109
pression de calcul de l'enveloppe
pression relative utilisée pour déterminer le calcul de l'enveloppe

Note 1 à l'article: Elle est au moins égale à la pression relative maximale dans l'enveloppe à la température de calcul de l'enveloppe.

3.110
pression de calcul de la cloison
pression relative à la surface de la cloison

Note 1 à l'article: Elle est au moins égale à la pression différentielle maximale à la surface de la cloison pendant les activités de maintenance.

3.111
unité de séparation
unité destinée à isoler électriquement un côté du circuit principal de l'autre, principalement à des fins d'essais ou de maintenance sur site

3.112
décharge disruptive
phénomène associé à la défaillance de l'isolation sous l'action d'une contrainte électrique, dans lesquels la décharge court-circuite complètement l'isolation, réduisant la tension entre électrodes à une valeur nulle ou presque nulle

Note 1 à l'article: Ce terme s'applique aux décharges dans les diélectriques solides, liquides ou gazeux et à leurs combinaisons.

Note 2 à l'article: Une décharge disruptive dans un diélectrique solide occasionne la perte définitive de la rigidité diélectrique (isolation non autorégénératrice); dans les diélectriques liquides ou gazeux, cette perte peut n'être que momentanée (isolation autorégénératrice).

Note 3 à l'article: Le terme "amorçage" est utilisé lorsque la décharge disruptive se produit dans un diélectrique gazeux ou liquide. Le terme "contournement" est utilisé lorsque la décharge disruptive longe la surface d'un diélectrique solide entouré d'un gaz ou d'un liquide isolant. Le terme "perforation" est utilisé lorsque la décharge disruptive se produit à travers un diélectrique solide.

3.113
tronçon de LIG
partie d'une LIG définie par des exigences opérationnelles ou autres telles que la longueur maximale pour l'essai diélectrique ou la séquence d'installation

Note 1 à l'article: Une LIG peut être constituée d'un ensemble de plusieurs tronçons de LIG.

Note 2 à l'article: Elle peut être constituée d'un ou de plusieurs compartiments.

Note 3 à l'article: Les tronçons peuvent être isolés par des unités de séparation.

4 Conditions normales et spéciales de service

4.1 Conditions normales de service

4.1.1 Généralités

Le paragraphe 4.1.1 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Les conditions normales de service applicables à une LIG selon les conditions d'installation, sont décrites en 4.101, 4.102 et 4.103. Lorsque plusieurs modes d'installation sont employés, les paragraphes qui conviennent doivent s'appliquer à chaque tronçon de la LIG.

4.1.2 Appareillage pour l'intérieur

Le paragraphe 4.1.2 de l'IEC 62271-1:2017 est applicable.

4.1.3 Appareillage pour l'extérieur

Le paragraphe 4.1.3 de l'IEC 62271-1:2017 est applicable.

4.2 Conditions spéciales de service

Le paragraphe 4.2 de l'IEC 62271-1:2017 est applicable.

4.101 Installation à l'air libre

Pour la détermination des caractéristiques assignées des LIG dans le cas d'une installation à l'air libre, les conditions normales de service de l'IEC 62271-1:2017 doivent s'appliquer. Ces conditions sont aussi valables dans le cas des tranchées ouvertes.

Si les conditions réelles de service diffèrent des conditions normales de service, les caractéristiques assignées doivent être adaptées en conséquence.

4.102 Installation enterrée

Les valeurs générales de résistivité thermique et de température du sol sont:

– 1,2 K · m/W, et 20 °C en été;
– 0,85 K · m/W, et 10 °C en hiver.

À titre de recommandation, les valeurs données dans l'IEC 60287-3-1, peuvent être prises en considération.

Pour des lignes de transport longues (plusieurs kilomètres), il convient également d'envisager des mesurages de résistivité du sol sur site.

NOTE 1 L'utilisation d'un remblai contrôlé avec une résistivité thermique de sol donnée peut également être envisagée.

NOTE 2 Un risque d'emballement thermique existe en cas d'assèchement du sol qui entoure la LIG enterrée. Pour éviter l'assèchement du sol, une température maximale de l'enveloppe en service située dans une plage comprise entre 50 °C et 60 °C est généralement réputée acceptable.

Il convient que la profondeur de pose fasse l'objet d'un accord entre le constructeur et l'utilisateur. La détermination de la profondeur de pose doit prendre en compte les contraintes thermomécaniques, les exigences de sécurité et les réglementations locales.

4.103 Installation en tunnel, puits ou situations similaires

Un système de refroidissement forcé constitue une méthode adaptée à la gestion de la chaleur résiduelle, qui peut être utilisée dans le cas de tunnels, puits ou installations similaires.

Dans le cas de longs puits verticaux, de tunnels inclinés ou de tronçons de ces tunnels, une attention particulière doit être portée aux gradients de température et de densité.

5 Caractéristiques assignées

5.1 Généralités

L'Article 5 de l'IEC 62271-1:2017 n'est pas applicable et est remplacé comme suit.

Les caractéristiques assignées d'une LIG sont les suivantes:

a) la tension assignée (U_r);
b) le niveau d'isolement assigné (U_d, U_p, U_s);
c) la fréquence assignée (f_r);
d) le courant permanent assigné (I_r);
e) le courant de courte durée admissible assigné (I_k) (pour les circuits principaux et les circuits de mise à la terre);
f) la valeur de crête du courant admissible assigné (I_p) (pour les circuits principaux et les circuits de mise à la terre);

g) la durée de court-circuit assignée (t_k);

h) la tension d'alimentation assignée des circuits auxiliaires et de commande (U_a);

i) la fréquence d'alimentation assignée des circuits auxiliaires et de commande.

5.2 Tension assignée (U_r)

Le paragraphe 5.2 de l'IEC 62271-1:2017 est applicable.

5.3 Niveau d'isolement assigné (U_d, U_p, U_s)

Le paragraphe 5.3 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Les niveaux d'isolement assignés doivent être choisis dans l'IEC 62271-203 sur la base d'une étude de coordination d'isolement spécifique à l'installation, de façon à prendre en considération des paramètres tels que les surtensions, les réflexions de tension, etc. Il est recommandé d'effectuer des études de coordination d'isolement spécifiques pour chaque installation. Pour plus d'informations, voir [1][1].

Bien qu'il soit possible, dans une large mesure, d'éviter des défauts d'arc internes par le choix d'un niveau d'isolement approprié, il convient d'envisager des moyens de limitation des surtensions externes (parafoudres, par exemple) à chaque extrémité de l'installation.

5.4 Fréquence assignée (f_r)

Le paragraphe 5.4 de l'IEC 62271-1:2017 est applicable.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Le courant permanent assigné est défini pour une LIG monophasée ou triphasée installée en surface pour une température de l'air ambiant de 40 °C. Pour les autres conditions d'installation, le courant en service continu maximal admissible peut être différent du courant permanent assigné. Voir l'Annexe A.

5.6 Courant de courte durée admissible assigné (I_k)

Le paragraphe 5.6 de l'IEC 62271-1:2017 est applicable.

5.7 Valeur de crête du courant admissible assigné (I_p)

Le paragraphe 5.7 de l'IEC 62271-1:2017 est applicable.

5.8 Durée de court-circuit assignée (t_k)

Le paragraphe 5.8 de l'IEC 62271-1:2017 est applicable.

5.9 Tension d'alimentation assignée des circuits auxiliaires et de commande (U_a)

Le paragraphe 5.9 de l'IEC 62271-1:2017 est applicable.

[1] Les chiffres entre crochets renvoient à la Bibliographie.

5.10 Fréquence d'alimentation assignée des circuits auxiliaires et de commande

Le paragraphe 5.10 de l'IEC 62271-1:2017 est applicable.

5.11 Pression d'alimentation assignée en gaz comprimé pour les systèmes à pression entretenue

Le paragraphe 5.11 de l'IEC 62271-1:2017 n'est pas applicable.

6 Conception et construction

L'Article 6 de l'IEC 62271-1:2017 est applicable, à l'exception de ce qui suit.

Il convient d'accéder aisément à tout matériel de LIG qui nécessite une maintenance préventive systématique ou des essais de diagnostic.

Il convient de concevoir les LIG de telle manière que les opérations normales d'exploitation, d'inspection et de maintenance puissent être effectuées sans risque, y compris la vérification de la séquence des phases après installation et après extension.

Il convient de concevoir le matériel de telle manière que les contraintes mécaniques provoquées par toutes les charges applicables, par exemple la dilatation thermique, le déplacement admis et accepté des fondations, les vibrations externes, les tremblements de terre, le chargement des sols, le vent et la glace ne compromettent pas les caractéristiques assignées du matériel.

6.1 Exigences pour les liquides utilisés dans les LIG

Le paragraphe 6.1 de l'IEC 62271-1:2017 n'est pas applicable.

6.2 Exigences pour les gaz utilisés dans les LIG

Le paragraphe 6.2 de l'IEC 62271-1:2017 est applicable. Si un mélange gazeux est utilisé, il convient que le constructeur fournisse des informations relatives aux caractéristiques du gaz, telles que la rigidité diélectrique, le rapport de mélange, le procédé de mélange et la pression de remplissage.

NOTE Se référer aux références [2], [3] et [4].

6.3 Raccordement à la terre

Le paragraphe 6.3 de l'IEC 62271-1:2017 est applicable avec les ajouts suivants:

6.3.101 Mise à la terre des circuits principaux

Pour assurer la sécurité lors de travaux de maintenance, toutes les parties des circuits principaux auxquelles il est exigé ou prévu d'accéder doivent pouvoir être mises à la terre. De plus, il doit être possible, après ouverture de l'enveloppe, de raccorder des prises de terre au conducteur pendant la durée des travaux.

La mise à la terre peut être réalisée par

a) des sectionneurs de terre avec un pouvoir de fermeture égal à la valeur de crête du courant admissible assigné, s'il est toujours possible que le circuit raccordé soit sous tension;
b) des sectionneurs de terre sans pouvoir de fermeture en court-circuit ou avec un pouvoir de fermeture en court-circuit inférieur à la valeur de crête du courant admissible assigné, s'il est avéré que le circuit raccordé est hors tension; ou
c) des dispositifs amovibles de mise à la terre, seulement après accord entre constructeur et utilisateur.

Chaque partie dont la déconnexion est possible doit pouvoir être mise à la terre.

Il convient de veiller à ce que le dispositif de mise à la terre initiale soit capable de dissiper le niveau maximal de la charge susceptible d'être piégée sur le circuit isolé.

Lorsque les sectionneurs de terre font partie du poste raccordé à la ligne de transport, l'utilisateur doit assurer qu'ils sont conformes aux points a) à c) ci-dessus.

Le circuit de mise à la terre peut être dégradé après avoir été soumis au courant de court-circuit assigné. À l'issue d'un tel événement, le circuit de mise à la terre peut être remplacé, le cas échéant.

6.3.102 Mise à la terre de l'enveloppe

Les enveloppes doivent pouvoir être connectées à la terre. Toutes les parties métalliques prévues pour être mises à la terre et ne faisant pas partie d'un circuit principal ou auxiliaire doivent être connectées à la terre. Pour l'interconnexion des enveloppes, châssis, etc., la fixation (par exemple, par boulonnage ou soudage) est généralement acceptée pour assurer la continuité électrique. Si la fixation est réalisée par boulonnage, des dispositions doivent être prévues afin de permettre un contact électrique adéquat. Dans le cas contraire, le joint mécanique doit être shunté par une connexion électrique appropriée, telle que des conducteurs en cuivre ou en aluminium de section adaptée.

La continuité des circuits de mise à la terre doit être assurée compte tenu des contraintes thermiques et électriques provoquées par les courants qui peuvent les traverser.

Il est prévu que la plupart des installations LIG soient solidement reliées entre elles et mises à la terre aux deux extrémités. La conception particulière a une influence sur la dissipation thermique, les tensions de pas et de touche et le champ magnétique externe. Ceux-ci sont traités à l'Annexe B.

La conception de la mise à la terre de l'enveloppe doit être compatible avec les mesures de protection contre la corrosion pour les LIG enterrées.

6.4 Matériels auxiliaires et de commande

Le paragraphe 6.4 de l'IEC 62271-1:2017 est applicable.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 n'est pas applicable.

6.6 Manœuvre à accumulation d'énergie

Le paragraphe 6.6 de l'IEC 62271-1:2017 n'est pas applicable.

6.7 Manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure (manœuvre indépendante sans accrochage mécanique)

Le paragraphe 6.7 de l'IEC 62271-1:2017 n'est pas applicable.

6.8 Organes de commande à manœuvre manuelle

Le paragraphe 6.8 de l'IEC 62271-1:2017 n'est pas applicable.

6.9 Fonctionnement des déclencheurs

Le paragraphe 6.9 de l'IEC 62271-1:2017 n'est pas applicable.

6.10 Indication de la pression/du niveau

Le paragraphe 6.10 de l'IEC 62271-1:2017 est applicable.

6.11 Plaques signalétiques

Le paragraphe 6.11 de l'IEC 62271-1:2017 n'est pas applicable et est remplacé comme suit:

6.11.1 Généralités

Pour les installations extérieures, les plaques signalétiques et leurs fixations doivent être résistantes aux intempéries et à la corrosion.

Chaque extrémité de l'installation, ainsi que chaque point dans lequel des interventions sont nécessaires à l'exploitation, doivent être équipés d'une plaque signalétique complète. Ces plaques signalétiques doivent contenir les informations suivantes:

- le nom du constructeur ou la marque
- la désignation du type et le numéro de série
- la tension assignée U_r
- la tension assignée de tenue au choc de foudre U_p
- la tension assignée de tenue au choc de manœuvre U_s
- la tension assignée de tenue de courte durée à fréquence industrielle U_d
- le courant permanent assigné I_r
- le courant de courte durée admissible assigné I_k
- la valeur de crête du courant admissible assigné I_p
- la fréquence assignée F_r
- la durée de court-circuit assignée T_k
- la pression de remplissage pour l'isolement; la pression fonctionnelle minimale pour l'isolement; la pression de calcul pour les enveloppes
- le type de gaz
- la masse du gaz

NOTE La présence du mot "assigné" est facultative sur les plaques signalétiques.

6.11.2 Application

Le paragraphe 6.11.2 de l'IEC 62271-1:2017 n'est pas applicable et est remplacé comme suit:

Comme les caractéristiques de différents tronçons peuvent être différentes, les enveloppes ou leur revêtement, le cas échéant, doivent comporter un marquage à des fins d'identification des matériels. Il convient que la distance maximale entre deux marquages d'identification fasse l'objet d'un accord entre le constructeur et l'utilisateur.

Les marquages doivent être durables et clairement lisibles, et doivent contenir les informations suivantes:

- le nom du constructeur ou la marque;
- la désignation du type;
- la tension assignée;
- le type de gaz et la pression de remplissage pour l'isolement.

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 est applicable.

6.13 Indicateur de position

Le paragraphe 6.13 de l'IEC 62271-1:2017 est applicable.

6.14 Degré de protection procuré par les enveloppes

6.14.1 Généralités

Le paragraphe 6.14.1 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Il n'existe aucune spécification pour le circuit principal ni pour les parties qui lui sont directement raccordées, du fait de l'étanchéité au gaz des enveloppes.

Les degrés de protection conformément à l'IEC 60529 doivent être spécifiés pour toutes les enveloppes des circuits appropriés à basse tension de commande et/ou auxiliaires.

Les degrés de protection s'appliquent aux conditions de service du matériel.

6.14.2 Protection des personnes contre l'accès aux parties dangereuses et protection du matériel contre la pénétration de corps solides étrangers (codification IP)

Le paragraphe 6.14.2 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Les moyens de protection ne s'appliquent qu'aux circuits de commande et/ou auxiliaires. Le premier chiffre caractéristique doit être supérieur ou égal à 3.

6.14.3 Protection contre la pénétration d'eau (codification IP)

Le paragraphe 6.14.3 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Lorsque les conditions de pose d'une installation conduisent à un risque de pénétration d'eau (installations enterrées, installations en tranchées, fourreau, etc.), le second chiffre caractéristique doit être spécifié, comme cela est présenté dans le Tableau 1 ci-après.

Tableau 1 – Second chiffre caractéristique du codage IP

Second chiffre caractéristique	Brève description	Définition
7	Protégé contre les effets d'une immersion temporaire dans de l'eau	Une pénétration d'eau provoquant des effets nuisibles ne doit pas être possible lorsque l'enveloppe est immergée temporairement dans l'eau, dans les conditions spécifiées de pression et de durée
Dans le cas de situations plus sévères que celles qui correspondent au second chiffre caractéristique 7, il convient que la protection fasse l'objet d'un accord entre le constructeur et l'utilisateur.		

6.14.4 Protection contre les impacts mécaniques dans les conditions normales de service (codification IK)

Le paragraphe 6.14.4 de l'IEC 62271-1:2017 est applicable.

6.15 Lignes de fuite pour les isolateurs d'extérieur

Le paragraphe 6.15 de l'IEC 62271-1:2017 n'est pas applicable.

6.16 Étanchéité au gaz et au vide

6.16.1 Généralités

Le paragraphe 6.16.1 de l’IEC 62271-1:2017 n’est pas applicable.

6.16.2 Systèmes à pression entretenue de gaz

Le paragraphe 6.16.2 de l’IEC 62271-1:2017 n’est pas applicable.

6.16.3 Systèmes à pression autonome de gaz

Le paragraphe 6.16.3 de l’IEC 62271-203:2022 est applicable avec l’ajout suivant:

Les caractéristiques d’étanchéité des systèmes à pression autonome et l’intervalle entre compléments de remplissage dans les conditions normales de service doivent être indiqués par le constructeur et doivent être cohérents avec une maintenance minimale et une philosophie d’inspection.

La valeur pour l’intervalle entre compléments de remplissage doit être d’au moins 10 ans pour les systèmes à SF_6 et, pour les autres gaz, il convient qu’elle soit cohérente avec les valeurs d’étanchéité. Les fuites éventuelles entre sous-ensembles ayant des pressions différentes doivent également être prises en compte.

6.16.4 Systèmes à pression scellés

Le paragraphe 6.16.4 de l’IEC 62271-1:2017 est applicable.

6.16.5 Cloisons internes

Dans le cas particulier de la maintenance d'un compartiment dont les compartiments adjacents contiennent du gaz sous pression, il convient que le constructeur indique aussi le taux de fuite de gaz admissible à travers les cloisons, et l'intervalle entre compléments de remplissage doit rester supérieur ou égal à un mois. Des moyens doivent être fournis pour permettre les compléments de remplissage des systèmes à gaz en toute sécurité alors que le matériel est en service.

La manipulation du gaz dans le cadre des travaux de réparation et de maintenance doit être faite selon la réglementation locale, voir l’IEC 62271-4.

6.17 Étanchéité des systèmes de liquide

Le paragraphe 6.17 de l’IEC 62271-1:2017 n’est pas applicable.

6.18 Risque de feu (inflammabilité)

Le paragraphe 6.18 de l’IEC 62271-1:2017 n’est pas applicable.

6.19 Compatibilité électromagnétique (CEM)

Le paragraphe 6.19 de l’IEC 62271-1:2017 n’est pas applicable.

6.20 Émission de rayons X

Le paragraphe 6.20 de l’IEC 62271-1:2017 n’est pas applicable.

6.21 Corrosion

Le paragraphe 6.21 de l’IEC 62271-1:2017 est applicable avec les ajouts suivants:

6.21.101 Protection contre la corrosion des installations enterrées

Le choix de la protection contre la corrosion, c'est-à-dire du revêtement externe et de tout système actif de protection, doit prendre en compte les conditions particulières telles que: le lieu, la nature et l'état du sol ou du remblai, le matériau d'enveloppe et le type de mise à la terre adopté.

En général, la protection contre la corrosion des LIG est similaire à celle des pipelines ou des câbles de puissance. L'enveloppe est revêtue d'une ou de plusieurs couches de caoutchouc ou d'un matériau plastique. Le revêtement agit comme un système passif de protection contre la corrosion, en empêchant le contact de l'enveloppe métallique du matériel électrique avec l'humidité ou l'eau.

La protection passive contre la corrosion est exigée et tout système actif contre la corrosion, s'il est requis et installé par suite d'un accord entre l'opérateur et le fournisseur, doit être disposé conformément aux conditions d'environnement sur toute la longueur de la LIG.

6.21.102 Protection contre la corrosion des installations non enterrées

Le paragraphe 6.21 de l'IEC 62271-1:2017 est applicable.

6.22 Niveaux de remplissage pour l'isolement, la coupure et/ou la manœuvre

Le paragraphe 6.22 de l'IEC 62271-1:2017 est applicable.

6.101 Réduction des effets des défauts internes

6.101.1 Généralités

La probabilité d'un défaut conduisant à un défaut d'arc interne dans une LIG construite selon le présent document est très faible. Cela résulte de l'utilisation d'un gaz isolant autre que l'air à la pression atmosphérique, exempt de pollution, d'humidité ou de vermine.

Des exemples de dispositions pour éviter un défaut d'arc interne, et pour limiter leur durée et leurs conséquences sont

– la coordination de l'isolement,
– la limitation et la surveillance des fuites de gaz,
– la protection rapide,
– les dispositifs de court-circuitage rapide des arcs,
– les verrouillages entre les appareils de connexion,
– la commande à distance,
– les décharges de pression, internes et/ou externes, et
– le contrôle de la main-d'œuvre sur site.

Il convient également de prendre des dispositions pour réduire le plus possible les effets de défauts d'arcs internes conduisant à un arc sur la continuité de service de la LIG. Il convient que l'effet d'un arc soit limité au compartiment dans lequel il s'est produit.

Si, en dépit des dispositions prises, un essai fait l'objet d'un accord entre le constructeur et l'utilisateur pour vérifier l'effet des défauts d'arcs internes, il convient de conduire cet essai selon le 7.105 de l'IEC 62271-203:2022.

Dans le cas de LIG sous enveloppe monophasée installée dans des réseaux à neutre isolé ou mis à la terre par bobine d'extinction, et équipé d'une protection pour limiter la durée des défauts internes à la terre, les essais ne sont généralement pas nécessaires.

6.101.2 Effets externes de l'arc

Des précautions adéquates au niveau des installations doivent être prises pour réduire les dangers dus aux risques tolérables. Pour plus d'informations, voir [4].

Afin d'atteindre une protection du personnel élevée, les effets externes d'un arc doivent être limités (en prenant les précautions appropriées) à l'apparition d'un trou ou d'une déchirure sur l'enveloppe, sans aucune fragmentation.

Le constructeur doit fournir des informations suffisantes pour permettre à l'utilisateur de prendre ses précautions.

Le constructeur et l'utilisateur peuvent convenir d'une durée pendant laquelle un arc dû à un défaut interne, jusqu'à une valeur donnée du courant de court-circuit, ne provoque pas d'effets externes (se reporter également au 6.102.2).

6.101.3 Localisation de défaut interne

Des dispositifs appropriés doivent être disponibles pour permettre de déterminer la localisation de défauts.

6.102 Enveloppes

6.102.1 Généralités

L'enveloppe doit être en métal, reliée en permanence à la terre et capable de résister à la pression normale et aux pressions transitoires de service.

Les enveloppes de matériels à remplissage de gaz conformes au présent document sont, en service, sous pression permanente, et sont soumises à des conditions de service particulières qui les différencient des réservoirs d'air comprimé et des réservoirs de stockage similaires. Ces conditions sont les suivantes:

– le circuit principal est entouré d'une enveloppe pour empêcher toute approche dangereuse des parties actives, et les enveloppes ont une forme qui leur permet d'être conformes au niveau d'isolement assigné (voir 5.3) du matériel lorsqu'elles sont remplies à une pression égale ou supérieure à la pression minimale fonctionnelle de gaz pour l'isolement (voir 5.11)) (des considérations d'ordre électrique plutôt que mécanique sont déterminantes pour le choix des formes et des matériaux utilisés);
– les enveloppes sont généralement remplies d'un gaz non corrosif, sec, stable et inerte. Le gaz doit rester dans cette condition (uniquement avec de faibles variations de pression) afin d'assurer le fonctionnement normal de l'installation. Cependant, puisque les enveloppes ne sont pas soumises à la corrosion interne, il n'est pas nécessaire de prévoir ces facteurs lors de la détermination de la conception des enveloppes (toutefois, il convient de tenir compte de l'effet de vibrations transmises potentielles).

Pour toute installation à l'extérieur, le constructeur doit tenir compte de l'influence des conditions climatiques (voir l'Article 4).

Dans le cas d'une installation enterrée, les conditions d'environnement doivent être prises en compte. En ce qui concerne la protection contre la corrosion externe, voir 6.21.

6.102.2 Conception des enveloppes

Les parois des enveloppes doivent avoir une épaisseur déterminée d'après la pression de calcul et d'après les durées minimales suivantes dans le cas d'un arc interne sans perforation:

– 0,1 s pour les courants de court-circuit de 40 kA et plus;
– 0,2 s pour les courants de court-circuit plus faibles.

Pour réduire le plus possible le risque de perforation, la valeur et la durée du courant de défaut ainsi que la conception de l'enveloppe et la taille des compartiments doivent être soigneusement coordonnées.

En l'absence d'un accord international sur la normalisation d'une procédure, les méthodes de calcul de l'épaisseur et la construction des enveloppes soudées ou moulées peuvent être choisies dans des codes reconnus de réservoirs à pression et de gazoducs, en prenant comme base la température et la pression de calcul définies par le présent document.

Lors de la conception d'une enveloppe, il convient également de tenir compte des données suivantes:

– la mise à vide éventuelle de l'enveloppe au cours des opérations normales de remplissage;
– la différence totale de pression possible, de part et d'autre des parois de l'enveloppe ou des cloisons;
– la pression entre compartiments résultant d'une éventuelle fuite anormale lorsque des compartiments adjacents remplis à des pressions de remplissage différentes;
– la possibilité d'apparition d'un défaut interne (voir 6.101).

La température de calcul de l'enveloppe est généralement la limite supérieure de la température de l'air ambiant, en tenant compte de l'augmentation de l'échauffement dû au passage du courant permanent assigné. Il convient de prendre en considération le rayonnement solaire en cas d'effet significatif de celui-ci.

La pression de calcul de l'enveloppe est au moins égale à la pression maximale atteinte à l'intérieur de l'enveloppe à la température de calcul.

Pour déterminer la pression de calcul de l'enveloppe, la température du gaz doit être considérée comme égale à la moyenne des températures maximales de l'enveloppe et du conducteur de circuit principal au courant assigné en service continu, à moins que la pression de calcul ne puisse être déduite des rapports d'essai d'échauffement existants.

Lors de la conception de l'enveloppe, les charges mécaniques autres que celles provoquées par la surpression interne doivent être prises en compte, comme les efforts dus à la dilatation thermique (voir 6.106) les vibrations externes (voir 6.107), les chargements du sol pour les installations enterrées, d'autres charges externes, tremblements de terre, vent, neige, glace, etc.

Si la résistance des enveloppes et parties d'enveloppes n'a pas été complètement déterminée par calcul, des épreuves (voir 7.101) doivent être réalisées pour prouver qu'elle satisfait aux exigences.

Les matériaux utilisés dans la construction des enveloppes doivent avoir des propriétés physiques minimales connues et certifiées, fondées sur les calculs et/ou les épreuves. Le constructeur doit être responsable du choix des matériaux et du respect de ces propriétés minimales, fondées sur les certificats de fournisseurs ou d'après des essais réalisés par lui-même, ou d'après les deux à la fois.

6.103 Cloisons et compartimentage

Les LIG doivent être divisées en compartiments en vue de satisfaire aux conditions normales de fonctionnement et d'obtenir une limitation des effets d'un arc à l'intérieur du compartiment (voir 6.101).

La manière dont la LIG est divisée en compartiments a une influence sur:

– l'installation;
– les essais sur site;

– la maintenance et la réparation;
– la manipulation du gaz.

Les cloisons sont généralement constituées par un matériau isolant mais ne sont pas destinées à assurer par elles-mêmes la sécurité électrique du personnel, sécurité pour laquelle d'autres moyens, tels que la mise à la terre du matériel, peuvent s’appliquer. Toutefois, les cloisons doivent assurer la sécurité mécanique vis-à-vis de la pression différentielle du gaz qui existe avec les compartiments voisins.

Une cloison séparant un compartiment rempli d'un gaz isolant d'un compartiment adjacent rempli de liquide ne doit pas comporter de fuite anormale, au niveau de la séparation, affectant les propriétés diélectriques des deux milieux.

Il convient de prendre en considération le compartimentage du système de LIG afin de satisfaire aux exigences de fonctionnement, de limitation de la partie de la LIG affectée par le défaut et de facilité de maintenance ou de réparations.

6.104 Tronçons d’un système de LIG

Le cloisonnement d’un système de LIG peut être réalisé à l’aide d’unités de séparation. La longueur de ces tronçons le long du système est déterminée en fonction de certaines exigences telles que l’accès et la longueur maximale pour les essais, l’évolution de l’installation dans le cas de projets longs, ou en fonction des conditions de fonctionnement et de maintenance.

6.105 Décharge de pression

6.105.1 Généralités

Les dispositifs de décharge de pression prévus conformément au 6.105 doivent être placés de façon à réduire le plus possible le danger pour les personnes pendant qu'elles effectuent les tâches normales d'exploitation sur la LIG si des gaz ou vapeurs s'échappent sous pression.

NOTE Le terme "dispositif de décharge de la pression" recouvre à la fois des soupapes de décharge caractérisées par une pression d’ouverture et une pression de fermeture, et des dispositifs de décharge sans refermeture, tels que des diaphragmes et des disques de rupture.

6.105.2 Limitation de la pression maximale de remplissage

Pour remplir un compartiment de gaz, un régulateur de pression doit être monté sur le tuyau de remplissage afin d'empêcher que la pression dépasse de plus de 10 % la pression de calcul. En variante, le régulateur peut être monté sur l'enveloppe elle-même.

Il convient de choisir la pression de remplissage en tenant compte de la température du gaz au moment du remplissage, par exemple en utilisant des manomètres avec compensation de température.

6.105.3 Dispositifs de décharge pour limiter l’élévation de pression en cas de défaut interne

Comme, après un arc dû à un défaut interne, les enveloppes endommagées sont remplacées, les dispositifs de décharge de pression ne doivent être prévus que pour limiter les effets externes de l'arc (voir 6.101.2).

Dans le cas d’un défaut interne, selon le volume du compartiment de gaz et la pression de remplissage, la valeur et la durée du courant de court-circuit ne dépassent pas la pression spécifiée pour l’essai individuel de série de l’enveloppe; si tel est le cas, un dispositif de décharge n’est pas obligatoire.

Si les dispositifs de décharge sont utilisés dans un espace confiné accessible au personnel, des précautions doivent être prises pour assurer la sécurité en cas de décharge (voir également l'Article 12).

Dans le cas d'un défaut interne provoquant la déformation plastique d'une enveloppe, il convient de vérifier l'absence de déformation sur les enveloppes voisines.

En cas d'emploi de disques de rupture pour la décharge de pression, il convient de porter une attention particulière à leur pression de rupture, comparée à la pression de calcul de l'enveloppe pour diminuer les risques de rupture intempestive des disques.

6.106 Compensation de la dilatation thermique

Du fait des différences de température entre les parties de la LIG, entre la LIG et son environnement, ou encore entre des parties de la LIG par rapport à leur température lors de la construction, des parties de l'installation LIG subissent des mouvements les unes par rapport aux autres, et par rapport à leur environnement.

Les mouvements relatifs ou les forces entre les parties de la LIG et/ou leur environnement peuvent être déterminés soit par des mesurages, soit par des calculs fondés sur la différence de température maximale de ces parties par rapport à leur température durant la construction. Lorsqu'une compensation s'avère nécessaire, les méthodes suivantes doivent être utilisées:

a) la compensation entre les parties conductrices et l'enveloppe doit être réalisée par des contacts glissants ou des moyens analogues;
b) la compensation entre l'enveloppe et l'environnement (charpente fixe, sol environnant) doit être réalisée par des moyens appropriés.

Il convient de faire référence à des normes ou méthodes appropriées pour le calcul des forces résultantes et des mouvements relatifs entre l'enveloppe et son environnement, ainsi que pour l'interprétation des résultats. Ceci est particulièrement important dans le cas de LIG enterrées, qui sont fortement affectées par des facteurs tels que les ancrages, le compactage et la nature du sol, la configuration géométrique de la ligne, etc.

6.107 Vibrations externes

Dans certaines conditions, la LIG peut être exposée à des vibrations externes. Une LIG fixée à un pont utilisé aussi bien par des piétons que par des automobiles ou des trains constitue un exemple type. Une LIG directement connectée à des transformateurs de puissance ou des bobines d'inductance est un autre exemple.

Lorsqu'une ligne de transport est fixée à une source de vibrations, il est conseillé de réduire les contraintes mécaniques par l'installation de dispositifs d'amortissement placés entre la source et les éléments de charpente fixés de manière rigide à la ligne de transport. Une telle disposition peut réduire de manière considérable les contraintes mécaniques dynamiques subies par la structure de la ligne de transport. Le niveau résiduel des contraintes dynamiques doit être pris en compte comme base pour le dimensionnement mécanique, en combinant les forces qui en résultent avec les autres charges mécaniques qui s'appliquent à la LIG pour déterminer les niveaux de contraintes résultants, et assurer que ces niveaux sont inférieurs aux niveaux admis dans les matériaux employés.

Dans le cas d'un pont, une attention particulière doit être portée aux mouvements relatifs entre le pont et son environnement. Ces mouvements peuvent produire des charges mécaniques supplémentaires qu'il est nécessaire de prendre en considération lors de la détermination des niveaux de contraintes résultants en vue du dimensionnement mécanique.

6.108 Charpentes pour les LIG non enterrées

6.108.1 Généralités

Les charpentes pour les LIG ont une influence sur le comportement mécanique des LIG. La construction de la charpente peut varier suivant sa fonction, la configuration de la LIG et les caractéristiques des fondations, du tunnel ou du puits destinés à recevoir la LIG. C'est pour cette raison que les paramètres de la conception et les exigences applicables à la charpente sont décrits en 6.108.

6.108.2 Paramètres de la conception

Il convient de prendre en considération les forces et charges suivantes pour la conception de la charpente:

– le poids de la LIG;
– les forces dues à la pression interne du gaz;
– la friction entre les surfaces du support et de la semelle de la LIG;
– les forces dues à la dilatation thermique de la LIG;
– la force sismique, le cas échéant;
– la force due au vent, le cas échéant;
– la force due au courant de court-circuit;
– la charge de glace, le cas échéant;
– les forces dues à d'autres impacts externes, tels que les vibrations;
– l'effort de traction de ligne sur la traversée gaz/air.

Lorsque la charpente ne fait pas partie intégrante du système de mise à la terre, des moyens doivent être fournis pour éliminer les courants de Foucault dans la charpente et permettre la protection contre la corrosion.

6.108.3 Types de charpentes

Les charpentes se répartissent en deux catégories de base:

a) les supports flexibles ou coulissants: ces charpentes sont conçues pour supporter et permettre un certain mouvement du fait de la dilatation thermique de la LIG;
b) les supports rigides: ces charpentes sont conçues pour bloquer la LIG et supporter les forces dues à la dilatation thermique de l'enveloppe et à la dilatation des compensateurs d'enveloppe, le cas échéant, ainsi que celles dues à la pression interne du gaz.

7 Essais de type

7.1 Généralités

Le paragraphe 7.1 de l'IEC 62271-1:2017 est applicable avec l'ajout suivant:

Les essais de type doivent être réalisés sur des ensembles ou sous-ensembles représentatifs.

Il n'est pas possible de soumettre toutes les dispositions prévues à des essais de type, compte tenu de la multiplicité des combinaisons possibles des matériels. Les caractéristiques d'une disposition donnée peuvent être déduites à partir des données d'essai obtenues avec des dispositions comparables. Tous les essais doivent être effectués sur le matériel rempli avec le type de gaz spécifié à la pression assignée de remplissage, sauf spécification contraire au paragraphe correspondant.

Les résultats de tous les essais de type doivent être enregistrés dans des rapports d'essais de type contenant assez de données pour prouver la conformité à cette spécification, et assez d'informations pour pouvoir identifier les parties essentielles du matériel en essai. Des informations générales sur les charpentes doivent être incluses dans les rapports d'essai.

Les essais et vérifications de type comprennent les essais énumérés en 7.1.101 et 7.1.102.

7.1.101 Essais de type obligatoires

Les essais de type obligatoires suivants doivent être réalisés:

	Paragraphe
a) Essais de vérification du niveau d'isolement du matériel, y compris les essais de décharges partielles et les essais diélectriques des circuits auxiliaires	7.2
b) Essais de vérification au courant permanent de toute partie du matériel et mesurage de la résistance du circuit principal	7.4 et 7.5
c) Essais de vérification de l'aptitude des circuits principaux et des circuits de mise à la terre à supporter la valeur de crête du courant admissible assigné et le courant de courte durée admissible assigné	7.6
d) Essais de vérification de protection des personnes contre le contact avec des parties actives des circuits auxiliaires	7.7
e) Essais de vérification de la résistance mécanique des enveloppes	7.101
f) Essai de vérification de la résistance mécanique des cloisons	7.102
g) Essais d'étanchéité au gaz	7.8

7.1.102 Essais de type spéciaux

Ils font l'objet d'un accord entre constructeur et utilisateur.

a) Essais anticorrosion (le cas échéant)	7.103
b) Essais mécaniques sur les contacts glissants	7.104
c) Essais de vérification de la protection du matériel contre les effets externes dus aux intempéries et aux agents atmosphériques	7.106
d) Essais pour évaluer les effets d'un arc dû à un défaut interne	7.105
e) Essai de longue durée pour évaluer le comportement des installations enterrées	Annexe C

NOTE Certains de ces essais de type peuvent compromettre l'aptitude des parties en essai à leur emploi ultérieur en service.

7.2 Essais diélectriques

7.2.1 Généralités

Le paragraphe 7.2.1 de l'IEC 62271-1:2017 n'est pas applicable.

7.2.2 Conditions de l'air ambiant pendant les essais

Le paragraphe 7.2.2 de l'IEC 62271-1:2017 n'est pas applicable.

7.2.3 Modalités des essais sous pluie

Le paragraphe 7.2.3 de l'IEC 62271-1:2017 n'est pas applicable.

7.2.4 Disposition du matériel

Le paragraphe 7.2.4 de l'IEC 62271-1:2017 n'est pas applicable et est remplacé comme suit:

Les essais diélectriques doivent être effectués à la pression minimale fonctionnelle du gaz isolant spécifiée par le constructeur. La température et la pression du gaz doivent être enregistrées durant les essais et indiquées dans le rapport d'essai.

7.2.5 Conditions de réussite des essais

Le paragraphe 7.2.5 de l'IEC 62271-1:2017 est applicable.

7.2.6 Application de la tension d'essai et conditions d'essai

Le paragraphe 7.2.6 de l'IEC 62271-1:2017 n'est pas applicable et est remplacé comme suit:

Les tensions d'essai spécifiées en 7.2.7 et 7.2.8 doivent être appliquées en connectant successivement chaque conducteur de phase du circuit principal à la borne à haute tension de la source d'essai. Tous les autres conducteurs du circuit principal et des circuits auxiliaires doivent être reliés au conducteur de terre, ou au châssis et à la borne de terre de la source d'essai.

Lorsque chaque phase est individuellement enfermée dans une enveloppe métallique, seuls les essais à la terre, et non les essais entre phases, sont effectués.

7.2.7 Essais de l'appareillage de U_r ≤ 245 kV

7.2.7.1 Généralités

Le paragraphe 7.2.7.1 de l'IEC 62271-203:2022 est applicable avec les ajouts suivants:

7.2.7.2 Essais de tension à fréquence industrielle

Le circuit principal de la LIG doit être soumis à des essais de tension de courte durée à fréquence industrielle, selon l'IEC 60060-1. La tension d'essai doit être élevée jusqu'à la valeur d'essai et maintenue pendant 1 min. L'essai doit être effectué à sec seulement.

7.2.7.3 Essais de tension de choc de foudre

Pendant les essais, la borne du générateur de choc, raccordée à la terre, doit être connectée à l'enveloppe de la LIG.

La longueur de l'objet en essai doit être prise en considération pour éviter les surtensions dues aux ondes mobiles.

7.2.8 Essais de l'appareillage de U_r > 245 kV

7.2.8.1 Généralités

Le paragraphe 7.2.8.1 de l'IEC 62271-203:2022 est applicable avec les ajouts suivants:

7.2.8.2 Essais de tension à fréquence industrielle

La LIG doit être soumise à des essais de tension de courte durée à fréquence industrielle, selon l'IEC 60060-1. La tension d'essai doit être élevée jusqu'à la valeur d'essai et maintenue pendant 1 min. L'essai doit être effectué à sec seulement.