IEC 62271-204 EXV

Edition 2.0 2022-09
EXTENDED VERSION

INTERNATIONAL STANDARD

colour inside

This extended version of IEC 62271-204:2022 includes the content of the references made to IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2022

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

IEC 62271-204:2022-09 EXV(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 1: Common specifications for alternating current switchgear and controlgear

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 17: High-voltage switchgear and controlgear.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
17/1090/DISH	17/1095/RVDISH

Full information on the voting for the approval of this interpretation sheet can be found in the report on voting indicated in the above table.

Interpretation of 4.2.2 of IEC 62271-1:2017 regarding the altitude correction factor

Subclause 4.2.2 of IEC 62271-1:2017 contains two references for calculation of the required insulation withstand level at altitudes higher than 1 000 m, IEC 60071-2:1996 and IEC TR 62271-306. The two references are in conflict, as the altitude correction factor according to IEC 60071-2:1996 starts at sea level and that of IEC TR 62271-306 starts at an altitude of 1 000 m. This results in different altitude correction factors.

As already stated in 5.3 of IEC 62271-1:2017, the rated insulation levels refer to normal service conditions. Altitudes up to 1 000 m above sea level are covered and need no altitude correction.

For altitudes higher than 1 000 m the equation provided in 4.5.1.1 b) of IEC TR 62271-306:2012 and in H.3.4 of IEC 60071-2:2018 shall be used, i.e.

$$k_{\text{alt}} = e^{m\left(\frac{H-1\,000}{8\,150}\right)}$$

ICS 29.130.10; 29.130.99

IEC 62271-1:2017-07/ISH1:2021-05(en-fr)

where

k_{alt} is the altitude correction factor;

H is the altitude in m above sea level;

m is an exponent.

Conservative values for the exponent m are provided in Table 4 of IEC TR 62271-306:2012. For further details about the exponent m, see H.4 of IEC 60071-2:2018.

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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

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This extended version (EXV) of the official IEC Standard provides the user with a comprehensive content of the Standard.

IEC 62271-204:2022 EXV includes the content of the references made to IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2022.

Particular subclauses of IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2022 are displayed in the content on a blue background.

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 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 60038:2009, *IEC standard voltages*

IEC 60050-131:2002, *International Electrotechnical Vocabulary (IEV) – Part 131: Circuit theory*

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-192:2015, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability*

IEC 60050-351, *International Electrotechnical Vocabulary (IEV) – Part 351: Control technology*

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60050-551, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*

IEC 60050-581:2008, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60050-601, *International Electrotechnical Vocabulary (IEV) – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60050-605, *International Electrotechnical Vocabulary (IEV) – Chapter 605: Generation, transmission and distribution of electricity – Substations*

IEC 60050-614:2016, *International Electrotechnical Vocabulary (IEV) – Part 614: Generation, transmission and distribution of electricity – Operation*

IEC 60050-811, *International Electrotechnical Vocabulary (IEV) – Part 811: Electric traction*

IEC 60050-826:2004, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

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 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*
IEC 60071-1:2006/AMD1:2010

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

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

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

IEC 60255-21-1:1988, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section One: Vibration tests (sinusoidal)*

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

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

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

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 60507, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems*

IEC 60512-2-2, *Connectors for electronic equipment – Tests and measurements – Part 2-2: Electrical continuity and contact resistance tests – Test 2b: Contact resistance – Specified test current method*

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

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

IEC TS 60815-2:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC TS 60815-3:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-17:2009, *Electromagnetic compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-4-29, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61180, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

IEC 61810-7:2006, *Electromechanical elementary relays – Part 7: Test and measurement procedures*

IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

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*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR TR 18-2, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

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 60050-131, IEC 60050-151, IEC 60050-192, IEC 60050-351, IEC 60050-441, IEC 60050-551, IEC 60050-581, IEC 60050-601, IEC 60050-605, IEC 60050-614, IEC 60050-811 and IEC 60050-826, some of which are recalled hereunder, 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

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

3.1 General terms and definitions

3.1.1
switchgear and controlgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:2000, 441-11-01]

3.1.2
external insulation
distances in atmospheric air and along the surfaces in contact with atmospheric air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other environmental conditions from the site

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

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

3.1.3
degree of protection
extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and against mechanical impact

[SOURCE: IEC 60529:1989, 3.3, modified – leave out “verified by standardized test methods” and add “against mechanical impact” after "water and".]

3.1.4
IP code
coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection

[SOURCE: IEC 60529:1989, 3.4]

3.1.5
protection provided by an enclosure against access to hazardous parts
protection of persons against

– contact with hazardous low-voltage live parts;
– contact with hazardous mechanical parts;
– approach to hazardous high-voltage live parts below adequate clearance inside an enclosure

Note 1 to entry: This protection may be provided:

– by means of the enclosure itself;
– by means of barriers as part of the enclosure or distances inside the enclosure.

[SOURCE: IEC 60529:1989, 3.6]

3.1.6
IK code
coding system to indicate the degree of protection provided by an enclosure against harmful external mechanical impacts

[SOURCE: IEC 62262:2002, 3.3]

3.1.7
maintenance
combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required

Note 1 to entry: Management is assumed to include supervision activities.

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.1.8
visual inspection
visual investigation of the principal features of the switchgear and controlgear

Note 1 to entry: This inspection is generally directed toward pressures and/or levels of fluids, tightness, position of relays, pollution of insulating parts, but actions such as lubricating, cleaning, washing, etc. which can be carried out with the switchgear and controlgear in service are also included.

Note 2 to entry: Observations resulting from inspection can lead to the decision to carry out overhaul.

Note 3 to entry: This inspection can be used for determining the state of tested objects on e.g. cracks in solid insulators.

3.1.9
diagnostic test
comparative test of the characteristic parameters of switchgear and controlgear to verify that it performs its functions, by measuring one or more of these parameters

Note 1 to entry: The result from a diagnostic test can lead to the decision to carry out overhaul.

3.1.10
overhaul
work performed with the objective of repairing or replacing parts which are found to be out of tolerance by inspection, diagnostic test, examination or as required by manufacturer's maintenance manual, in order to restore the component and/or the switchgear and controlgear to an acceptable condition (within tolerance)

3.1.11
failure
loss of ability to perform as required

Note 1 to entry: A failure of an item is an event that results in a fault of that item: see fault (IEC 60050-192:2015, 192-04-01).

Note 2 to entry: Qualifiers, such as catastrophic, critical, major, minor, marginal and insignificant, can be used to categorize failures according to the severity of consequences, the choice and definitions of severity criteria depending upon the field of application.

Note 3 to entry: Qualifiers, such as misuse, mishandling and weakness, may be used to categorize failures according to the cause of failure.

[SOURCE: IEC 60050-192:2015, 192-03-01]

3.1.12
major failure (of switchgear and controlgear)
failure of switchgear and controlgear which causes the cessation of one or more of its fundamental functions

Note 1 to entry: A major failure may result in an immediate change in the system operating conditions, for example, the backup protective equipment will be required to remove the fault or will result in mandatory removal from service within 30 min for unscheduled maintenance.

3.1.13
minor failure (of switchgear and controlgear)
any failure of a constructional element or a subassembly which does not cause a major failure of the switchgear and controlgear

3.1.14
defect
imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time

3.1.15
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

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

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.1.16
monitoring
observation of the operation of a system or part of a system to verify correct functioning by detecting incorrect functioning, this being done by measuring one or more variables of the system and comparing the measured values with the specified values

Note 1 to entry: Some definitions are given for this term in IEC 60050 (all parts). They are related to different cases of application.

3.1.17
supervision
activity, performed either manually or automatically, intended to observe the state of an item

Note 1 to entry Automatic supervision may be performed internally or externally to the item.

3.1.18
site pollution severity class
SPS
classification of pollution severity at a site, from very light to very heavy, as a function of the SPS (site pollution severity)

Note 1 to entry: Adapted from: IEC TS 60815-1:2008, 3.1.15, modified – the term (site pollution severity) is added.

3.1.19
internal insulation
internal distances of the solid, liquid or gaseous parts of the insulation of equipment which are protected from the effects of atmospheric and other external conditions

[SOURCE: IEC 60050-614:2016, 614-03-03, modified – addition of "parts of".]

3.1.20
non-sustained disruptive discharge
NSDD
disruptive discharge associated with current interruption that does not result in the resumption of power frequency current or, in the case of capacitive current interruption, does not result in current in the main load circuit

3.2 Assemblies of switchgear and controlgear

3.2.1
test object
equipment needed to represent the switchgear and controlgear for a particular type test

3.3 Parts of assemblies

3.3.1
transport unit
part of switchgear and controlgear intended for transportation without being dismantled

3.3.2
busbar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: In many cases, the busbar consists of a bar.

[SOURCE: IEC 60050-151:2001, 151-12-30]

3.4 Switching devices

3.4.1
(mechanical) switch
mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions which may include specified operating overload conditions and also carrying for a specified time currents under specified abnormal circuit conditions such as those of short-circuit

Note 1 to entry: A switch may be capable of making but not breaking short-circuit currents.

[SOURCE: IEC 60050-441:2000, 441-14-10]

3.4.2
disconnector
mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying currents for a specified time under abnormal conditions such as those of short-circuit.

[SOURCE: IEC 60050-441:2000, 441-14-05]

3.5 Parts of switchgear and controlgear

3.5.1
enclosure
housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: Enclosures provide protection of persons or livestock against access to hazardous parts.
Barriers, shapes of openings or any other means (whether attached to the enclosure or formed by the enclosed equipment) suitable to prevent or limit the penetration of the specified test probes, are considered as a part of the enclosure, when they are secured in position either by means of interlocks, keys, or by hardware requiring a tool to be removed.

[SOURCE: IEC 60050-826:2004, 826-12-20, modified – the Note 1 to entry has been added]

3.5.2
hazardous part
part that is hazardous to approach or touch

[SOURCE: IEC 60529:1989, 3.5]

3.5.3
contact (of a mechanical switching device)
conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:2000, 441-15-05]

3.5.4
auxiliary circuit (of a switching device)
all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit, the earthing circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:2000, 441-15-04, modified – "earthing circuit" has been added]

3.5.5
control circuit (of a switching device)
all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.6
auxiliary switch (of a mechanical switching device)
switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:2000, 441-15-11]

3.5.7
control switch (for control and auxiliary circuits)
mechanical switching device which serves the purpose of controlling the operation of switchgear or controlgear, including signalling, electrical interlocking, etc.

Note 1 to entry: A control switch consists of one or more contact elements with a common actuating system.

[SOURCE: IEC 60050-441:2000, 441-14-46]

3.5.8
auxiliary contact
contact included in an auxiliary circuit and operated by the switching device

[SOURCE: IEC 60050-441:2000, 441-15-10, modified – delete "mechanically"]

3.5.9
control contact
contact included in a control circuit of a switching device and operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09, modified – delete "mechanical" and "mechanically"]

3.5.10
connection (bolted or the equivalent)
two or more conductors designed to ensure permanent circuit continuity when forced together by means of screws, bolts or the equivalent

3.5.11
position indicating device
part of a mechanical switching device which indicates whether it is in the open, closed, or where appropriate, earthed position

[SOURCE: IEC 60050-441:2000, 441-15-25]

3.5.12
monitoring device
device intended to observe automatically the status of an item

3.5.13
pilot switch
non-manual control switch actuated in response to specified condition of an actuating quantity

Note 1 to entry: The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

[SOURCE: IEC 60050-441:2000, 441-14-48]

3.5.14
partition (of an assembly)
part of an assembly separating one compartment from other compartments

[SOURCE: IEC 60050-441:2000, 441-13-06]

3.5.15
actuator
part of the actuating system to which an external actuating force is applied

Note 1 to entry: The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

[SOURCE: IEC 60050-441:2000, 441-15-22]

3.5.16
splice
connecting device with barrel(s) accommodating electrical conductor(s) with or without additional provision to accommodate and secure the insulation

[SOURCE: IEC 60050-581:2008, 581-24-19, modified – addition of "electrical".]

3.5.17
terminal
point of interconnection of an electric circuit element, an electric circuit or a network with other electric circuit elements, electric circuits or networks

Note 1 to entry: For an electric circuit element, the terminals are the points at which or between which the related integral quantities are defined. At each terminal, there is only one electric current from outside into the element.

Note 2 to entry: The term “terminal” has a related meaning in IEC 60050-151.

[SOURCE: IEC 60050-131:2002, 131-11-11]

3.5.18
terminal block
assembly of terminals in a housing or body of insulating material to facilitate interconnection between multiple conductors

[SOURCE: IEC 60050-581:2008, 581-26-26]

3.5.19
contactor
mechanical contactor
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:2000, 441-14-33]

3.5.20
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

Note 1 to entry: Starters may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:2000, 441-14-38]

3.5.21
vacuum interrupter
component being part of a switching device in which electrical contacts operate in a highly evacuated, hermetically sealed environment

3.5.22
operation counter
device indicating the number of operating cycles a mechanical switching device has accomplished

3.5.23
coil
set of series-connected turns, usually coaxial

[SOURCE: IEC 60050-151:2001, 151-13-15]

3.5.24
auxiliary and control circuits
entity of

– control and auxiliary circuits, mounted on or adjacent to the switchgear or controlgear, including circuits in central control cubicles;
– equipment for monitoring, diagnostics, etc. that is part of the auxiliary circuits of the switchgear or controlgear;
– circuits connected to the secondary terminals of instrument transformers, that are part of the switchgear or controlgear

3.5.25
subassembly (of auxiliary and control circuits)
part of auxiliary and control circuits, with regard to function or position, having its own interface and normally placed in a separate enclosure

3.5.26
interchangeable subassembly (of an auxiliary and control circuits)
subassembly which is intended to be placed in various positions within an auxiliary and control circuits, or intended to be replaced by other similar subassemblies

Note 1 to entry: An interchangeable subassembly has an accessible interface.

3.5.27
interlocking device
device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.6 Operational characteristics of switchgear and controlgear

3.6.1
dependent power operation (of a mechanical switching device)
operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors, etc.)

[SOURCE: IEC 60050-441:2000, 441-16-14]

3.6.2
stored energy operation (of a mechanical switching device)
operation by means of energy stored in the drive mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions

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

– the manner of storing the energy (spring, weight, etc.);
– the origin of the energy (manual, electric, etc.);
– the manner of releasing the energy (manual, electric, etc.).

[SOURCE: IEC 60050-441:2000, 441-16-15, modified – addition of "drive".]

3.6.3
independent unlatched operation
stored energy operation where energy is stored and released in one continuous operation such that the speed and force of the operation are independent of the rate of applied energy

Note 1 to entry: The energy stored for the operation may originate from the operator (manual) or a power source.

3.6.4
positively driven operation
operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts

Note 1 to entry: A positively driven operating device is made by the association of a moving part, linked mechanically to the main contact of the primary circuit, without the use of springs, and a sensing element. In the case of mechanical auxiliary contacts, this sensing element can be simply the fixed contact, directly connected to the secondary terminal. In the case where the function is achieved electronically, the sensing element can be a static transducer (optical, magnetic, etc.) associated with a static switch, or associated with an electronic or electro-optic transmitting element.

[SOURCE: IEC 60050-441:2000, 441-16-12, modified – the Note 1 to entry has been added]

3.6.5 Terms and definitions relative to pressure (or density)

3.6.5.1
filling pressure p_{re} for insulation and/or switching
filling density ρ_{re} for insulation and/or switching
pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

3.6.5.2
filling pressure p_{rm} for operation
filling density ρ_{rm} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the energy storage device is filled before being put into service or automatically replenished

3.6.5.3
alarm pressure p_{ae} for insulation and/or switching
alarm density ρ_{ae} for insulation and/or switching
pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided

3.6.5.4
alarm pressure p_{am} for operation
alarm density ρ_{am} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal from the energy storage device may be provided

3.6.5.5
minimum functional pressure p_{me} for insulation and/or switching
minimum functional density ρ_{me} for insulation and/or switching
pressure (in Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained

3.6.5.6
minimum functional pressure p_{mm} for operation
minimum functional density ρ_{mm} for operation
pressure (in Pa), for operation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment of the energy storage device becomes necessary

Note 1 to entry: This pressure is often designated as interlocking or lockout pressure.

3.6.6 Terms and definitions relating to gas and vacuum tightness

3.6.6.1
controlled pressure system for gas
volume which is automatically replenished from an external compressed gas supply or internal gas source

Note 1 to entry: Examples of controlled pressure systems are air-blast circuit-breakers or pneumatic drive mechanisms.

Note 2 to entry: A volume may consist of several permanently connected gas-filled compartments.

3.6.6.2
closed pressure system for gas
volume which is replenished when needed by manual connection to an external gas source

Note 1 to entry: Example of closed pressure systems are SF_6 single-pressure circuit-breakers.

3.6.6.3
sealed pressure system
volume for which no further liquid, gas or vacuum processing is required during its expected operating duration

Note 1 to entry: Examples of sealed pressure systems are vacuum interrupters or some SF_6 circuit-breakers.

Note 2 to entry: Sealed pressure systems are completely assembled and tested in the factory.

Note 3 to entry: Expected operating duration starts when the device is sealed.

3.6.6.4
absolute leakage rate
F
amount of gas escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in Pa $\times$ m^3 x s^{-1}.

3.6.6.5
permissible leakage rate
F_p
maximum permissible absolute leakage rate of gas specified for a part, a component or a sub-assembly, or by using the tightness coordination chart, for an arrangement of parts, components or subassemblies connected together in one pressure system

3.6.6.6
relative leakage rate
F_{rel}
absolute leakage rate related to the total amount of gas in the system at filling pressure (or density)

Note 1 to entry: The relative leakage rate is expressed in percentage per year or per day.

3.6.6.7
time between replenishments
t_r
time elapsed between two replenishments performed manually when the pressure (density) reaches the alarm level, to compensate the leakage rate F

Note 1 to entry: This value is applicable to closed pressure systems.

3.6.6.8
number of replenishments per day
N
number of replenishments to compensate the leakage rate F

Note 1 to entry: This value is applicable to controlled pressure systems.

3.6.6.9
pressure drop
Δp
drop of pressure in a given time caused by the leakage rate F, without replenishment

3.6.6.10
tightness coordination chart
survey document supplied by the manufacturer, used when testing parts, components or sub-assemblies, to demonstrate the relationship between the tightness of a complete system and that of the parts, components and/or sub-assemblies

3.6.6.11
sniffing
action of slowly moving a leak meter sensing probe around an assembly to locate a gas leak

3.6.6.12
cumulative leakage measurement
measurement which takes into account all the leaks from a given assembly to determine the leakage rate

3.6.7 Terms and definitions relating to liquid tightness

3.6.7.1
absolute leakage rate
F_{liq}
amount of liquid escaped by time unit

Note 1 to entry: The absolute leakage rate is usually expressed in $cm^3 \times s^{-1}$.

3.6.7.2
permissible leakage rate
$F_{\mathrm{p(liq)}}$
maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

3.6.7.3
number of replenishments per day
N_{liq}
number of replenishments to compensate the leakage rate F_{liq}

3.6.7.4
pressure drop
Δp_{liq}
drop in pressure in a given time caused by the leakage rate F_{liq} without replenishment

3.7 Characteristic quantities

3.7.1
isolating distance (of a pole of a mechanical switching device)
clearance between open contacts meeting the withstand voltage requirements specified for disconnectors

[SOURCE: IEC 60050-441:2000, 441-17-35, modified – "safety" replaced by "withstand voltage".]

3.7.2
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.7.3
highest voltage for equipment
U_{m}
greatest value of phase-to-phase voltage (RMS value) for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards

Note 1 to entry: Under normal service conditions specified by the relevant apparatus committee this voltage can be applied continuously to the equipment.

[SOURCE: IEC 60050-614: 2016, 614-03-01, modified – The note to entry was added]

3.7.4
supply voltage (of auxiliary and control circuits)
RMS value or, if applicable, the DC value, of the voltage existing at a given instant at a point of supply, measured over a given time interval

Note 1 to entry: If a supply voltage is specified for instance in the supply contract, then it is called "declared supply voltage".

Note 2 to entry: The supply voltage of auxiliary and control circuits is measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

[SOURCE: IEC 60050-614: 2016, 614-01-03, modified – add Note 2 to entry]

3.8 Index of definitions

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

Unless otherwise specified, high-voltage switchgear and controlgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal service conditions listed in 4.1.

Operation under normal service conditions is considered to be covered by the type tests according to this document and relevant product standard.

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

The normal service conditions for indoor switchgear and controlgear are:

a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h does not exceed 35 °C. The ambient air temperature does not drop below –5 °C;

b) there is no influence from solar radiation;

c) the altitude does not exceed 1 000 m;

d) the ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt and would be considered as having site pollution severity class (SPS) “very light” according to IEC TS 60815-1:2008;

e) the conditions of humidity are as follows:

   – the average value of the relative humidity, measured over a period of 24 h, does not exceed 95 %;

   – the average value of the water vapour pressure, over a period of 24 h, does not exceed 2,2 kPa;

   – the average value of the relative humidity, over a period of one month, does not exceed 90 %;

   – the average value of the water vapour pressure, over a period of one month, does not exceed 1,8 kPa.

   NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

   NOTE 2 High humidity can also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

f) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.1.3 Outdoor switchgear and controlgear

The normal service conditions for outdoor switchgear and controlgear are:

a) the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h does not exceed 35 °C;

   the ambient air temperature does not drop below -25 °C;

   NOTE 1 Rapid temperature changes can occur, for example a hot sunny day followed by a sudden rain.

b) solar radiation does not exceed a level of 1 000 W/m^2;

   NOTE 2 Details of global solar radiation are given in IEC 60721-2-4 [6].

c) the altitude does not exceed 1 000 m;

d) the ambient air may be polluted by dust, smoke, corrosive gas, vapours or salt, the pollution does not exceed site pollution severity class (SPS) “medium” as defined by IEC TS 60815-1:2008;

e) ice coating does not exceed 20 mm;

f) the wind speed does not exceed 34 m/s;

NOTE 3 Characteristics of wind are defined in IEC 60721-2-2 [8].

g) the average humidity values given in 4.1.2 e) may be exceeded. Condensation or precipitation may occur;

NOTE 4 Characteristics of precipitation are defined in IEC 60721-2-2 [8].

NOTE 5 The conditions of humidity are always the effect of a combination of relative humidity with other environmental parameters, primarily temperature and rapid change of temperature.

h) vibrations due to causes external to the switchgear and controlgear or earth tremors do not exceed the impact of vibrations caused by operation of the switchgear itself.

4.2 Special service conditions

4.2.1 General

When high-voltage switchgear and controlgear is expected to be used under conditions different from the normal service conditions given in 4.1, the user's requirements should refer to standardized steps in 4.2.2 up to 4.2.7 if not provided by product standards.

NOTE 1 Appropriate actions are also taken to ensure proper operation under such conditions of other components, such as relays.

NOTE 2 Detailed information concerning classification of environmental conditions is given in IEC 60721-3-3 [9] (indoor) and IEC 60721-3-4 [10] (outdoor).

4.2.2 Altitude

For installations at an altitude higher than 1 000 m, the required insulation withstand level of external insulation at the service location shall be determined according to Clause 4 of IEC 60071-2:1996. The rated insulation level of the switchgear and controlgear should be equal to or higher than this value, reference is made to IEC TR 62271-306 [4].

NOTE 1 For internal insulation, the dielectric characteristics are identical at any altitude and no special precautions need to be taken. For external and internal insulation, refer to IEC 60071-2:1996.

NOTE 2 For low-voltage auxiliary and control equipment, no special precautions need to be taken if the altitude is lower than 2 000 m. For higher altitudes, refer to IEC 60664-1 [11].

4.2.3 Exposure to pollution

For outdoor application ambient air that may be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds severity class (SPS) “medium” as defined by IEC TS 60815-1:2008 should be classified as “heavy” or “very heavy” as defined by IEC TS 60815-1:2008.

For indoor application, ambient air that may be polluted by dust, smoke, corrosive gas, vapours or salt at a level that exceeds severity class (SPS) “very light” as defined by IEC TS 60815-1:2008 should be classified as “light”, “medium”, “heavy” or “very heavy” as defined by IEC TS 60815-1:2008.

NOTE More information about exposure to pollution can be found in Annex K (informative).

For indoor application up to and including 52 kV, IEC TS 62271-304 [12] can be specified, in particular if there are concerns regarding pollution of the switchgear insulation.

4.2.4 Temperature and humidity

For installation at a location where the ambient temperature can be different from the normal service condition ranges stated in 4.1, the ranges of minimum and maximum temperature to be specified should be:

a) -50 °C to 40 °C for extremely cold climates;

b) -40 °C to 40 °C for very cold climates;

c) -30 °C to 40 °C for cold climates;

d) -25 °C to 40 °C for cold climates (indoor conditions);

e) -15 °C to 40 °C for moderate climates (indoor conditions);

f) -5 °C to 55 °C for very hot climates.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be up to 98 %.

NOTE In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature and/or atmospheric pressure can occur.

4.2.5 Exposure to abnormal vibrations, shock or tilting

Standard switchgear and controlgear is designed for mounting on substantially level structures, free from excessive vibration, shock, or tilting. Where any of these standard conditions may not exist, the requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level according to a relevant publication or specification (e.g. IEC TR 62271-300 [13], IEC 62271-207 [14] and IEC TS 62271-210 [15]) should be specified by the user. In case of earthquake risk, the user should specify the operational requirements and admissible damage level.

Installations with other unusual forms of vibration shall be identified, such as installations in close proximity to mine blasting or mobile applications.

NOTE Other relevant publications for seismic evaluations are IEEE Standard 693 [16] and IEEE Standard C37.81 [17].

4.2.6 Wind speed

If the wind speed is expected to be in excess of the normal service wind speed of 34 m/s, the user should specify the requirements for a particular application.

4.2.7 Other parameters

When special environmental conditions prevail at the location where switchgear and controlgear is to be placed in service, they should be specified by the user by reference to IEC 60721-1 [18], IEC 60721-2 (all parts) [19] and IEC 60721-3 (all parts) [20].

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

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)

5.2.1 General

The rated voltage (U_r), as used in this document, is the phase-to-phase RMS voltage equal to the maximum system voltage for which the equipment is designed. It indicates the maximum value of the "highest system voltage" of networks for which the equipment may be used (see 3.7.3, highest voltage for equipment U_m). The rated voltages are given in 5.2.2 and 5.2.3 below.

NOTE The term "rated maximum voltage" used in most IEEE switchgear standards has the same meaning as the term "rated voltage" as used in this document.

5.2.2 Range *I* for rated voltages of 245 kV and below

Series I: 3,6 kV – 7,2 kV – 12 kV – 17,5 kV – 24 kV – 36 kV – 40,5 kV – 52 kV – 72,5 kV – 100 kV – 123 kV – 145 kV – 170 kV – 245 kV.

Series II (Voltages based on the current practice in some countries, e.g. US):

4,76 kV – 8,25 kV– 15 kV (see Note 1) – 15,5 kV– 25,8 kV (see Note 2) – 27 kV – 38 kV – 48,3 kV – 72,5 kV – 123 kV–145 kV – 170 kV – 245 kV.

NOTE 1 The 15 kV rating is used in US and some other countries. It has historically been associated with metal-clad and metal-enclosed switchgear used for applications that are primarily indoors and/or outdoors where the insulation level is less than that required for outdoor overhead applications. For applications other than metal-clad or metal-enclosed switchgear, the 15,5 kV rating is preferred.

NOTE 2 The 25,8 kV, still used in IEEE C37.04 [21] as a circuit breaker rating and in some other countries, has been replaced by the 27 kV rating in most relevant equipment standards. For new applications and designs, the 27 kV rating is preferred.

5.2.3 Range *II* for rated voltages above 245 kV

300 kV – 362 kV – 420 kV – 550 kV – 800 kV – 1 100 kV – 1 200 kV.

5.3 Rated insulation level (U_d, U_p, U_s)

The rated insulation level of switchgear and controlgear shall be selected from the values given in Table 1, Table 2, Table 3 and Table 4.

Withstand values given in Table 1, Table 2, Table 3 and Table 4 cover the application of switchgear and controlgear under normal service conditions defined in 4.1 including altitudes from sea level up to 1 000 m. However for testing purposes to verify a rating or capability, they shall be considered as insulation values at the standardized reference atmosphere temperature (20 °C), pressure (101,3 kPa) and humidity (11 g/m^3) specified in IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010. For special service conditions, refer to IEC TR 62271-306 [4].

NOTE According to IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 the insulation levels in Table 1 to Table 4 cover the temperature range of -40 °C up to 40 °C.

The rated withstand voltage values for lightning impulse voltage (U_p), switching impulse voltage (U_s) (when applicable), and rated short-duration power-frequency voltage (U_d) shall be selected without crossing the horizontal marked lines in Table 1, Table 2, Table 3, and Table 4.

The "common values" used in Table 1 and Table 2 apply to phase-to-earth, between phases and across the open switching device, if not otherwise specified in this document. The withstand voltage values "across the isolating distance" apply to the switching devices where the clearance between open contacts is designed to meet the dielectric requirements specified for disconnectors.

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.

Table 1 – Rated insulation levels for rated voltages of range *I*, series *I*

<table>
<tr><th rowspan="2">Rated voltage
U_r
kV (RMS value)</th><th colspan="2">Rated short-duration power-frequency withstand voltage
U_d
kV (RMS value)</th><th colspan="2">Rated lightning impulse withstand voltage
U_p
kV (peak value)</th></tr>
<tr><th>Common value</th><th>Across the isolating distance</th><th>Common value</th><th>Across the isolating distance</th></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td></tr>
<tr><td rowspan="2">3,6</td><td rowspan="2">10</td><td rowspan="2">12</td><td>20</td><td>23</td></tr>
<tr><td>40</td><td>46</td></tr>
<tr><td rowspan="2">7,2</td><td rowspan="2">20</td><td rowspan="2">23</td><td>40</td><td>46</td></tr>
<tr><td>60</td><td>70</td></tr>
<tr><td rowspan="2">12</td><td rowspan="2">28</td><td rowspan="2">32</td><td>60</td><td>70</td></tr>
<tr><td>75</td><td>85</td></tr>
<tr><td rowspan="2">17,5</td><td rowspan="2">38</td><td rowspan="2">45</td><td>75</td><td>85</td></tr>
<tr><td>95</td><td>110</td></tr>
<tr><td rowspan="2">24</td><td rowspan="2">50</td><td rowspan="2">60</td><td>95</td><td>110</td></tr>
<tr><td>125</td><td>145</td></tr>
<tr><td rowspan="2">36</td><td rowspan="2">70</td><td rowspan="2">80</td><td>145</td><td>165</td></tr>
<tr><td>170</td><td>195</td></tr>
<tr><td>40,5 (NOTE)</td><td>80</td><td>90</td><td>185</td><td>215</td></tr>
<tr><td>52</td><td>95</td><td>110</td><td>250</td><td>290</td></tr>
<tr><td>72,5</td><td>140</td><td>160</td><td>325</td><td>375</td></tr>
<tr><td rowspan="2">100</td><td>150</td><td>175</td><td>380</td><td>440</td></tr>
<tr><td>185</td><td>210</td><td>450</td><td>520</td></tr>
<tr><td rowspan="2">123</td><td>185</td><td>210</td><td>450</td><td>520</td></tr>
<tr><td>230</td><td>265</td><td>550</td><td>630</td></tr>
<tr><td rowspan="2">145</td><td>230</td><td>265</td><td>550</td><td>630</td></tr>
<tr><td>275</td><td>315</td><td>650</td><td>750</td></tr>
<tr><td rowspan="2">170</td><td>275</td><td>315</td><td>650</td><td>750</td></tr>
<tr><td>325</td><td>375</td><td>750</td><td>860</td></tr>
<tr><td rowspan="3">245</td><td>360</td><td>415</td><td>850</td><td>950</td></tr>
<tr><td>395</td><td>460</td><td>950</td><td>1 050</td></tr>
<tr><td>460</td><td>530</td><td>1 050</td><td>1 200</td></tr>
<tr><td colspan="5">NOTE The rated voltage of 40,5 kV is recognized in IEC 60038:2009 with a note that unification with the rated voltage of 36 kV is under consideration. Present values are adopted from IEC 60071-1:2006, Annex B.</td></tr>
</table>

Table 2 – Rated insulation levels for rated voltages of range *I*, series *II* (based on current practice in some countries, including US)

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across the isolating distance	Common value	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
4,76	19	21	60	66
8,25	36	40	95	105
15 (NOTE)	36	40	95	105
15,5	36	40	95	105
	50	55	110	121
25,8 (NOTE)	60	66	125	138
			150	165
27	60	66	125	138
	70	77	150	165
38	70	77	150	165
	80	88	170	187
	95	105	200	220
48,3	105	115	250	275
	120	132	250	275
72,5	160	--	350	385
	175	193	350	385
123	260	286	550	--
	280	308	550	605
145	310	--	650	--
	335	369	650	715
170	365	--	750	--
	385	424	750	825
245	425	--	900	--
	465	512	900	990
NOTE For 15 kV and 25,8 kV ratings, see NOTE 1 and NOTE 2 in 5.2.2.				

Table 3 – Rated insulation levels for rated voltages of range *II*

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases (NOTE 2)	Across open switching device and/or isolating distance (NOTE 2)	Phase-to-earth and across open switching device (NOTE 2)	Between phases (NOTES 2 and 3)	Across isolating distance (NOTES 1 and 2)	Phase-to-earth and between phases (NOTE 2)	Across open switching device and/or isolating distance (NOTES 1 and 2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	395	435	750	1 125	700(+245)	950	950(+170)
			850	1 275		1 050	1 050(+170)
362	450	520	850	1 275	800(+295)	1 050	1 050(+205)
			950	1 425		1 175	1 175(+205)
420	520	610	950	1 425	900(+345)	1 300	1 300(+240)
			1 050	1 575		1 425	1 425(+240)
550	620	800	1 050	1 680	900(+450)	1 425	1 425(+315)
			1 175	1 760		1 550	1 550(+315)
800	830	1 150	1 425	2 420	1 175(+650)	2 100	2 100(+455)
			1 550	2 480			
1 100	1 100	1 100	1 550	2 635	1 550 + (900)	2 250	2 250 + (630)
		1 100 + (635)	1 800	2 880	1 675 + (900)	2 400	2 400 + (630)
1 200	1 200	1 200	1 800	2 970	1 675 + (980)	2 400	2 400 + (685)
		1 200 + (695)	1 950	3 120		2 550	2 550 + (685)

NOTE 1 In column (6), values in brackets are the peak values $U_r \times \sqrt{2}/\sqrt{3}$ of the power-frequency voltage applied to the opposite terminal (combined voltage).

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

NOTE 2 Values of column (2) are applicable:

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

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

The values of columns (3),(4), (5), (6), (7) and (8) are applicable for type tests only.

NOTE 3 These values are derived using the multiplying factors given in Table 3 of IEC 60071-1:2006/AMD1:2010.

Table 4 – Additional rated insulation levels for range II, based on current practice in some countries, including US

Rated voltage U_r kV (RMS value)	Rated short-duration power-frequency withstand voltage U_d kV (RMS value)		Rated switching impulse withstand voltage U_s kV (peak value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth and between phases (NOTE)	Across open switching device and/or isolating distance (NOTE)	Phase-to-earth switching device closed (NOTE)	Terminal to terminal, switching device open (NOTE)	Phase-to-earth and between phases (NOTE)	Across open switching device and/or isolating distance (NOTE)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
362	555	555	825	900	1 300	1 300
362	610	671	885	825+(295)	1 300	1 430
550	860	890	1 180	1 300	1 800	1 800
550	810	891	1 150	1 000+(450)	1 800	1 980
800	960	960	1 430	1 500	2 050	2 050
800	940	1 034	1 300	1 000+(650)	2 050	2 255

NOTE Values of column (2) are applicable:

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

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

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

In Column (5), values in brackets are the peak values $U_r \sqrt{2}/\sqrt{3}$ of the power-frequency voltage applied to the opposite terminal (combined voltage).

5.4 Rated frequency (f_r)

The preferred values of the rated frequency are 16,7 Hz, 25 Hz, 50 Hz and 60 Hz.

5.5 Rated continuous current (I_r)

This rating defines the RMS value of the current the switchgear and controlgear can carry continuously for its service conditions (see Clause 4).

The values of rated continuous current should be selected from the R 10 series, specified in IEC 60059.

NOTE 1 The R 10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n.

NOTE 2 The term rated continuous current associated with the continuous current test in 7.5 as used in this edition is equivalent to the term rated normal current used in the previous edition of this document.

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)

This rating defines the RMS value of the short-circuit current that the switchgear and controlgear can carry in the closed position during its rated duration (see 5.8) under its service conditions (see Clause 4).

The value of rated short-time withstand current should be selected from the R 10 series specified in IEC 60059.

NOTE The R 10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n.

5.7 Rated peak withstand current (I_p)

This rating defines the peak current associated with the first major loop of the rated short-time withstand current that the switchgear and controlgear can carry in the closed position under its service conditions (see Clause 4).

The rated peak withstand current is obtained by multiplying the RMS value of the rated short-time withstand current with a peak factor. This peak factor is a function of the DC time constant of the network and the rated frequency.

A DC time constant of 45 ms covers the majority of cases and corresponds to a rated peak withstand current equal to 2,5 times the rated short-time withstand current for a rated frequency of 50 Hz. For a rated frequency of 60 Hz, it is equal to 2,6 times the rated short-time withstand current.

Table 5 gives peak factors for different time constants and rated frequencies.

NOTE 1 IEC TR 62271-306 [4] gives the information for calculating peak factors according to rated frequency and time constant of the network.

NOTE 2 For non-simultaneous drive mechanisms of each pole the peak factor can be different, for details, see IEC TR 62271-306 [4].

Table 5 – Peak factors for rated peak withstand current

Rated frequency (f_r) Hz	DC time constant ms			
	45	60	75	120
16,7	2,1	2,3	2,4	2,5
25	2,3	2,4	2,5	2,6
50	2,5	2,6	2,7	2,7
60	2,6	2,7	2,7	2,7

5.8 Rated duration of short-circuit (t_k)

This rating defines the interval of time for which the switchgear and controlgear can carry, in the closed position, a current equal to its rated short-time withstand current.

The preferred value of rated duration of short-circuit is 1 s.

An alternative value lower or higher than 1 s may be chosen, e.g. 0,5 s, 2 s, 3 s.

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

5.9.1 General

Several auxiliary voltages can be used on a single piece of switchgear and controlgear.

5.9.2 Rated supply voltage (U_a)

The rated supply voltage should be selected from the standard values given in Table 6 and Table 7.

Table 6 – Direct current voltage

U_a V
24
48
60
110
125
220
250

Table 7 – Alternating current voltage

Line number	Three-phase, three-wire or four-wire systems V	Single-phase, three-wire systems V	Single-phase, two-wire systems V
(1)	(2)	(3)	(4)
1	–	120/240	120
2	120/208	–	120
3	(220/380)	–	(220)
4	230/400	–	230
5	(240/415)	–	(240)
6	277/480	–	277
7	347/600	–	347

The value 230/400 V indicated in line 4 of this table should be, in the future, the IEC standard voltage replacing the values 220/380 V and 240/415 V in lines 3 and 5 and its adoption is recommended in new systems. The voltage variations of existing systems at 220/380 V and 240/415 V should be brought within the range 230/400 V ± 23/40 V. The reduction of this range will be considered at a later stage of standardization.

NOTE The lower values in the column (2) of this table are voltages to neutral and the higher values are voltages between phases. The lower value in the column (3) is the voltage to neutral and the higher value is the voltage between lines.

5.10 Rated supply frequency of auxiliary and control circuits

When alternating current supply voltage is used, the preferred values of rated supply frequency are 50 Hz and 60 Hz.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Not applicable.

6 Design and construction

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

Not applicable.

6.2 Requirements for gases in GIL

The manufacturer shall specify the type and the required quantity, and quality of the gas used in switchgear and controlgear.

The manufacturer shall provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality (refer to 11.5.2 and item a) of 11.5.3). This requirement does not apply to sealed pressure systems.

For sulphur hexafluoride (SF_6) filled switchgear and controlgear, SF_6 in accordance with IEC 60376 for new SF_6 and IEC 60480 for reused SF_6 shall be used. For switchgear and controlgear with SF_6 mixtures, reference is made to IEC 62271-4.

In order to prevent condensation, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling density for insulation ρ_{re} shall be such that the dew point at filling pressure (density) for insulation is not higher than –5 °C for a measurement at 20 °C during service life, refer to 11.3.6.

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

Switchgear and controlgear shall be provided with a reliable earthing point for connection of an earthing conductor suitable for specified fault conditions. The connecting point shall be marked with the "protective earth" symbol, as indicated by symbol IEC 60417-5019:2006-08. Conductive parts of the switchgear and controlgear intended to be connected to the earthing system, may be designed to be part of the earthing circuit.

All conductive components and enclosures that may be touched during normal operating conditions and are intended to be earthed shall be designed to carry 30 A (DC) with a voltage drop of maximum 3 V to the earthing point provided at the switchgear and controlgear.

NOTE For guidance on the connection of the earthing point of the switchgear and controlgear to the main station earth, Clause 10 of IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014 [22] applies.

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

6.4.1 General

Switchgear and controlgear include all auxiliary and control equipment and circuits, including but not limited to, electronic controls, supervision, monitoring and communication.

Auxiliary and control equipment and circuits shall operate normally when the voltage measured during operation at the supply terminals of the auxiliary and control equipment and circuits:

- is within 85 % to 110 % of rated supply voltage (U_a);

- in the case of DC, a ripple voltage is not greater than 5 % of U_a;
- is free of the voltage dips and interruptions which exceed the limits declared by the manufacturer according to IEC 61000-4-29 (DC supply voltage) and IEC 61000-4-11 (AC supply voltage).

In case of supply interruptions (also during operations) that exceed the duration limits declared by the manufacturer for normal operation:

- there shall be no false operation, false alarms or false remote signalling resulting from the interruption or re-instatement of the supply;
- the manufacturer shall state the behaviour of the device when the supply voltage gets interrupted (for example impact on internal energy storage);
- the manufacturer shall state the behaviour of the device when the supply voltage returns;
- subsequent actions shall only be completed in response to a new valid operational command (where applicable).

The fulfilment of the above conditions can be demonstrated at any convenient dip duration that exceeds the declared limit.

NOTE 1 Possible actions can be:

a) completing the pending action without manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;

b) manual intervention such that the equipment achieves a defined, safe operating state for example open, closed, charged, discharged;

c) completing the action after giving another command for the same switching operation that was interrupted.

This choice can also be dependent on the duration of the interruption.

Specific conditions are given in 6.9 for shunt closing releases, shunt opening releases and under-voltage releases.

For supply voltages lower than the minimum stated above, precautions shall be taken to prevent any damage to electronic equipment and/or unsafe operation.

Requirements for the interface with digital communication that ensure compliance with IEC 61850 (all parts) [23] are detailed in IEC 62271-3 [24].

NOTE 2 The logical nodes in IEC 62271-3:2015 (XCBR, XSWI) and their additional data objects described in Annex B of IEC 62271-3:2015 cover only some properties required by the electronic nameplates of some switchgear and controlgear of the IEC 62271 series of standards. The other properties required for the physical nameplate, tendering, quotation and ordering phases are not covered.

6.4.2 Protection against electric shock

6.4.2.1 Protection of auxiliary and control circuits from the main circuit

Auxiliary and control circuits that are installed on the frame of switchgear and controlgear shall be suitably protected against disruptive discharge from the main circuit. This is verified by dielectric type tests specified in 7.2, see 7.2.5 c).

6.4.2.2 Safety clearance during service

Auxiliary and control circuits to which access is required during service shall be accessible without the need to compromise clearances to hazardous parts.

6.4.3 Components installed in enclosures

6.4.3.1 Selection of components

All components used in the auxiliary and control circuits shall be designed or selected to be operational with their rated characteristics over the full range of service conditions inside auxiliary and control circuits enclosures. Suitable precautions (for example, heaters, ventilators, insulation, etc.) should be taken to ensure that those service conditions essential for proper operation of relays, contactors, low-voltage switches, meters, operation counters, push-buttons, etc. are maintained.

NOTE These internal conditions in control cabinet for auxiliary and control circuits can differ from the external service conditions specified in Clause 4.

The loss of "suitable precautions" shall not cause failure of the auxiliary and control circuits within the enclosure or untimely operation of the switchgear within the specified time. Selection of components should take into account the temperature obtained in the cabinet of the control and auxiliary circuit during a 2-hour period following the loss of the "suitable precautions" in order to ensure the proper operation of switchgear and controlgear until the end of this 2-hour period.

After this 2-hour period non-operation is acceptable. If the loss of the "suitable precautions" is longer than 2 h but does not exceed 24 h in total, the functionality of the switchgear and controlgear shall come back to its original characteristics when the service conditions are recovered.

Where heating is essential for correct functioning of the equipment, monitoring of the heating circuit shall be provided.

In the case of switchgear and controlgear designed for outdoor installation, suitable arrangements (ventilation and/or internal heating, etc.) may be required to prevent harmful condensation in auxiliary and control circuit enclosures.

6.4.3.2 Accessibility

Closing and opening actuators and emergency shut-down system actuators shall be located between 0,4 m and 2 m above the floor, ground or operating platform normally used by operating personnel.

Other actuators should be located at such a height that they can be easily operated, and indicating devices should be located at such a height as to be readily legible.

Where a component may need adjustment during its service life, access shall be provided with protection level of at least IP XXB, refer to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

6.4.3.3 Identification

Identification of components installed in enclosures shall be in agreement with the indication on the wiring diagrams and drawings. If a component is of the plug-in type, an identifying mark should be placed on the component and on the fixed part where the component plugs in.

6.4.3.4 Requirements for auxiliary and control circuit components

6.4.3.4.1 General

The auxiliary and control circuit components shall comply with applicable IEC standards if one exists. Annex D (informative) is provided as a quick reference to many of the component standards.

6.4.3.4.2 Cables and wiring

Where a facility for external wiring is provided, it shall be through an appropriate connecting device, e.g. terminal blocks or plug-in terminations.

Polarity reversal at the interfacing point shall not damage auxiliary and control circuits.

Terminal blocks should be fixed. Cables between two terminal blocks shall have no intermediate splices or soldered joints.

Cables and wiring shall be adequately supported and shall not rest against sharp edges.

The available wiring space for external connection shall permit spreading of the cores of multi-core cables and the proper termination of the conductors without undue stresses.

Conductors connected to components mounted on doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these doors.

6.4.3.4.3 Terminals

If facilities are provided for connecting incoming and outgoing neutral, protective and PEN (protective earthed neutral) conductors, they shall be situated in the vicinity of the associated phase conductor terminal.

6.4.3.4.4 Auxiliary switches

Auxiliary switches shall be suitable for the number of operating cycles specified for the high-voltage switching device to which they are linked.

Auxiliary switches which are operated in conjunction with the main contacts shall be positively driven in both directions. An auxiliary switch may consist of a set of two one-way positively driven auxiliary contacts (one for each direction).

6.4.3.4.5 Auxiliary and control contacts

Auxiliary and control contacts shall be suitable for the number of operating cycles specified for the switching device. This requirement is verified by the mechanical endurance test of the high-voltage switching devices to which they are linked.

The operational characteristics of the auxiliary contacts that are made available to the user shall comply with one of the classes shown in Table 8.

Table 8 – Auxiliary contact classes

DC current				
Class	Rated continuous current	Rated short-time withstand current	Breaking capacity	
			$U_a \leq 48$ V	110 V $\leq U_a \leq$ 250 V
1	10 A	100 A/30 ms		440 W
2	2 A	100 A/30 ms		22 W
3	200 mA	1 A/30 ms	50 mA	

NOTE 1 Control contacts which are included in a control circuit of a mechanical switching device can be covered by this table.

NOTE 2 If insufficient current is flowing through the contact, oxidation can increase the resistance. Therefore, a minimum value of current is specified for class 1 contact.

NOTE 3 In the case of the application of solid state contacts, the rated short-time withstand current can be reduced if current-limiting equipment, other than fuses, is employed.

NOTE 4 For all classes, breaking capacity are based on a circuit time constant of 20 ms with a tolerance of $^{+20}_{0}$ %.

NOTE 5 An auxiliary contact which complies with class 1 2 or 3 for DC is normally able to handle corresponding AC current and voltage.

NOTE 6 Breaking current at a defined voltage value between 110 V and 250 V can be deduced from the indicated power value for class 1 and class 2 contacts (for example, 2 A at 220 V DC for a class 1 contact).

Examples of the use of the three contact classes are shown in Figure 1.

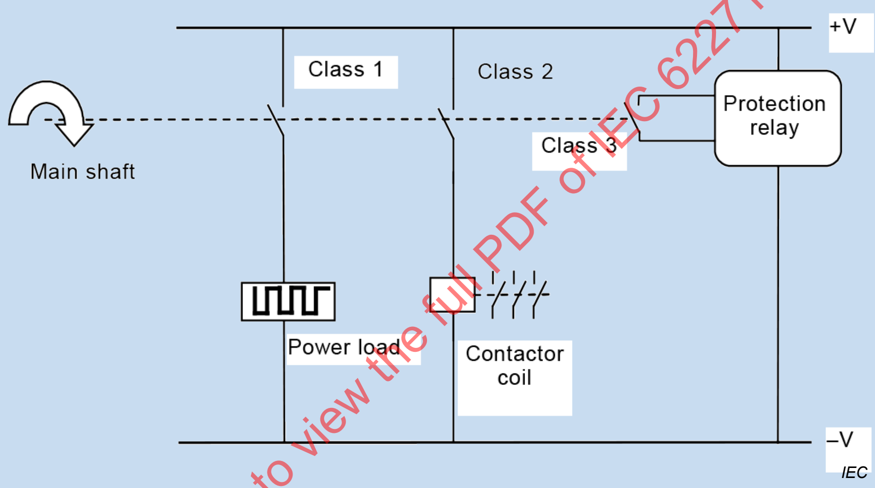


Figure 1 – Examples of classes of contacts

6.4.3.4.6 Heating elements

All heating elements shall be designed to prevent touching an electrically live part.

Where contact with a heater or shield can occur accidentally, the surface temperature shall not exceed the temperature limits for accessible parts not to be touched in normal operation, as specified in 7.5.6.

6.4.3.5 Operation counter

Operation counters shall be suitable for their intended duty in terms of environmental conditions and for the number of operating cycles specified for the switching devices.

6.5 Dependent power operation

Not applicable.

6.6 Stored energy operation

Not applicable.

6.7 Independent manual or power operation (independent unlatched operation)

Not applicable.

6.8 Manually operated actuators

Not applicable.

6.9 Operation of releases

Not applicable.

6.10 Pressure/level indication

6.10.1 Gas pressure

Closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum functional pressure for insulation and/or operation above 0,2 MPa (absolute pressure), shall be provided with a device capable of monitoring the pressure (or density).

The uncertainty of the gas monitoring device should be established and take into account pressure coordination (filling, minimum functional and alarm pressure) and leakage rate.

6.10.2 Liquid level

A device for checking the liquid level, with indication of minimum and maximum limits permissible for correct operation, shall be provided. This requirement is not applicable to dashpots or shock-absorbers.

6.11 Nameplates

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

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

Switching devices, the incorrect operation of which can cause damage or which are used for assuring isolating distances, shall be provided with locking facilities (for example, provision for padlocks).

6.13 Position indication

Indication of the actual position of the main contacts of the switching devices shall be provided unless the contacts themselves are visible in all positions.

Requirements for position indicating devices are as follows:

- it shall be possible to read the position-indicating device when operating locally;
- all stable positions such as open, closed and test positions shall be clearly indicated.

Identification of the open, closed and where appropriate earthed positions should use symbols and/or colours defined by the relevant IEC publications: IEC 60073 [25] for colours, IEC 60417 [26] for symbols and IEC 60617 [27] for diagrams.

6.14 Degree of protection provided by enclosures

6.14.1 General

The enclosures shall provide degrees of protection in accordance with 6.14.2 through 6.14.4.

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)

The degree of protection of persons and of equipment provided by an enclosure against access to hazardous parts of the main circuit, control and/or auxiliary circuits and to any hazardous moving parts and against ingress of solid foreign objects shall be at least IP1XB according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

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)

For equipment of indoor installation, no minimum degree of protection against harmful ingress of water is specified, i.e. the second characteristic numeral of the IP code is X according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

Equipment for outdoor installation shall be at least IPX3 according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013. If it is provided with additional protection features against rain and other weather conditions (supplementary letter W), the performance refers to the situation with these features in place and shall be demonstrated according to Annex C (normative) (see 7.7.1).

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 9 – 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)

For indoor installation, the preferred impact level is IK07 according to IEC 62262:2002 (2 J).

For outdoor installation without additional mechanical protection, the minimum impact level shall be IK10 according to IEC 62262:2002 (20 J).

Insulators and bushings of high-voltage switchgear and controlgear are not subjected to this requirement.

6.15 Creepage distances for outdoor insulators

Not applicable.

6.16 Gas and vacuum tightness

6.16.1 General

Not applicable.

6.16.2 Controlled pressure systems for gas

Not applicable.

6.16.3 Closed pressure systems for gas

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment. The maximum values under the standardized ambient temperature of 20 °C are:

– for SF_6 and SF_6 mixtures, 0,5 % per year;

– for other gases, 1 % per year.

NOTE 1 Some local or governmental regulations can require a lower SF_6 leakage rate, e.g. 0,1 % per year.

The tightness characteristic of a closed pressure system and the time between replenishments under normal service conditions shall be stated by the manufacturer. This time shall be at least 10 years for maintenance planning purposes. Means shall be provided to enable gas systems to be replenished while the equipment is in service.

NOTE 2 The term “in service” implies “under live conditions”.

NOTE 3 Manufacturer’s instructions and the user’s operating practices provide guidance for replenishing gas.

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

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

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

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

NOTE 2 The global warming potential (GWP) of gases in GIS is the major reason for requiring low permissible leakage rates. Solutions with alternative gases with GWP lower than 1 000 exist. GWP (100 years) of SF_6 is 23 500 according the IPCC – AR5 Climate Change 2013 [31].

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

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

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

The tightness of sealed pressure systems is specified by their expected operating duration. The expected operating duration shall be specified by the manufacturer and shall be at least 20 years. Other preferred values are 30 years and 40 years.

The tightness of gas insulated switchgear and controlgear shall be designed in a way to ensure that the minimum functional pressure (density) shall not be attained before the expected end of life. The manufacturer shall specify a permissible leakage rate.

NOTE 1 For some designs verification of an expected operating duration greater than 20 years can be impractical for a type or routine test.

NOTE 2 Sealed SF_6 switchgear and controlgear is considered to have insignificant SF_6 losses (less than 0,1 % per year) during their expected operating duration.

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

Not applicable.

6.18 Fire hazard (flammability)

Not applicable.

6.19 Electromagnetic compatibility (EMC)

Not applicable.

6.20 X-ray emission

Not applicable.

6.21 Corrosion

Due to the large number of parameters to be considered no standard requirements can be given. General recommendations are given in IEC TR 62271-306 [4].

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

The pressure (or density) or liquid mass shall be assigned by the manufacturer. The pressure (or density) of gas is referred to atmospheric conditions of 20 °C at which gas filled switchgear is filled before being put into service.

In addition to the filling levels the following values have to be assigned by the manufacturer (when applicable):

– alarm pressure p_{ae} (or density ρ_{ae}) for insulation and/or switching;

– alarm pressure p_{am} (or density ρ_{am}) for operation;

– minimum functional pressure p_{me} (or density ρ_{me}) for insulation and/or switching;

– minimum functional pressure p_{mm} (or density ρ_{mm}) for operation.

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

7.1.1 Basics

The type tests are for the purpose of proving the ratings and characteristics of switchgear and controlgear, their operating devices and their auxiliary equipment. Each individual type test or type test sequence shall be made on test objects as defined in 3.2.1, in the condition as required for service (filled with the specified types and quantities of liquid or gas), with their operating devices and auxiliary equipment, all of which in principle shall be in, or restored to, a new and clean condition at the beginning of each type test or type test sequence.

Reconditioning during individual type tests or test sequence may be allowed, according to the relevant IEC product standard. The manufacturer shall provide a statement to the testing laboratory of those parts that may be renewed during the tests.

Tolerances on test quantities are listed in Table E.1.

Information regarding the extension of validity of type tests is given in Annex J (informative).

7.1.2 Information for identification of test objects

The manufacturer shall submit to the testing laboratory, drawings and other data containing sufficient information to unambiguously identify by type the essential details and parts of the switchgear and controlgear presented for test. A summary list of the drawings and data schedules shall be supplied by the manufacturer and shall be uniquely referenced and shall contain a statement that the manufacturer guarantees that the drawings or data sheets listed are the correct version and represent the switchgear and controlgear to be tested.

The testing laboratory shall check that drawings and data sheets adequately represent the essential details and parts of the test object but is not responsible for the accuracy of the detailed information.

Particular drawings or data required to be submitted by the manufacturer to the test laboratory for identification of essential parts of test object are specified in Annex A (normative).

7.1.3 Information to be included in type-test reports

The results of all type-tests shall be recorded in type-test reports containing sufficient data to prove compliance with the ratings and the test clauses of the relevant standards and sufficient information shall be included so that the essential parts of the test object can be identified. In particular, the following information shall be included:

– the manufacturer;
– the type designation and the serial number of the test object;
– the rated characteristics of the test object as specified in the relevant IEC standard;
– the general description of the test object, including number of poles;
– the manufacturer, type, serial numbers and ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances);
– the general details of the supporting structure of the switching device or enclosed switchgear of which the switching device forms an integral part;
– the details of the operating-mechanism and devices employed during tests, where applicable;
– photographs to illustrate the condition of the test object before and after test;
– sufficient outline drawings and data schedules to represent the test object;

- the reference numbers of all drawings including revision number submitted to identify the essential parts of the test object;
- a statement that the test object complies with the drawings submitted;
- details of the testing arrangements (including diagram of test circuit);
- statements of the behaviour of the test object during tests, its condition after tests and any parts renewed or reconditioned during the tests;
- in case of breaking operations with some specific technologies, NSDDs may occur during the recovery voltage period. Their number is of no significance to interpreting the performance of the device under test. They shall be reported in the test report only in order to differentiate them from restrikes;
- records of the test quantities during each test or test duty, as specified in the relevant IEC standard;
- the location, laboratory name where the tests were conducted and date of test.

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

Not applicable.

7.2.2 Ambient air conditions during tests

Not applicable.

7.2.3 Wet test procedure

Not applicable.

7.2.4 Arrangement of the equipment

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

a) Short-duration power-frequency withstand voltage tests

The test object shall be considered to have passed the test if no disruptive discharge occurs.

If during a wet test a disruptive discharge (as defined in IEC 60060-1:2010) on external self-restoring insulation occurs, this test shall be repeated in the same test condition without intermediate cleaning and the test object shall be considered to have passed this test successfully if no further disruptive discharge occurs.

b) Impulse tests

The test procedure B of IEC 60060-1:2010, adapted for test objects that have self-restoring and non-self-restoring insulation, is the preferred test procedure. The test object has passed the impulse tests if the following conditions are fulfilled:

– each series has at least 15 tests;

– the number of disruptive discharges does not exceed two for each complete series;

– no disruptive discharge on non-self-restoring insulation occurs. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge.

This procedure leads to a maximum possible number of 25 impulses per series.

Procedure C of IEC 60060-1:2010 may be used when all three poles are tested, refer to 7.2.6.2.

c) General comment

– When testing switchgear and controlgear, the part of equipment through which the test voltage is applied may be subjected to numerous test sequences to check the insulating properties of other downstream parts of equipment (circuit-breakers, disconnectors, other bays). It is recommended that parts be tested in sequence, starting with the first connected part. When this part has passed the test according to the above-mentioned criteria, its qualification is not impaired by possible disruptive discharges which could occur in it during further tests on other parts.

These discharges can have been generated by accumulation of discharge probability with the increased number of voltage applications or by reflected voltage after a disruptive discharge at a remote location within the equipment. To reduce the probability of occurrence of these discharges in gas-filled equipment, the pressure of compartments which are not subject of the test can be increased. Compartments at increased pressure should be clearly identified in the test report(s).

– A disruptive discharge to the auxiliary and control circuits shall be considered as a failure.

7.2.6 Application of test voltage and test conditions

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

The tests shall be performed with the test values equal to the rated withstand voltages selected from Table 1 or Table 2.

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

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

In the closed position, the tests shall be performed in conditions 1, 2 and 3 of Table 10. In the open position, the tests shall be performed as stated below (but refer to 7.2.4). In addition, phase-to-phase switching impulse voltage tests shall be performed as stated below. The tests shall be performed with the test values equal to the rated withstand voltages.

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

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

The test object shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse 250/2 500 µs according to IEC 60060-1:2010. Wet tests shall be performed for outdoor switchgear and controlgear with external insulation only.

The isolating distance shall be tested with the preferred method a) of 7.2.6.3.

The insulation between poles shall be tested in dry conditions only according to Table 13 with a test voltage as per column 5 of Table 3 and/or Table 4, by the preferred method a) of 7.2.6.3 in which the main part shall be equal to or higher than 90 % of the value given in column 4 of Table 3 and Table 4. This value shall not exceed 100 % of the value indicated in column 4 of Table 3 and Table 4 without the consent of the manufacturer. The complementary part shall be applied to the adjacent phase in phase opposition in order that the sum of both voltages (main part and complementary part) is equal to the value indicated in column 5 of Table 3 and Table 4.

The actual voltage share shall be as balanced as possible. Any unbalanced share of the total test voltage is more severe. When voltage components are different in shape and/or amplitude, the test shall be repeated reversing the connections.

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

Not applicable.

7.2.10 Partial discharge tests

Unless otherwise specified by the relevant product standard, partial discharge tests are not required. When tests are required, the measurements shall be made according to IEC 60270.

7.2.10.1 General

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

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

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

7.2.10.2 Test procedure

The applied power-frequency voltage is raised to a pre-stress value which is identical to the power-frequency withstand voltage test and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage is decreased to a specific value defined in Table 6 depending on the configuration of equipment and system neutral.

The extinction voltage shall be recorded.

Table 10 – Test voltage for measuring PD intensity

	System with effectively earthed neutral		System without effectively earthed neutral	
	Pre-stress voltage $U_{pre\text{-}stress}$ (1 min)	Test voltage for PD measurement $U_{pd\text{-}test}$ (>1 min)	Pre-stress voltage $U_{pre\text{-}stress}$ (1 min)	Test voltage for PD measurement $U_{pd\text{-}test}$ (>1 min)
Single-phase enclosures design (phase-to-earth voltage)	$U_{pre\text{-}stress} = U_d$	$U_{pd\text{-}test} = 1{,}2\ U_r / \sqrt{3}$	$U_{pre\text{-}stress} = U_d$	$U_{pd\text{-}test} = 1{,}2\ U_r$
Three-phase enclosures design	$U_{pre\text{-}stress} = U_d$	$U_{pd\text{-}test,\ ph\text{-}ea} = 1{,}2\ U_r / \sqrt{3}$ $U_{pd\text{-}test,\ ph\text{-}ph} = 1{,}2\ U_r$	$U_{pre\text{-}stress} = U_d$	$U_{pd\text{-}test,\ ph\text{-}ea} = 1{,}2\ U_r$

U_r: rated voltage for equipment.

U_d: power-frequency withstand test voltage as per Table 2 and Table 3.

$U_{pre\text{-}stress}$: pre-stress voltage.

$U_{pd\text{-}test}$: test voltage for PD measurement.

$U_{pd\text{-}test,\ ph\text{-}ea}$: test voltage for PD measurement, phase-to-earth.

$U_{pd\text{-}test,\ ph\text{-}ph}$: test voltage for PD measurement, phase-to-phase.

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

7.2.10.3 Maximum permissible partial discharge intensity

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

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

7.2.11 Dielectric tests on auxiliary and control circuits

The dielectric test on auxiliary and control circuits are covered under 7.10.5.

7.2.12 Voltage test as condition check

Not applicable.

7.3 Radio interference voltage (RIV) test

Not applicable.

7.4 Measurement of the resistance of circuits

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.

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

One sample of each type of class 1 and class 2 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current of (10 ± 2) mA when energized by a source having an open circuit voltage of 6 V DC with a relative tolerance of $^{0}_{-15}$ % and the resistance measured according to IEC 60512-2-2.

The resistance of the closed class 1 and class 2 auxiliary contacts shall not exceed 50 Ω under these measuring conditions.

NOTE On contact materials, oxidation which decreases the effective current-carrying capabilities can occur. This results in an increased contact resistance or even no conduction at very low voltage while no problems are observed at higher voltage. This test is intended to verify the contact performance under these low-voltage conditions. The assessment criterion takes into account the non-linearity of the resistance. The 50 Ω value results from statistical considerations and has already been taken into account by users.

7.4.2 Measurement of the resistance of auxiliary contacts class 3

One sample of class 3 auxiliary contacts shall be inserted into a resistive load circuit through which flows a current ≤10 mA when energized by a source having an open circuit voltage ≤30 mV DC and the resistance measured according to 4.12 of IEC 61810-7:2006.

The resistance of the closed class 3 auxiliary contacts shall not exceed 1 Ω.

7.4.3 Electrical continuity of earthed metallic parts test

Generally visual inspection is sufficient to assess compliance with requirements in 6.3.

However, as an alternative, the metallic components and enclosures that may be touched during normal operating conditions and are intended to be earthed may be tested at 30 A (DC) to the earthing point provided. The voltage drop shall be lower than 3 V.

NOTE It may be necessary to locally remove coating at measuring points.

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

7.4.4.1 Resistance measurement test procedure

When resistance measurements are called for as a condition check after a specific test, the following procedure shall be applied.

The resistance across the contacts or connections being checked shall be measured before the test. The measuring test points shall be the nearest accessible points to and on either side of the contacts or connections in question. An average value of the resistance shall be calculated based on three measurements. If the test object comprises switching devices, one no-load open and close operation cycle shall be made on each device between each of the measurements. If the test object comprises removable elements, one remove / replace cycle shall be made between each of the measurements.

The measurements shall be made with DC at full rated continuous current (-20 % to 0 %) if less than or equal to 50 A or any convenient value of current between (and including) 50 A and the rated continuous current if it is higher than 50 A.

NOTE In some designs it may be only practical that several connections and/or contacts are measured in series in the main circuit or even the complete poles of a device are measured during type testing.

After the completion of the test, the resistance shall be measured again using the identical procedure to that used for the resistance measurements made prior to the tests. Before this resistance measurement, some conditioning of the contacts is acceptable based on the manufacturer's recommendations such as no-load operation cycles or the application of rated continuous current for some time.

The resistance measurements before and after shall be performed at ambient temperature with a maximum difference of 10 K between the measurements. The resistance increase is calculated by the difference between the average value of the measurements before and after the test.

7.4.4.2 Making and breaking tests

For making and breaking tests of any switching device, the resistance condition check of the test sample after completion of the test is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.1 is not greater than 100 %.

NOTE The acceptance criterion of 100 % increase in resistance as a condition check after making and breaking test is a default value for this document. The criterion may not be appropriate for all switchgear designs, e.g. designs with parallel arcing and main contacts. In such cases, the relevant product standards provide their own methods or criteria for a condition check.

7.4.4.3 Other tests

For tests other than making and breaking tests, the resistance condition check of the test object after completion of the test is considered to be satisfactory if the resistance increase for each phase determined in 7.4.4.1 is not greater than 20 %. If the resistance increase exceeds 20 % then a continuous current test (7.5) is applicable to determine if the test object can carry its rated continuous current.

NOTE The acceptance criterion of 20 % increase in resistance as a condition check after test is a default value for this document. The criterion may not be appropriate for all switchgear designs, in which case, the relevant product standards provide their own methods or criteria for a condition check.

7.5 Continuous current test

7.5.1 Condition of the test object

The continuous current test of the main circuits shall be made on a test object, if applicable, with clean contacts and filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

7.5.2 Arrangement of the equipment

The test shall be made indoors in an environment substantially free from air currents, except those generated by heat from the test object. In practice, this condition is reached when the air velocity does not exceed 0,5 m/s.

For continuous current tests of parts other than auxiliary equipment, the test object and their accessories shall be mounted in all significant respects as in service, including all normal covers of any part of the test object (including any extra cover for testing purpose, for example cover surrounding a busbar extension), and shall be protected against undue external heating or cooling.

When the test object, according to the manufacturer's instructions, may be installed in different positions, the continuous current tests shall be made in the most unfavourable position.

These tests shall be made in principle on three-pole switchgear and controlgear but may be made on a single pole or on a single unit provided the influence of the other poles or units is negligible. This is the general case for non-enclosed switchgear above 52 kV. For three-pole switchgear and controlgear with a rated continuous current not exceeding 1 250 A, the tests may be made with all poles connected in series.

For particularly large test objects for which the insulation to earth has no significant influence on temperature rises, this insulation may be appreciably reduced.

For three-pole test objects, the test shall be made in a three-phase circuit with the exceptions mentioned above.

Where temporary connections to the main circuit are used, they shall be such that there is no significant difference in heat conducted away from, or conveyed to, the test object compared to the connections intended to be used for service (see 7.5.4.2).

NOTE To make the continuous current test more reproducible, the type and/or sizes of the temporary connections can be specified in relevant standards.

7.5.3 Test current and duration

7.5.3.1 Test on main circuit

The test shall be made at the rated continuous current (I_r) of the switchgear and controlgear. The supply current shall be practically sinusoidal.

This requirement is fulfilled when the RMS value of the harmonics does not exceed 5 % of the value of the fundamental current. By agreement of the manufacturer harmonic content higher than 5 % may be accepted.

Test object shall be tested at rated frequency with a tolerance of $^{+2}_{-5}$ %. The test frequency shall be recorded in the test report.

For switchgear and controlgear rated for both frequencies at 50 Hz and 60 Hz and having no ferromagnetic components adjacent to the current-carrying parts, the test can be performed at 50 Hz and covers both frequencies provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values. Tests performed at 60 Hz cover both frequencies.

The test shall be made over a period of time sufficient for the temperature rise to reach a stable value. This condition is deemed to be obtained when the variation of temperature rise does not exceed 1 K in 1 h. This criterion will normally be met after test duration of five times the thermal time constant of the test object.

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

7.5.3.2 Test of the auxiliary and control equipment

The test is made with the specified supply voltage (AC or DC), and for AC at its rated frequency (tolerance $^{+2}_{-5}$ %).

The auxiliary equipment shall be tested at its rated supply voltage (U_a) or at its rated continuous current. The AC supply voltage shall be practically sinusoidal.

Coils rated for continuous duty shall be tested over a period of time sufficient for the temperature rise to reach a constant value. This condition is usually obtained when the variation does not exceed 1 K in 1 h.

For circuits energized only during operations, the tests shall be made under the following conditions.

a) When the operating device has an automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the circuit shall be energized 10 times, for either 1 s or until the automatic breaking device operates, the interval between the instant of each energizing being 10 s or, if the construction of the operating device does not permit this, the lowest interval possible.

b) When the operating device has no automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the test shall be made by energizing the circuit once for duration of 15 s.

7.5.4 Temperature measurement during test

7.5.4.1 Ambient air temperature

The ambient air temperature is the average temperature of the air surrounding the test object (for enclosed switchgear and controlgear, it is the air outside the enclosure). It shall be recorded during the tests by means of at least three thermometers, thermocouples or other temperature-measuring devices equally distributed around the test object at about the average height of its current-carrying parts and at a distance of about 1 m from the test object. The thermometers or thermocouples shall be protected against air currents and undue influence of heat.

In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples may be put into small bottles containing about 0,5 l of oil.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions of the test room, the temperature of an identical switchgear and controlgear under the same conditions, but without current, may be taken as a substitute for the ambient air temperature. This additional switchgear and controlgear shall not be subjected to an undue amount of heat.

The ambient air temperature during tests shall be more than 10 °C but shall not exceed 40 °C without the consent of the manufacturer. No correction of the temperature-rise values shall be made for ambient air temperatures within this range and above.

7.5.4.2 Temperature of test object

Precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the test object and the variations in the ambient air temperature.

For coils, the method of measuring the temperature rise by variation of resistance shall normally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point.

The surface temperature of a component immersed in a dielectric liquid shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

For measurement with thermometers or thermocouples, the following precautions shall be taken:

a) the bulbs of the thermometers or thermocouples shall be protected against cooling from outside (dry clean wool, etc.). The protected area shall, however, be negligible compared with the cooling area of the apparatus under test;

b) good heat conductivity between the thermometer or thermocouple and the surface of the part under test shall be ensured;

c) when bulb thermometers are employed in places where there is any varying magnetic field, it is recommended to use alcohol thermometers in preference to mercury thermometers, as the latter are more liable to be influenced under these conditions.

Sufficient temperature measurements shall be made during the test, at time intervals not exceeding 30 min, in order to calculate the thermal time constant, and shall be recorded in the test document.

The temperatures at the terminals of the main circuit and at the temporary connections at a distance of 1 m from the terminals shall be measured. The difference in temperature rise shall not exceed 5 K.

However, if the temperature rise of the temporary connections at the distance of 1 m from the terminal of the main circuit exceeds by more than 5 K the temperature rise of the terminal, the test can be considered as valid if all criteria to pass the test defined in 7.5.6 are fulfilled.

7.5.5 Resistance of the main circuit

A measurement of the resistance of the main circuit shall be made before the continuous current test, with the test object at the ambient air temperature according to the measurement procedure as defined in 7.4.4.

The resistance value measured before the continuous current tests is made for comparison between the switchgear and controlgear type tested for continuous current and all other switchgear and controlgear of the same type subjected to routine tests (see Clause 8).

7.5.6 Criteria to pass test

7.5.6.1 General

The test object has passed the test if the temperature rise of the parts of the test object for which limits are specified, has not exceeded the values specified in Table 14.

If the insulation of a coil is made of several different insulating materials, the permissible temperature rise of the coil shall be taken as that for the insulating material with the lowest limit of temperature rise.

If the test object is fitted with various equipment complying with particular standards (for example, rectifiers, motors, low-voltage switches, etc.), the temperature rise of such equipment shall not exceed the limits specified in the relevant standards.

Table 11 – Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.5.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
1 Contacts (refer to point 4)		
Bare-copper or bare-copper alloy		
– in OG (refer to point 5)	75	35
– in NOG (refer to point 5)	115	75
– in oil	80	40
Silver-coated or nickel-coated (refer to point 6)		
– in OG (refer to point 5)	115	75
– in NOG (refer to point 5)	115	75
– in oil	90	50
Tin-coated (refer to point 6)		
– in OG (refer to point 5)	90	50
– in NOG (refer to point 5)	90	50
– in oil	90	50
2 Connection, bolted or the equivalent (refer to point 4)		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
– in OG (refer to point 5)	100	60
– in NOG (refer to point 5)	115	75
– in oil	100	60
Silver-coated or nickel-coated (refer to point 6)		
– in OG (refer to point 5)	115	75
– in NOG (refer to point 5)	115	75
– in oil	100	60
Tin-coated		
– in OG (refer to point 5)	105	65
– in NOG (refer to point 5)	105	65
– in oil	100	60
3 All other contacts or connections made of bare metals or coated with other materials	(Refer to point 7)	(Refer to point 7)
4 Terminals for the connection to external conductors by screws or bolts (refer to points 8 and 14)		
– bare	100	60
– silver or nickel coated	115	75
– tin-coated	105	65
– other coatings	(Refer to point 7)	(Refer to point 7)
5 Oil for oil switching devices (refer to points 9 and 10)	90	50
6 Metal parts acting as springs	(Refer to point 11)	(Refer to point 11)

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3 in 7.5.6.2) (Refer to NOTE 1)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C (NOTE 2) K
7 Materials used as insulation and metal parts in contact with insulation of the following classes (refer to point 12)		
– Y	90	50
– A	105	65
– E	120	80
– B	130	90
– F	155	115
– Enamel: oil base	100	60
synthetic	120	80
– H	180	140
– C other insulating material	(Refer to point 13)	(Refer to point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible surfaces	(Refer to point 15)	(Refer to point 15)
Surfaces of manual control components to be touched in normal operation:		
– Uncoated metal	55	15
– Coated metal	55	15
– Non metal	65	25
Other surfaces to be touched in normal operation but not to be held continuously in the hand:		
– Uncoated metal	65	25
– Coated metal	70	30
– Non metal	80	40
Surfaces not to be touched in normal operation:		
– Uncoated metal	80	40
– Coated metal	80	40
– Non metal	90	50

NOTE 1 The points referred to in this table are those in 7.5.6.2.

NOTE 2 For switchgear and controlgear with special service conditions including a maximum temperature different from 40 °C, the maximum values of temperature applies and the maximum values of temperature rise are calculated accordingly.

7.5.6.2 Particular points of Table 14

The following points are referred to in Table 14 and complete it.

Point 1 According to its function, the same part may belong to several categories as listed in Table 14.

In this case the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.

Point 2 For vacuum switching devices, the values of temperature and temperature-rise limits do not apply to parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 14.

Point 3 Care shall be taken to ensure that no damage is caused to the surrounding insulating materials.

Point 4 When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be:

a) for contacts, those of the surface material having the lowest value permitted in item 1 of Table 14;

b) for connections, those of the surface material having the highest value permitted in item 2 of Table 14.

Point 5 NOG (Not Oxidizing Gases), for the purposes of this document, are non-reactive gases that are considered as not accelerating ageing of contacts by corrosion or oxidation, due to their chemical characteristics and demonstrated operational records.

Recognized NOG are SF_6, N_2, CO_2, CF_4. They can be used pure or as a mixture of various NOG.

OG (Oxidizing Gases), for the purposes of this document, are reactive gases that can accelerate ageing of contacts either by corrosion phenomena (presence of humidity) or by oxidation phenomena (mostly due to ambient air medium like oxygen). Gases classified as OG are ambient air, “dry” air, any gas not classified as NOG and any mixture including part of OG.

NOTE Some gases considered as OG in the classification above could be re-classified as NOG, in future revision of this document.

For description of these corrosion and oxidation phenomena, refer to IEC TR 60943 [2].

Due to the absence of corrosion and oxidation in NOG, a harmonization of the limits of temperature for different contact and connection parts in the case of gas insulated switchgear appears appropriate.

The permissible temperature limits for bare copper and bare copper alloy parts are equal to the values for silver-coated or nickel-coated parts in the case of NOG atmospheres.

In the particular case of tin-coated parts, due to fretting corrosion effects, an increase of the permissible temperatures is not applicable, even under the corrosion and oxidation free conditions of NOG. Therefore, the values for tin-coated parts are lower.

Point 6 The quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area:

a) after the making and breaking test (if any);

b) after the short-time withstand current test;

c) after the mechanical endurance test.

according to the relevant standard for each equipment. Otherwise, the contacts shall be regarded as "bare".

Point 7	When materials other than those given in Table 14 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.
Point 8	The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.
Point 9	The temperature is to be measured at the upper part of the oil.
Point 10	Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.
Point 11	The temperature shall not reach a value where the elasticity of the material is impaired.
Point 12	Classes of insulating materials are those given in IEC 60085.
Point 13	The temperature is limited only by the requirement not to cause any damage to surrounding parts.
Point 14	These values do not take into account any influence on insulation of cable or cable termination.
Point 15	For further details regarding temperature limits for hot surfaces to be touched, refer to IEC Guide 117 [3].

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

The tests apply to the main circuits and where applicable, to the earthing circuits of the test object to demonstrate their ability to carry their rated peak withstand current and their rated short-time withstand current for their rated duration of short-circuit.

The test shall be made with a power supply of any suitable voltage and at the rated frequency with a tolerance of ±10 % except as provided in 7.6.3.

For rated frequencies of 50 Hz and 60 Hz, tests may be performed at either frequency provided that the rated peak withstand current is demonstrated.

The test may be performed at any convenient ambient temperature.

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

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

The AC component of the test current shall be equal to the AC component of the rated short-time withstand current (I_k) of the switchgear and controlgear with the tolerances and alternatives given below. The peak current (for a three-phase circuit, the highest value in one of the outer phases) shall be not less than the rated peak withstand current (I_p) and shall not exceed it by more than 5 % without the consent of the manufacturer.

For three-phase tests, the AC component of the test current in any phase shall not vary from the average of the currents in the three phases by more than 10 %. The average of the RMS values of the AC component of the test currents shall be not less than the rated value.

Either of two methods may be used:

Method 1: the test current I_t shall be applied for a time t_t equal to the rated duration t_k of short-circuit with a tolerance of the AC component of $^{+5}_{0}$ %.

Method 2: the value of the Joule integral $\int I^2 dt$ of the AC component along the test shall be not less than the value of $I_k^2 \times t_k$ calculated from the rated short-time current (I_k) and the rated duration of short-circuit (t_k), and shall not exceed this value by more than 10 % without the consent of the manufacturer, refer to Annex B (informative).

The following deviations are permitted:

a) if the decrement of the short-circuit of the test laboratory is such that the specified RMS value cannot be obtained for the rated duration without applying initially an excessively high current, the RMS value of the test current may be permitted to fall below the specified value during the test and the duration of the test may be increased appropriately, provided that the value of the peak current is not less than that specified and the time is not extended to more than 5 s;

b) if, in order to obtain the required peak current, the RMS value of the current is increased above the specified value, the duration of the test may be reduced accordingly;

c) separation of the peak withstand current test and the short-time withstand current test is permissible:
   - for the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0,3 s;
   - for the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the rated duration. However, deviation in time according to item a) is permitted.

   for switching devices the test object shall be kept in closed position between the tests;

d) when the characteristics of the test laboratory are such that the frequency of the test current cannot be kept within its specified tolerance for the specified duration, the frequency at the beginning of the test shall be within the specified tolerance and a decrease down to 80 % of the specified frequency is allowed.

7.6.4 Conditions of the GIL after test

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

7.7.1 Verification of the IP coding

In accordance with the requirements specified in Clauses 11, 12, 13 and 15 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013, tests shall be performed, to demonstrate performances as required in 6.14, on the enclosures of switchgear and controlgear fully assembled as under service conditions. As real cable connections entering the enclosures are not normally installed for type tests, corresponding filler pieces shall be used. Transport units of switchgear shall be closed for the tests by covers providing identical protection qualities as for the joints.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts as deemed necessary.

When the supplementary letter W is used, test method given in Annex C (normative) shall be applied.

7.7.2 Verification of the IK coding

The requirements specified in 6.14.4 shall be demonstrated according to IEC 62262:2002; tests shall be performed on the enclosures of switchgear and controlgear fully assembled as under service conditions.

After the test, the enclosure shall show no breaks and the deformation of the enclosure shall not affect the normal function of the equipment, reduce the insulating and/or creepage distances or reduce the specified degree of protection against access to hazardous parts below the permitted values. Superficial damage, such as removal of paint, breaking of cooling ribs or of similar parts, or depression of small dimension can be ignored.

The tests shall, however, be made only if there are doubts regarding the compliance with these requirements, they shall be performed in each position of the relevant parts deemed necessary.

Auxiliary equipment such as meters, relays etc., which may form part of the enclosure is exempted from receiving impacts in this test.

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

7.8.1 General

The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C. Acceptable test condition is an ambient temperature in a range of 15 °C up to 30 °C.

If tightness tests at the temperature limits of the service condition are required in the relevant product standards, an increased leakage rate is permissible. The increased temporary leakage rate shall not exceed the values given in Table 15.

Tightness test shall be performed with the same fluid and under the same pressure (density) as used in service. If the fluid itself is not traceable additional traceable fluids may be added, for example helium. The leakage test method shall have sufficient sensitivity; reference is made to IEC TR 62271-306 [4].

Where possible, the tests should be performed on a complete system. If this is not practical, the tests may be performed on parts, components or subassemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart (refer to IEC TR 62271-306 [4]). The possible leakages between subassemblies of different pressures shall also be taken into account.

The tightness test of switchgear and controlgear containing a mechanical switching device shall be performed both in the closed and open position of the device, unless the leakage rate is independent of the position of the main contacts.

Cumulative leakage measurement, which takes into account all the leaks from a given assembly to determine the leakage rate, shall be used in the calculation of leakage rates.

The type test report should include such information as:

– description of the object under test, including its internal volume and the nature of the filling gas or liquid;
– whether the object under test is in the closed or open position (if applicable);
– the pressures and temperatures recorded at the beginning and end of the test and the number of replenishments (if any needed);
– the value of the ambient temperature during the test.
– the cut-in and cut-off pressure settings of the pressure (or density) control or monitoring device;
– an indication of the calibration of the meters used to detect leakage rates;
– the results of the measurements;
– the test gas and if applicable the conversion factor to assess the results.

In general, for the application of an adequate test method, reference is made to IEC 60068-2-17:1994 [31].

Table 12 – Permissible leakage rates for gas systems

Temperature °C	Permissible leakage rate
Maximum service temperature (≥ 40 °C)	$3F_p$
Standardized ambient temperature (20 °C)	F_p
Minimum service temperature (any value down to and including -40 °C)	$3F_p$
Minimum service temperature (any value below -40 °C)	$6F_p$

7.8.2 Controlled pressure systems for gas

Preferred method for checking the relative leakage rate F_{rel} is by measuring the pressure drop Δp over a time period t that is of sufficient duration to permit a determination of the pressure drop (within the filling and replenishing pressure range). A correction shall be made to take into account the variation of ambient air temperature during the course of the test. During this period the replenishment device shall be inoperative.

$$F_{rel} = \frac{\Delta p}{p_r} \times \frac{24}{t} \times 100 \text{ (\% per day)}$$

$$N = \frac{\Delta p}{p_r - p_m} \times \frac{24}{t}$$

where

t is the test duration (h);

p_r is the filling pressure (Pa);

p_m is the measured pressure after time t (Pa);

Δp is the pressure drop between p_r and p_m after time t (Pa);

N is the number of replenishments per day.

NOTE The linearity of the formula is considered to be maintained provided that Δp is of the same order of magnitude as $p_r - p_m$.

7.8.3 Closed pressure systems for gas

The test Q_m (Test method 1: cumulative test) described in IEC 60068-2-17:1994 is the preferred method to determine the relative leakage rate F_{rel} in gas systems and calculate the time between replenishments t_r. Detailed information about test procedure, sensitivity of measurement and example of calculation are also given in IEC TR 62271-306 [4].

Alternative methods of leak detection are also given in IEC TR 62271-306 [4] that may be used to measure the leakage rate, which allows in combination with the tightness coordination chart, the calculation of:

– the relative leakage rate;
– the time between replenishments (without considering extreme temperature conditions of number of operations).

The tightness test is considered to be successful when the measured leakage rate does not exceed the permissible leakage rate stated in Table 15 within the limits of +10 %. This inaccuracy of the measurement shall be taken into account when calculating the period of time between replenishments.

7.8.4 Sealed pressure systems

Tightness tests on sealed pressure systems shall be as follows

a) Switchgear using gas

   The tests shall be performed according to the preferred method of 7.8.3.

b) Switchgear using vacuum interrupters

   No specific tightness tests are required for vacuum interrupters since their tightness is verified during manufacturing process and because they are considered to have a zero leakage rate during their life. Nevertheless, instead of a tightness test, the vacuum integrity needs to be verified where specific standards ask for a tightness test as condition check (for example mechanical test, low and high temperature tests, etc.).

   The integrity of the vacuum may be verified by the dielectric condition check test, refer to 7.2.12.

7.8.5 Liquid tightness tests

The purpose of tightness tests is to demonstrate that the total system leakage rate F_{liq} does not exceed the specified value $F_{p(liq)}$.

The object under test shall be as in service conditions with all its accessories and its normal fluid, mounted as close as possible as in service.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) and/or during operations is acceptable, provided that this rate resets to the initial value after the temperature is returned to normal ambient air temperature and/or after the operations are performed. The increased temporary leakage rate shall not impair the safe operation of the switchgear and controlgear.

The switchgear shall be observed over a period sufficient to determine a possible leak or the pressure drop Δp_{liq}. In this case, the calculations given in 7.8.2 are valid.

As an alternative, using liquids different from those in service or gas for the test is possible but requires justification by the manufacturer.

The test report shall include such information as:

– a general description of the object under test;
– the number of operations performed;
– the nature and pressure(s) of the liquid;
– the ambient air temperature during test;
– the results with the switchgear device in closed and in open position (where applicable).

7.9 Electromagnetic compatibility tests (EMC)

Not applicable.

7.10 Additional test on auxiliary and control circuits

Not applicable.

7.11 X-radiation test procedure for vacuum interrupters

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

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

The pressure test requirements shall be at least as follows:

- Cast aluminium and composite aluminium enclosures
  – type test pressure = [3,5 / 0,7] × design pressure

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

- Welded aluminium and welded steel enclosures
  – type test pressure = $[(2,3 / \nu) \times (\sigma_t / \sigma_a)]$ × design pressure

  where

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

  σ_t is the permissible design stress at test temperature;

σ_a is the permissible design stress at design temperature.

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

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

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

7.101.3 Non-destructive pressure test

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

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

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

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

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

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

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

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

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

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

where

p is the design pressure;

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

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

σ_t is the permissible design stress at test temperature;

σ_a is the permissible design stress at design temperature.

7.102 Pressure test on partitions

The purpose of this test is to demonstrate the safety margin of the partition submitted to pressure in service condition. For further information, see EN 50089 [19].

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

The type test pressure shall be three times the design pressure.

7.103 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

The routine tests are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practicable at the manufacturer's works on each apparatus manufactured. By agreement, any routine test may be made on site.

The routine tests given in this document comprise:

a) dielectric test on the main circuit in accordance with 8.2;
b) tests on auxiliary and control circuits in accordance with 8.3;
c) measurement of the resistance of the main circuit in accordance with 8.4;
d) tightness test in accordance with 8.5;
e) design and visual checks in accordance with 8.6.

Additional routine tests may be necessary and are, when needed, specified in the relevant IEC standards.

When switchgear and controlgear is not completely assembled before transport, separate tests shall be made on all transport units. In this event, the manufacturer shall demonstrate the validity of this test (for example, leakage rate, test voltage, resistance of part of the main circuit).

Test reports of the routine tests are not required unless otherwise agreed upon between the manufacturer and the user.

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

A dry, short-duration power-frequency voltage test shall be applied. The test procedure shall be according to IEC 60060-1:2010 and to 7.2, except that each pole or transport unit shall be tested. For sealed pressure systems, the test shall be made at the filling pressure for insulation.

The test voltage shall be the rated short-duration power-frequency withstand voltage specified in column 2 of Tables 1 through 4.

When the insulation of switchgear and controlgear is provided only by solid-core insulators and air at ambient pressure, the power-frequency voltage withstand test may be omitted if the dimensions between the conductive parts – between phases, across open switching devices and between conductive parts and the frame – are checked by dimensional measurements.

Bases for the checking of dimensions are the dimensional (outline) drawings, which are part of the type test report (or are referred to in it) of the particular switchgear and controlgear. Therefore, in these drawings all information necessary for dimensional checking including the permissible tolerances shall be given.

8.3 Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to the circuit diagrams and wiring diagrams

The nature of the materials, the quality of assembly, the finish and, if necessary, the protective coatings against corrosion shall be checked. A visual inspection is also necessary to check the satisfactory installation of the thermal insulation, if any.

A visual inspection of actuators, interlocks, locks, etc., shall be made.

Components for auxiliary and control circuits inside enclosures shall be checked for proper mounting. The location of the means provided for connecting external wiring shall be checked to ensure that there is sufficient wiring space for spreading of the cores of multi-core cables and for the proper connection of the conductors.

The conductors and cables shall be checked for proper routing. Special attention shall be given to ensure that no mechanical damage can occur to conductors and cables due to the proximity of sharp edges or heating elements, or to the movement of moving parts.

Furthermore, the identification of components and terminals and, if applicable, the identification of cables and wiring shall be verified. In addition, the conformity of auxiliary and control circuits to the circuit diagrams and wiring diagrams shall be checked.

8.3.2 Functional tests

Functional tests are specified, where relevant, in the relevant IEC product standards. When specified, they shall be made on all auxiliary and control circuits to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device.

Operation tests on auxiliary and control circuits, subassemblies and components may be omitted if they have been fully tested during a test applied to the whole switchgear and controlgear.

8.3.3 Verification of protection against electrical shock

Protection against direct contact with the main circuit and safe accessibility to the auxiliary and control equipment parts liable to be touched during normal operation shall be checked. The preferred method is by visual inspection.

Where visual inspection cannot provide confirmation of the electrical continuity of earthed metallic parts, the alternative procedure defined in 7.4.3 shall be applied.

8.3.4 Dielectric tests

Only power frequency tests shall be performed. This test shall be made under the same conditions as those detailed in 7.10.5.

The test voltage shall be 1 kV with duration of 1 s.

8.4 Measurement of the resistance of the main circuit

For the routine test, the DC voltage drop or resistance of each pole of the main circuit shall be measured under conditions as nearly as possible similar, with regard to ambient air temperature and points of measurement, to those under which the corresponding measurement before the continuous current test was made. The test current shall be within the range stated in 7.4.4.

The measured resistance shall not exceed $1{,}2 \times R_u$, where R_u is equal to the resistance measured before the continuous current test.

In the case of assemblies it may be necessary to calculate the expected resistance based on relevant type tests.

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

8.5.1 General

Routine tests shall be performed to demonstrate the tightness criteria according to 6.16 at ambient temperature with the switchgear parts, components or subassemblies at or above the minimum functional pressure (or density) for insulation.

8.5.2 Controlled pressure systems for gas

The test procedure corresponds to 7.8.2.

8.5.3 Closed pressure systems for gas

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and subassemblies.

For parts or subassemblies tested in factory, the cumulative test is the preferred method.

For gas-filled systems tested in factory, the probing test using a sniffing device may be used. If any leak is detected, the test shall be considered to be failed or the leak shall be quantified by using a cumulative method.

For routine tests at site, the probing test using a sniffing device is the preferred method.

The sensitivity of the sniffing device shall be at least 10^{-8} Pa × m^3/s.

8.5.4 Sealed pressure systems

Depending on the insulation medium two situations are considered:

a) Switchgear using gas

The preferred test procedure corresponds to 7.8.4, item a).

An alternative test procedure corresponds to the sealing tracer gas test with mass spectrometer, refer to IEC 60068-2-17:1994 [31].

b) Switchgear using vacuum interrupters

The vacuum tightness shall be demonstrated by a dielectric test according to 7.2.12 carried out after the mechanical routine test specified in the relevant product standards.

8.5.5 Liquid tightness tests

Routine tests shall be performed at normal ambient air temperature with the completely assembled switchgear and controlgear device. Testing of subassemblies is also permissible. In this case, a final check shall be performed at site.

The test methods correspond to those of the type tests (refer to 7.8.5).

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

The switchgear and controlgear shall be checked to verify its compliance with the purchase specification, if any.

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)

9.1 General

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.

9.2 Selection of rated values

The rated values should be chosen in accordance with this document having regard for the characteristics of the system as well as its anticipated future development. A list of ratings is given in Clause 5.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltage, the type of neutral earthing of the system and the type of overvoltage limiting devices (see IEC 60071-2:1996). Other parameters, such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m, should also be considered.

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the switchgear and controlgear is to be located in the system. Reference is made to IEC 60909-0 [33] and IEC TR 60909-1 [34] in this regard.

9.3 Cable-interface considerations

For connection to cables, the maximum temperature at the terminals at full continuous current should be below the temperature limits of the cable insulation and cable termination.

9.4 Continuous or temporary overload due to changed service conditions

Equipment could be required to carry a load current above its rated continuous current during a short period of time or when ambient temperatures are favourable to do it provided the temperature does not exceed the maximum temperature value specified in Table 14; reference is made to IEC TR 62271-306 [4].

NOTE For certain devices (e.g. load break switches) the temporary overload could result in a load current that exceeds the switching capability of the switchgear.

9.5 Environmental aspects

9.5.1 Service conditions

Selected switchgear and controlgear and its associated operating devices and auxiliary equipment should be designed and validated to comply with at least the specific service conditions required by the user or appropriate arrangements should be made.

9.5.2 Clearances affected by service conditions

Where clearances may be compromised by environmental related changes in the service access level (for example accumulation of snow, sand, etc.) the use of increased clearances should be considered.

9.5.3 High humidity

For the normal service conditions present in 4.1.2 e), condensation may occasionally occur on, or in, indoor switchgear and controlgear.

To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions should be used.

Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear.

High humidity may also be due to ground level rainwater or for cable-connected applications of underground network applications from incoming cable raceways connected to switchgear.

9.5.4 Solar radiation

Under certain levels of solar radiation, appropriate measures, for example roofing, forced ventilation etc., may be necessary, or derating may be used, in order not to exceed the specified temperature and pressure rise limits. Tests with simulated solar gain may be used to demonstrate if measures or derating are needed.

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)

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

It is essential that the transport, storage and installation of switchgear and controlgear, as well as their operation and maintenance in service, is performed in accordance with instructions given by the manufacturer.

Consequently, the manufacturer shall provide the appropriate version of the instruction manual for the transport, storage, installation, operation and maintenance of switchgear and controlgear. The instructions for the transport and storage should be given at a convenient time before delivery, and the instructions for the installation, operation and maintenance should be given by the time of delivery at the latest. It is preferable that the operation manual be a separate document from the installation and maintenance manual.

It is impossible, here, to cover in detail the complete rules for the installation, operation and maintenance of each one of the different types of apparatus manufactured, but the following information is given relative to the most important points to be considered for the instructions provided by the manufacturer.

11.2 Conditions during transport, storage and installation

A special agreement should be made between manufacturer and user if the service conditions of temperature and humidity defined in the order cannot be guaranteed during transport, storage and installation. Special precautions may be essential for the protection of insulation during transport, storage and installation, and prior to energizing, to prevent moisture absorption due, for instance, to rain, snow or condensation. Vibrations during transport should be considered. Appropriate instructions should be given by the manufacturer.

Special packaging should be proposed by the manufacturer for long term storage of parts for maintenance needs according to customer specifications.

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

For each type of switchgear and controlgear the instructions provided by the manufacturer shall include at least the items listed below.

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

Each complete equipment shall be provided with adequate lifting facilities and labelled (externally) to show the correct method of lifting. The equipment shall be labelled (externally) to indicate its maximum mass, in kg, when fully equipped. Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site).

Required information for unpacking should be given.

11.3.3 Assembly

When the switchgear and controlgear is not fully assembled for transport, all transport units should be clearly marked. Drawings showing assembly of these parts should be provided with the switchgear and controlgear.

11.3.4 Mounting

Instructions for the mounting of switchgear and controlgear, operating device and auxiliary equipment should include sufficient details of locations and foundations to enable site preparation to be completed.

These instructions should also indicate:

– the total mass of the apparatus inclusive of extinguishing or insulating fluids;
– the mass of extinguishing or insulating fluids;
– the mass of each unit to be lifted separately.

11.3.5 Connections

Instructions should include information on:

– connection of conductors, comprising the necessary advice to prevent overheating and unnecessary strain on the switchgear and controlgear and to provide adequate clearance distances;
– connection of auxiliary circuits;
– connection of liquid or gas systems, if any, including size and arrangement of piping;
– connection for earthing;
– auxiliary contacts available to the user.

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

For controlled and closed pressure systems filled with gas mixture, the percentage of the different gases and their associated tolerances shall be defined by the manufacturer taking into account handling and uncertainty of measurement. Appropriate gas filling procedures are defined in IEC 62271-4.

During commissioning or maintenance, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling pressure (density) for insulation shall be checked by dew point measurement. Appropriate correction factors shall be used for measurements performed at temperatures other than 20 °C according to the manufacturer´s instruction manual.

The maximum allowable humidity content for equipment filled or re-filled with new or used gas should be such that the dew point inside the switchgear compartment is not higher than

– −10 °C for equipment with adsorber material;
– −15 °C for equipment without adsorber material

during commissioning or after maintenance for a measurement at filling pressure (density) for insulation and at 20 °C.

NOTE 1 These dew point values during commissioning are expected to give a dew point value lower than -5 °C during service life, for a measurement at 20 °C.

NOTE 2 The measurement of the dew point is specified at a given temperature due to the possible exchange of water between gas and solid materials when the temperature changes, which could change the measured value.

NOTE 3 An example of measurement and determination of the dew point is given in IEEE C37.122.5 [35].

11.3.7 Final installation inspection

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

These data should include:

a) access limitations to the local site;
b) local working conditions and any restrictions that may apply (for example, safety equipment, normal working hours, union requirements for supervisor, manufacturer's and local installation crew, etc.);
c) availability and capacity of lifting and handling equipment;
d) availability, number and experience of local personnel;
e) specific pressure vessel rules and procedures that may apply during installation and commissioning tests;
f) interface requirements for high-voltage cables and transformers;
g) in the case of extensions to existing switchgear and controlgear:
    1) provisions for the extension available within existing primary and secondary equipment;
    1) in-service conditions or operating restrictions that apply;
    2) safety regulations that locally apply.

11.3.9 Basic input data by the manufacturer

These data should include:

a) space necessary for installation and assembly;
b) size and weight of components and testing equipment;
c) site conditions regarding cleanliness and temperature for clean installation and preparation area;
d) number and experience of local personnel required for installation;
e) time and activity schedules for installation and commissioning;
f) electric power, lighting, water and other needs for installation and commissioning;
g) proposed training of installation and service personnel;
h) in case of extension to existing switchgear and controlgear:
    1) out-of-service requirements of existing components related to the installation schedule;
    2) safety precautions.
i) gas filling procedure (mixed gases) and dew point verification, if necessary.

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

The operating instructions given by the manufacturer shall contain the following information:

- a general description of the equipment with particular attention to the technical description of its characteristics and operation so that the user has an adequate understanding of the main principles involved;
- a description of the safety features of the equipment and the operation of the interlocks and padlocking facilities;
- as relevant, a description of the action to be taken to manipulate the equipment for operation isolation, earthing, maintenance, and testing;
- as relevant, measures against corrosion should be given.

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 manu-facturer 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

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

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

Where applicable, the following information shall be provided by the manufacturer:

a) type and required quantity and quality of liquid to be used in switchgear and controlgear;

b) type and required quantity and quality of gas to be used in switchgear and controlgear.

11.5.3 Recommendations for the manufacturer

The manufacturer should be responsible for ensuring the continued availability of spare parts required for maintenance for a period of not less than 10 years from the date of final manufacture of the switchgear and controlgear.

The manufacturer should inform the purchasers of a particular type of switchgear and controlgear about corrective actions required by systematic defects and failures detected in service.

The manufacturer's maintenance manual should include the following information listed below.

a) Extent and frequency of maintenance. For this purpose the following factors should be considered:
   1) switching operations (current and number);
   2) total number of operations;
   3) time in service (periodic intervals);
   4) environmental conditions;
   5) activity after a seismic event (if applicable);
   6) measurements and diagnostic tests, (if any).

b) Detailed description of the maintenance work:
   1) recommended place for the maintenance work (indoor, outdoor, in factory, on site, etc.);
   2) procedures for inspection, diagnostic tests, examination, overhaul;
   3) reference to drawings;
   4) reference to part numbers;
   5) use of special equipment or tools;
   6) precautions to be observed (for example cleanliness and possible effects of harmful arcing by-products);
   7) lubrication procedures.

c) Comprehensive drawings of the details of the switchgear and controlgear important for maintenance, with clear identification (part number and description) of assemblies, subassemblies and significant parts.

NOTE Expanded detail drawings which indicate the relative position of components in assemblies and subassemblies are a common illustration method.

d) Limits of values, which can be measured during operation or routine maintenance and tolerances which, when exceeded, make corrective action necessary, for example:

   1) pressures, density levels, gas mixtures tolerance;
   2) resistance and/or capacitance (of the main circuit);
   3) operating times;
   4) resistance of the main circuits;
   5) insulating liquid or gas characteristics;
   6) quantities and quality of liquid or gas (see IEC 60480 and IEC 62271-4 for SF_6);
   7) dew point inside gas-filled switchgear compartment according to 11.3.6;
   8) permissible erosion of parts subject to wear;
   9) torques;
   10) important dimensions.

e) Specifications for auxiliary maintenance materials, including warning of known non-compatibility of materials:

   1) grease;
   2) oil;
   3) fluid;
   4) cleaning and degreasing agents.

f) List of special tools, lifting and access equipment.

g) Tests after the maintenance work.

h) List of the recommended spare parts (description, reference number, quantities) and advice for storage.

i) Estimate of active scheduled maintenance time, carried out in accordance with an established time schedule.

j) How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

11.5.4 Recommendations for the user

If the user wishes to perform maintenance, the maintenance manual of the manufacturer should be followed.

The user should record the following information:

– the serial number and the type of the switchgear and controlgear;
– the date when the switchgear and controlgear is put in service;
– the results of all measurements and tests including diagnostic tests carried out during the life of the switchgear and controlgear;
– dates and extent of the maintenance work carried out;
– the history of service, periodical records of the operation counters and other indications (for example short-circuit operations);
– references to any failure report.

In case of failure and defects, the user should make a failure report and should inform the manufacturer by stating the special circumstances and measures taken. Depending upon the nature of the failure, an analysis of the failure should be made in collaboration with the manufacturer.

11.5.5 Failure report

The purpose of the failure report is to standardize the recording of the switchgear and controlgear failures with the following objectives:

– to describe the failure using a common terminology;
– to provide data for the user statistics;
– to provide a meaningful feedback to the manufacturer.

The following gives guidance on how to make a failure report.

A failure report should include the points listed below.

a) Identification of the switchgear which failed:
   1) substation name;
   2) identification of the switchgear (manufacturer, type, serial number, ratings);
   3) switchgear technology (air blast, minimum oil, SF_6, vacuum);
   4) location (indoor, outdoor);
   5) enclosure;
   6) drive mechanism, if applicable (hydraulic, pneumatic, spring, motor, manual).
b) History of the switchgear:
   1) date of commissioning of the equipment;
   2) date of failure/defect;
   3) total number of operating cycles, if applicable;
   4) date of last maintenance;
   5) details of any changes made to the equipment since manufacture;
   6) total number of operating cycles since last maintenance;
   7) condition of the switchgear when the failure/defect was discovered (in service, maintenance, etc.).
c) Identification of the subassembly/component responsible for the primary failure/defect:
   1) high-voltage stressed components;
   2) electrical control and auxiliary circuits;
   3) drive mechanism, if applicable;
   4) other components.
d) Stresses presumed to contribute to the failure/defect:
   1) operation mistake or misuse of the equipment;
   2) environmental conditions (temperature, wind, rain, snow, ice, pollution, lightning, etc.).
e) Classification of the failure/defect:
   1) major failure;
   2) minor failure;
   3) defect.
f) Origin and cause of the failure/defect:
   1) origin (mechanical, electrical, tightness if applicable);

2) cause (design, manufacture, inadequate instructions, incorrect mounting, incorrect maintenance, stresses beyond those specified, etc.)
3) operation mistake or misuse.

g) Consequences of the failure or defect:
1) switchgear down-time, which is time interval during which an item is in a down state;
2) time consumption for repair;
3) labour cost;
4) cost of spare parts.

A failure report may include the following information:

– drawings, sketches;
– photographs of defective components;
– single-line station diagram;
– operation and timing sequences;
– records or plots;
– references to maintenance or operating manuals.

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

High-voltage switchgear and controlgear, complying with the applicable IEC standards, can be considered safe when installed in accordance with the relevant installation rules including instructions provided by the manufacturers and used and maintained in accordance with the manufacturer's instructions (see Clause 11).

High-voltage switchgear and controlgear is normally only accessible by instructed persons. Performing operations and maintenance is only allowed to skilled persons. When unrestricted access is available to switchgear and controlgear, additional safety features may be required.

High-voltage switchgear and controlgear in accordance with IEC offers a high level of safety with regard to external effects that might harm personnel, mainly because the high-voltage parts may be surrounded by an enclosure. Nevertheless, high power equipment, can comprise some potential risks, some examples are:

- the enclosures, if any, may be pressurized with gas;
- pressure-relief devices may open due to exceptional conditions, e.g. resulting from an internal arc. In extreme circumstances, the arc can burn through the enclosures. Both result in the sudden release of hot gas;
- sudden events, which are in themselves with low risk to humans, may alarm personnel and lead to accidents (for example, a fall);
- commissioning, maintenance and extension activities may require special attention due to the complexity of the equipment and its internal parts which are mostly not visible.

Experience has shown that human error is a factor that shall be considered (for example, closing an earthing switch on an energized conductor).

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

The following list provides examples of precautions usually implemented by manufacturers.

– design and test pressurized enclosures, pressure relief devices and relevant switchgear elements to international established standards;
– provide adequate and easy means to check interlocking systems (the most reasonable way to avoid human error);
– explain safe operation of the switchgear and controlgear clearly in instruction manuals. Explain precautions to prevent improper operation and the consequences of improper operation;
– provide the user and/or contractor with appropriate information related to design of the surrounding area, possibly ventilation and gas detection information, to minimize personnel risks in case a failure occurs;
– provide safe procedures for dismantling and disposal.

12.3 Precautions by users

The following list provides examples of precautions that may be taken by users:

– limit access to the installation to people who are trained and authorized;
– keep operators and other personnel instructed regarding risks and safety requirements including local regulations;
– keep switchgear and controlgear maintained and up to date in terms of technical standards, especially interlocking and protection devices;
– use remote control and have the interlocking system working as intended;
– select equipment that minimizes the risk to personnel from improper operation (for example earthing switches with short-circuit making capacity on lines, motor actuators to allow remote operation);
– coordinate the protection system with product properties (for example, do not reclose on internal faults);
– prepare earthing procedures considering the difficulty of referring to and understanding the complex arrangement and operation of the switchgear and controlgear;
– label equipment clearly for easy identification of individual devices and gas compartments.

Especially during maintenance, repair or extension work:

– ensure that maintenance, repair and extension work is carried out only by qualified and trained personnel;
– prepare a safety and protection plan for the work. Indicate who is responsible for planning, implementing and enforcing safety and protection measures;
– check interlocking and protection devices before starting;
– pay special attention to manual operations, especially when the switchgear and controlgear is energized;
– inform personnel who may be near the switchgear and controlgear before operating the equipment (for example, a horn or flashing light);
– mark emergency exits and keep passages clear of obstructions;
– instruct the people involved how to work safely in a switchgear and controlgear environment and what to do in an emergency.

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

Documentation shall include the following relevant information about the environmental impact of the switchgear:

a) When fluids are used in switchgear and controlgear, instructions shall be provided in order to allow the user to:

1) minimize the leakage rate as far as is practicable;

2) control the handling of the new and used fluids. IEC 62271-4 is referred to for SF_6 and its mixtures refer to IEC 62271-4.

b) Instructions concerning disassembly and end-of-life procedures for the different materials of the equipment and indicate the possibility to recycle.

Also refer to 11.5.102.

Annex A
(normative)

Identification of test objects

A.1 General

For identification of a test object, the following topics shall be covered.

A.2 Data

– Manufacturer's name;
– Type designation, ratings and serial number of apparatus;
– Outline description of apparatus (including number of poles, interlocking system, busbar system, earthing system, and the arc extinguishing process);
– Make, type, serial numbers, ratings of essential parts, where applicable (for example, drive mechanisms, interrupters, shunt impedances, relays, fuse links, insulators);
– Rated characteristics of fuse links and protective devices;
– Whether the apparatus is intended for operation in the vertical and horizontal plane.

A.3 Drawings

Drawings to be submitted	Drawing content (as applicable)
Single-line diagram of main circuit	Type designation of principal components
General layout NOTE For an assembly it may be necessary to provide drawings of the complete assembly and of each switching device.	Overall dimensions Supporting structure and mounting points Enclosure(s) Pressure-relief devices Conducting parts of main circuit Earthing conductors and earthing connections Electrical clearances: – to earth, between open contacts; – between poles. Location and dimensions of barriers between poles Location of earthed metallic screens, shutters or partitions in relation to live parts Liquid insulation level Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulant in filled boxes Cable termination details

Drawings to be submitted	Drawing content (as applicable)
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Identity of springs Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and drive mechanisms)	Arrangement and identity of main components of the kinematic chains to: – main contacts; – auxiliary switches; – pilot switches; – position indication. Latching device Assembly of drive mechanism Interlocking devices Identity of springs Control and auxiliary devices
Electrical diagram of auxiliary and control circuits (if applicable)	Type designation of all components

Annex B
(informative)

Determination of the equivalent RMS value of a short-time current during a short-circuit of a given duration

The method illustrated in Figure B.1 could be used to determine the short-time current, if no digital equipment provides the proper computation (refer to 7.6.3).

The total time t_t of the test is divided into 10 equal parts by verticals 0 – 0,1... 1 and the RMS value of the AC component of the current is measured at these verticals.

These values are designated: Z_0, Z_1... Z_{10}

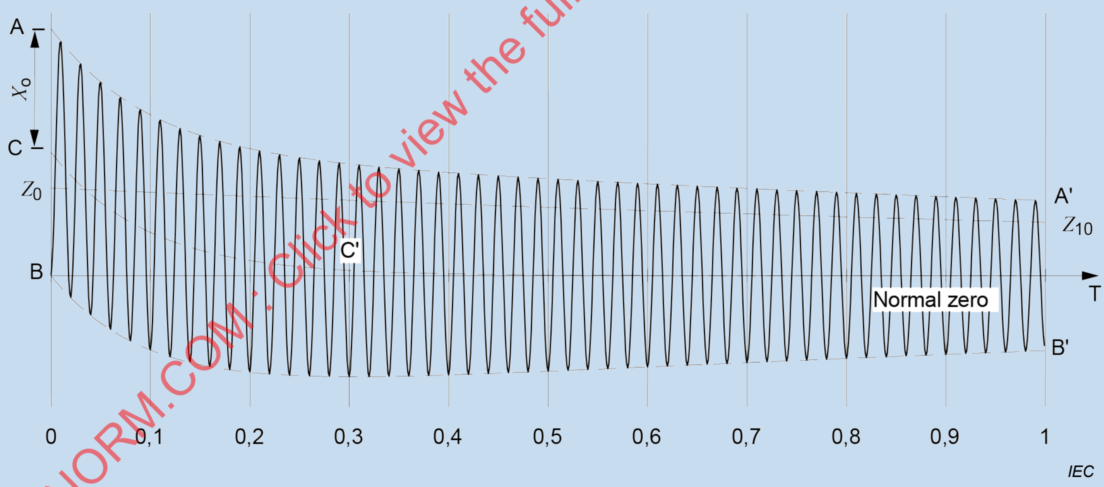
where

$Z = X/\sqrt{2}$ and X is the peak value of AC component of current.

The equivalent RMS current during the time t_t is given by:

$$I_t = \sqrt{\frac{1}{30}\left[Z_0^2 + 4\left(Z_1^2 + Z_3^2 + Z_5^2 + Z_7^2 + Z_9^2\right) + 2\left(Z_2^2 + Z_4^2 + Z_6^2 + Z_8^2\right) + Z_{10}^2\right]}$$

The DC component of current represented by CC' is not taken into account.



Key

AA' BB'	Envelopes of current wave
CC'	Displacement of current wave zero line from normal zero line at any instant
$Z_0 \ldots Z_{10}$	RMS value of AC component of current at any instant measured from normal zero
X_0	Peak value of AC component of current at instant of initiating short-circuit
BT	Duration of short-circuit, t_t

Figure B.1 – Determination of short-time current

Annex C
(normative)

Method for the weatherproofing test for outdoor switchgear and controlgear

The switchgear and controlgear to be tested shall be fully equipped and complete with all covers, screens, bushings, etc., and placed in the area to be subjected to with artificial precipitation. For switchgear and controlgear comprising several functional units a minimum of two units shall be used to test the joints between them.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the surfaces under test. The various parts of the switchgear and controlgear may be tested separately, provided that a uniform spray is simultaneously applied also to both of the following:

a) the top surfaces from nozzles located at a suitable height;
b) the floor outside the equipment for a distance of 1 m in front of the parts under test with the equipment located at the minimum height above the floor level specified by the manufacturer.

Where the width of the equipment exceeds 3 m, the spray may be applied to 3 m wide sections in turn. Pressurized enclosures need not be submitted to artificial precipitation.

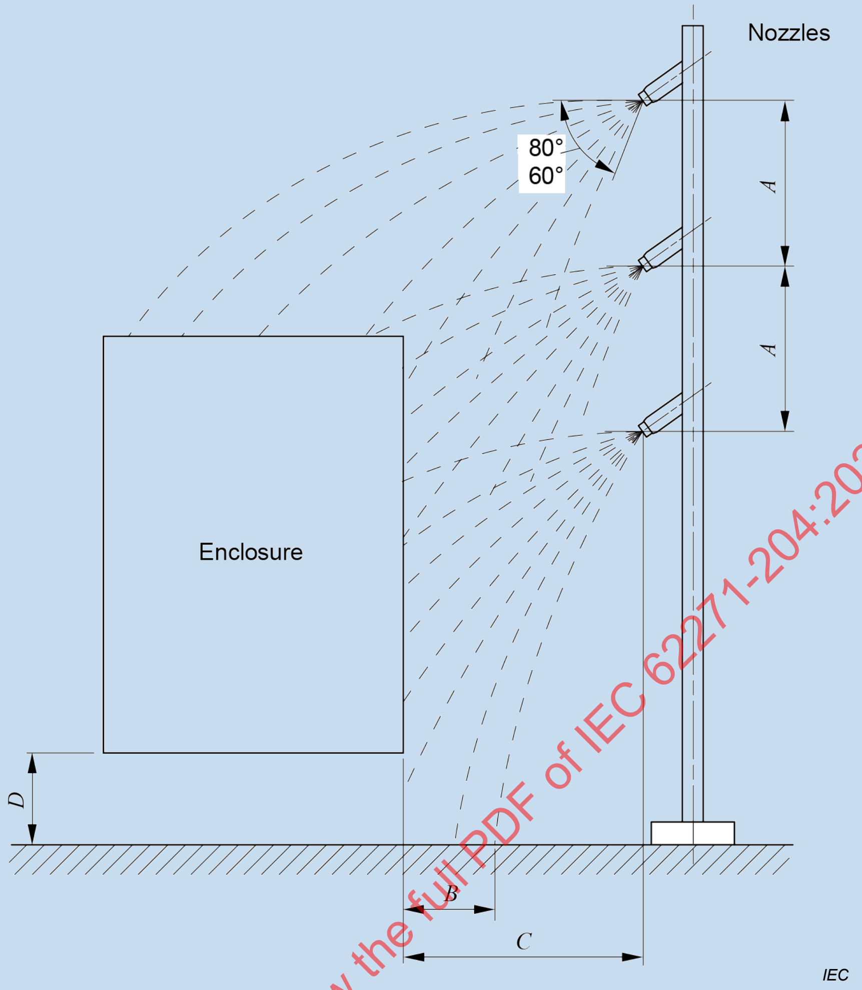
Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 3 l/min at a pressure of 460 kPa ± 46 kPa and a spray angle of 60° to 80°. The centre lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal as it is directed towards the surfaces being tested. It is convenient to arrange the nozzles on a vertical stand-pipe and to space them about 2 m apart (refer to test arrangement in Figure C.1).

The pressure in the feed pipe of the nozzles shall be 460 kPa ± 46 kPa under flow conditions. The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for duration of 5 min. The spray nozzles shall be at a distance between 2,5 m and 3 m from the nearest vertical surface under test.

NOTE When a nozzle in accordance with Figure C.2 is used, the quantity of water is considered to be in accordance with this standard when the pressure is 460 kPa ±10 %.

After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met:

a) no water shall be visible on the insulation of the main and auxiliary circuits;
b) no water shall be visible on any internal electrical components and drive mechanisms of the equipment;
c) no significant accumulation of water shall be retained by the structure or other non-insulating parts (to minimize corrosion).



A	About 2 m
B	1 m
C	2,5 m to 3 m
D	Minimum height above floor

Figure C.1 – Arrangement for weatherproofing test

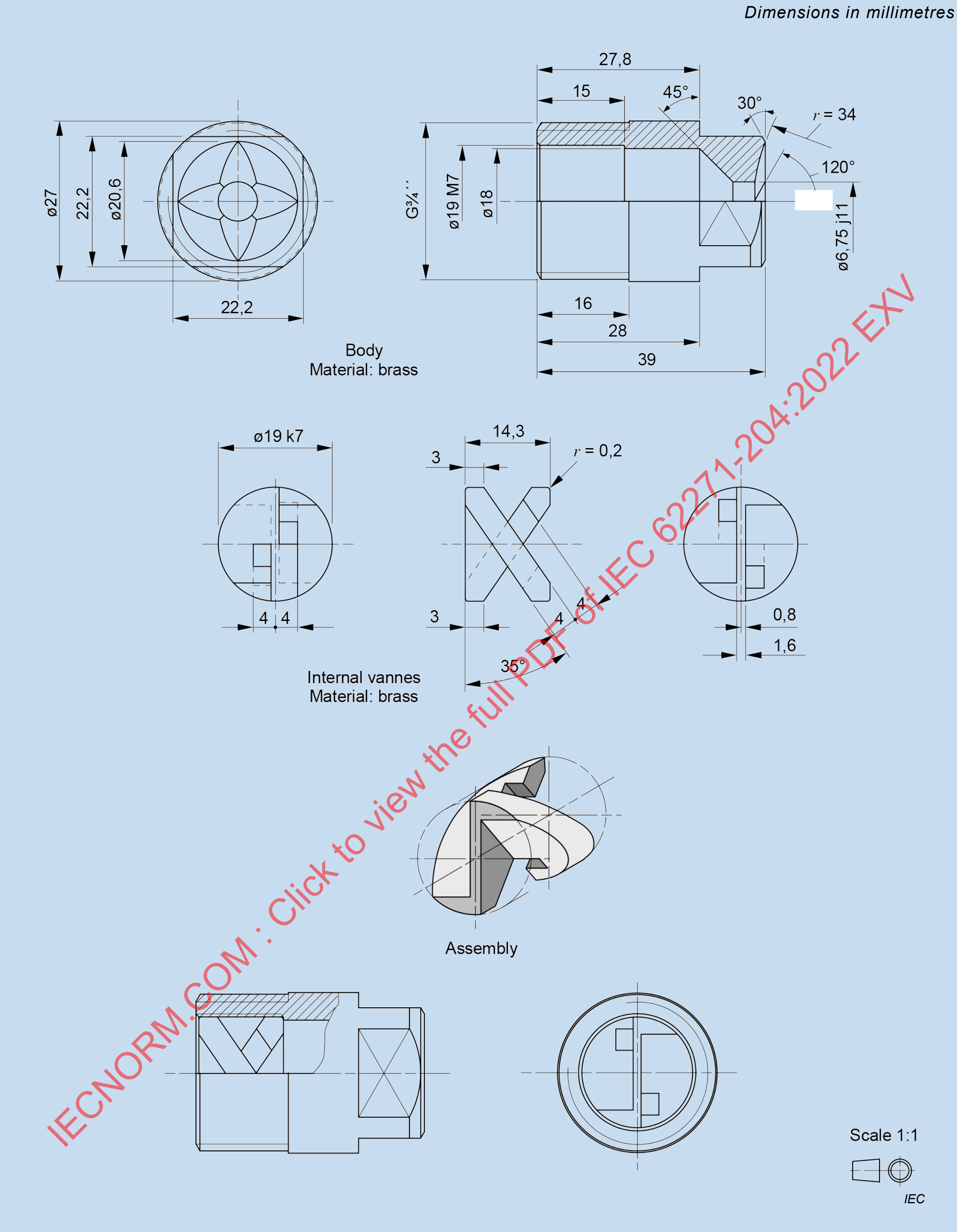


Figure C.2 – Nozzle for weatherproofing test

Annex D
(informative)

References for auxiliary and control circuit components

Table D.1 is provided as a quick reference to many of the component standards. The latest editions should be used.

Table D.1 – List of reference documents for auxiliary and control circuit components *(1 of 2)*

Device		IEC standard
Cables and wiring	Insulation of PVC wiring	IEC 60227 (all parts) [36]
	Size and area of conductors	IEC 60228 [37]
	Insulation of rubber cable	IEC 60245 (all parts)[38]
	Identification	IEC 60445 [39]
Terminals	Terminal blocks for round wire	IEC 60947-7-1 [40]
	Protective terminal blocks for round wire	IEC 60947-7-2 [41]
	Identification	IEC 60445 [39]
Relays	All-or-nothing relays	IEC 61810 (all parts) [42]
	Voltage ratings and operating range of all-or-nothing relays	IEC 61810-1 [43]
	Performance of relay contacts	IEC 61810-2 [44]
Contactors and motor starters	Electromechanical contactors for closing and opening electrical circuit	IEC 60947-4-1 [45]
	Electromechanical contactors combined with relay for short-circuit protection	IEC 60947-2 [46]
	Motor starters (AC)	IEC 60947-4-1 [45]
	AC semiconductor motor controllers	IEC 60947-4-2 [47]
	Motor protective overload relays	IEC 60947-4-1 [45]
Low-voltage switches	Low-voltage switches for motor circuits and distribution circuits	IEC 60947-3 [48]
	Manual control switches and push-buttons	IEC 60947-5-1 [49]
	Pilot switches: pressure, temperature switches etc.	IEC 60947-5-1 [49]
	Household humidity sensing controls	IEC 60730-2-13 [50]
	Household switches	IEC 60669-1 [51]
	Household thermostats	IEC 60730-2-9 [52]
	Lever (toggle) switch	IEC 61020-1 [53]
	Graphical symbols for manual switches	IEC 60417 [26]
	Colours of lights for manual switches	IEC 60073 [25]

Table D.1 *(2 of 2)*

Device		IEC standard
Low-voltage circuit-breakers and low-voltage circuit-breakers with residual current protection	Requirements	IEC 60947-2 [46]
Low-voltage fuses	General requirements	IEC 60269-1 [54]
	Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K	IEC 60269-2 [55]
Low-voltage disconnectors	Requirements	IEC 60947-3 [48]
Motors	Requirements	IEC 60034-1 [56]
Meters	Analogue meters	IEC 60051-1 [57]
	Ammeters and voltmeters	IEC 60051-2 [58]
	Frequency meters	IEC 60051-4 [59]
	Phase-angle and power-factor meters	IEC 60051-5 [60]
Lamp used as an indicator	Requirements	IEC 60947-5-1 [49]
	Graphical symbols	IEC 60417 [26]
	Colour lights	IEC 60073 [25]
Plugs, socket-outlets, and couplers	Requirements for plugs, sockets-outlet, industrial cable couplers, appliance couplers	IEC 60309-1 [61]
	Dimensional and interchangeability	IEC 60309-2 [62]
	Household plugs, socket-outlets and couplers	IEC TR 60083 [63]
	Other couplers and plugs	IEC 60130 (all parts) [64]
Printed circuit-boards	Requirements	IEC 62326-1 [65]
Resistors	Potentiometers	IEC 60393-1 [66]
	Resistors 1 W to 1 000 W	IEC 60115-4 (all parts) [67]
Illumination	Illumination fluorescents	IEC 60081 [68]
	Tungsten filament lamps	IEC 60064 [69]
NOTE For electronic components used in auxiliary and control equipment additional information can be found in IEC TR 62063 [70].		

Annex E
(normative)

Tolerances on test quantities during tests

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

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

A tolerance is defined as the range of the test value specified in the standard within which the measured test value shall lie for a test to be valid. In certain cases the test may remain valid even if the measured value falls outside the range: this is the case when it results in a more severe test condition.

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

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

a) testing stations shall aim wherever possible for the test value specified;
b) the tolerances on test quantities specified shall be observed by the testing station. Higher stresses exceeding those tolerance are permitted only with the consent of the manufacturer;
c) where, for any test quantity, no tolerance is given within this standard, or the standard to be applied, the type test shall be not less severe than specified. The upper stress limits are subject to the consent of the manufacturer.

Table E.1 – Tolerances on test quantities for type test

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.2 up to 7.2.12	Dielectric tests				
7.2.7.2, 7.2.8.2, 7.2.12, 7.10.5	Power-frequency voltage tests	Test voltage (RMS value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1:2010
		Frequency	–	45 Hz to 65 Hz	
		Wave shape	Peak value / RMS value = √2	±5 %	
7.2.7.3 and 7.2.8.4	Lightning impulse voltage tests	Peak value	Rated lightning impulse withstand voltage	±3 %	IEC 60060-1:2010
		Front time	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	
7.2.8.3	Switching impulse voltage tests	Peak value	Rated switching impulse withstand voltage	±3 %	IEC 60060-1:2010
		Front time	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
		Test voltage		±1 %	

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.3 and 7.9.1.1	Radio interference voltage tests	Tune frequency of measurement circuit		Within +10 % of 0,5 MHz or between 0,5 MHz to 2 MHz	
7.4.4	Measurement of the resistance of circuits	DC test current, I_{DC}	–	50 A < I_{DC} ≤ rated continuous current , or −20 %, +0 % of I_r ≤ 50 A	
7.5	Continuous current tests	Ambient air velocity	–	≤ 0,5 m/s	
		Test current frequency	Rated frequency	−5 %, +2 %	
		Test current	Rated continuous current	−0 %, +2 % These limits shall be kept only for the last two hours of testing period	
		Ambient air temperature T_a	--	10 °C < T_a ≤ 40 °C	
7.6	Short-time withstand current and peak withstand current tests	Test frequency	Rated frequency	±10 % at the beginning of the test, −20 %, +10 % at the end	
		Peak current (in one of the outer phases)	Rated peak withstand current	−0 %, +5 %	
		Average of AC component of three-phase test current	Rated short-time withstand current	See tolerances for I^2t in 7.6.3	7.6.3
		Ratio of AC component of test current in any phase versus average of the three phases	1	±10 %	
		Short-circuit current duration	Rated short-circuit duration	Maximum 5 s	7.6.3
		Value of I^2t	Value I^2t Derived from rated values short-time withstand current and duration.	−0 %, +10 %	
7.9.2.3	Oscillatory wave immunity test	Damped oscillatory wave tests	Test frequency 100 kHz, 1 MHz	±30 %	IEC 61000-4-18
7.10.3.3	Auxiliary contact rated short-time withstand current	Test current amplitude		−0 %, +5 %	
		Test current duration		−0 %, +10 %	
7.10.3.4	Auxiliary contact breaking capability	Test voltage amplitude		−0 %,+10 %	
		Test current amplitude		−0 %, +5 %	
		Circuit time constant		−0 %, +20 %	

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
7.10.4.2	Cold tests	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-1: 2007
7.10.4.3	Dry heat test	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-2: 2007
7.10.4.4	Cyclic humidity test	Minimum temperature of cycle		±3 K	IEC 60068-2-30: 2005
		Maximum temperature of cycle		± 2 K	
7.10.4.5	Vibration response and seismic tests				IEC 60255-21-1: 1988
7.11.1.3	Radiation instrument	Accuracy measurement of radiation		±25 %	
	Energy response	Accuracy measurement of energy		±15 %	

Annex F
(informative)

Information and technical requirements to be given with enquiries, tenders and orders

F.1 General

This annex provides a list of useful technical information items in a tabular form to be considered for possible exchange between user and supplier during contracting stage.

When in the table "supplier information" is mentioned, this means that only the supplier needs to deliver this information.

Attention should be paid to the fact that such table should be complemented with information and characteristics relevant for the type of switchgear and controlgear considered; see product standards.

F.2 Normal and special service conditions (refer to Clause 4)

		User requirements	**Supplier proposals**
Service condition	Indoor or outdoor		
Ambient air temperature: Minimum Maximum	 °C °C		
Solar radiation	W/m^2		
Altitude	m		
Pollution	Class		
Excessive dust or salt			
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in auxiliary and control circuits	kV		

F.3 Ratings (refer to Clause 5)

		User requirements	Supplier proposals
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase to earth and between phases Rated short-duration power-frequency withstand voltage (U_d) Rated switching impulse withstand voltage (U_s) – phase to earth – between phases Rated lightning impulse withstand voltage (U_p)	 kV kV kV kV kV		
Rated frequency (f_r)	Hz		
Rated continuous current (I_r)	A	According single line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short-circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 or 60	

F.4 Design and construction (refer to Clause 6)

To be complemented with information provided by relevant product standards.

		User requirements	Supplier proposals
Number of phases	Three- or single-phase encapsulation		
Mass of the heaviest transport unit			
Mounting provisions			
Type of gas-pressure or liquid-pressure system			
Overall dimensions of the installation			
Description by name and category of the various compartments			
Rated filling level and minimum functional level			
Low- and high-pressure interlocking and monitoring devices			
Interlocking devices			
Degrees of protection			
Arrangement of the external connections			
Accessible sides			
Volume of liquid or mass of gas or liquid for the different compartments			
Facilities for transport and mounting			

		User requirements	Supplier proposals
Instructions for operation and maintenance			
Specification of gas or liquid condition			

F.5 System information

		User information
Nominal voltage of system	kV	
Highest voltage of system	kV	
Number of phases		
Type of system neutral earthing		Effectively or non-effectively

F.6 Documentation for enquiries and tenders

	User requirements	Supplier proposals
Scope of supply (training, technical and layout studies and requirements for co-operation with other parties)		
Single-line diagram		
General arrangement drawings of substation layout		
Provisions for transport and mounting to be given by the user		
Foundation loading	Supplier information	
Gas schematic diagrams	Supplier information	
List of type test reports	Supplier information	
List of recommended spare parts	Supplier information	

Annex G
(informative)

List of symbols

Description	Symbol	Subclause
Absolute leakage rate	F	3.6.6.4
Absolute leakage rate	F_{liq}	3.6.7.1
Alarm pressure (or density) for insulation and/or switching	p_{ae} (ρ_{ae})	3.6.5.3
Alarm pressure for operation (or density)	p_{am} (ρ_{am})	3.6.5.4
Filling pressure	p_r	7.8.2
Filling pressure (or density) for insulation and/or switching	p_{re} (ρ_{re})	3.6.5.1
Filling pressure (or density) for operation	p_{rm} (ρ_{rm})	3.6.5.2
Main circuit resistance measured before continuous current test	R_u	8.4
Measured pressure	p_m	7.8.2
Minimum functional pressure (or density) for insulation and/or switching	p_{me} (ρ_{me})	3.6.5.5
Minimum functional pressure for operation (or density)	p_{mm} (ρ_{mm})	3.6.5.6
Number of replenishments per day	N	3.6.6.8
Number of replenishments per day	N_{liq}	3.6.7.3
Partial voltage with respect to earth	U_f	7.2.6.3 b)
Permissible leakage rate	F_p	3.6.6.5
Permissible leakage rate	$F_{p(liq)}$	3.6.7.2
Pressure drop	Δp	3.6.6.9
Pressure drop	Δp_{liq}	3.6.7.4
Protection against ingress of water coding	IP	6.14.3
Protection of equipment against mechanical impact under normal service conditions coding	IK	6.14.4
Radio interference voltage test	RIV	7.3
Rated continuous current	I_r	5.5
Rated duration of short-circuit	t_k	5.8
Rated frequency	f_r	5.4
Rated lightning impulse withstand voltage	U_p	5.3
Rated peak withstand current	I_p	5.7
Rated short-duration power-frequency withstand voltage	U_d	5.3
Rated short-time withstand current	I_k	5.6
Rated supply voltage	U_a	5.9.2
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_a	5.9
Rated switching impulse withstand voltage	U_s	5.3
Rated voltage	U_r	5.2
Relative leakage rate	F_{rel}	3.6.6.6
Time between replenishments	t_r	3.6.6.7

Description	Symbol	Subclause
Total test voltage	U_t	7.2.6.3 b)

Annex H
(informative)

Electromagnetic compatibility on site

EMC site measurements are not type tests but may be performed in special situations:

- where it is deemed necessary to verify that actual stresses are covered by the EMC severity class of the auxiliary and control circuits;
- in order to evaluate the electromagnetic environment;
- in order to apply proper mitigation methods, if necessary;
- to record the electromagnetically induced voltages in auxiliary and control circuits, due to switching operations both in the main circuit and in the auxiliary and control circuits. It is not considered necessary to test all auxiliary and control circuits in a substation under consideration. A typical configuration should be chosen.

Measurement of the induced voltages should be made at representative ports in the interface between the auxiliary and control circuits and the surrounding network, for example, at the input terminals of control cubicles, without disconnection of the system. Instrumentation for recording induced voltages should be connected as outlined in IEC TR 60816 [71].

Switching operations should be carried out at normal operating voltage, both in the main circuit and in the auxiliary and control circuits. Induced voltages will vary statistically and thus a representative number of both making and breaking operations should be chosen, with random operating instants.

The switching operations in the main circuit are to be made under no-load conditions. The tests will thus include the switching of parts of the substation but no switching of load currents and no fault currents.

The making operations in the main circuit should be performed with trapped charge on the load side corresponding to normal operating voltage. This condition may be difficult to obtain at testing, and, as an alternative, the test procedure may be as follows:

- discharge the load side before the making operation, to assure that the trapped charge is zero;
- multiply recorded voltage values at the making operation by 2, in order to simulate the case with trapped charge on the load side.

The switching device in the primary system shall preferably be operated at rated pressure and auxiliary voltage.

NOTE 1 The most severe cases, with regard to induced voltages, will normally occur when only a small part of a substation is switched.

NOTE 2 The most severe electromagnetic disturbances are expected to occur at disconnector switching, especially for GIS installations.

The recorded or calculated peak value of induced common-mode voltage, due to switching in the main circuit, should not exceed 1,6 kV for interfaces of the auxiliary and control circuits.

Annex I
(informative)

List of notes concerning certain countries

With reference to Annex SC of *IEC/ISO Directives Supplement – Procedures specific to IEC*, (2016), an IEC National Committee may provide a statement to be included in an International Standard, informing the user of the standard of particular conditions existing in its country.

Clause	Text
6.14.1	NOTE In addition to IEC 60529 enclosures are to be designed to prevent unauthorized access by provided provisions for locking or requiring a special tool to open doors. Doors hinges and access panels are not externally removable (US).
6.14.2	NOTE The minimum default code is IP2XB (US)
7.2.12	NOTE The required test voltage for disconnectors and switch disconnectors of all rated voltages is 100 % of the tabulated voltage in columns (3) of Tables 1 or 2 and 3 or 4 (Canada).

Annex J
(informative)

Extension of validity of type tests

J.1 General

An individual type test need not be repeated in some situations e.g.:

– for a change of construction detail, if the manufacturer can establish that this change does not influence the result of that individual type test;
– for a change in the installation instructions, provided that the test conditions are not invalidated by the new instructions (e.g. see J.2);
– for covering other values of ratings for the same switchgear and controlgear, if these new ratings are covered by the tests already performed (e.g. see J.3 or when lower performances are requested).

Particular examples where extension of a type test may be used to validate design changes or other similar equipment, without repeating type tests, are given in the following subclauses. It should be noted that supporting evidence should be provided to validate such extensions of type tests.

More details may be given in the product standards and/or technical reports, e.g. IEC TR 62271-307 [72].

J.2 Dielectric tests

For non-enclosed conductors, the dielectric tests performed cover other dispositions having equal or higher clearances to surroundings (e.g. height above ground) and between conductors, if the insulating materials and shapes of conductors and insulators are the same.

J.3 Short-time withstand current tests

Short-time withstand current and peak withstand current tests performed at 50 Hz or 60 Hz, using a peak factor of 2,6, cover both frequencies for networks having a DC time constant of 45 ms or smaller.

Short-time withstand current and peak withstand current tests performed at 50 Hz or 60 Hz using a peak factor of 2,7, cover both frequencies for any DC time constants.

J.4 Continuous current test

A test performed on a single pole, or on a single unit, covers larger arrangements (i.e. three pole or multiple units) provided that the influence with other poles or other units is negligible, as it is generally the case for non-enclosed switchgear and controlgear; this provision is applicable, for instance, to some outdoor transmission devices.

As stated in 7.5.3.1:

– for switchgear and controlgear rated for both frequencies at 50 Hz and 60 Hz and having no ferrous components adjacent to the current-carrying parts, test can be performed at 50 Hz and cover both frequencies provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values;
– tests performed at 60 Hz cover both frequencies.

J.5 Electromagnetic immunity test on auxiliary and control circuits

Subassemblies may be positioned in different places within the auxiliary and control circuits, without invalidating the type test of the complete system, provided that the overall wiring length and the number of individual wires connecting the subassembly to the auxiliary and control circuits is not greater than in the tested system.

Interchangeable subassemblies may be replaced by similar subassemblies, without invalidating the original type test, provided that:

– rules for design and installation given in IEC 61000-6-5 are followed;
– type tests have been performed on the most complete subassembly applicable to the type of switchgear and controlgear;
– manufacturer's design rules are the same as for the type-tested subassembly.

J.6 Environmental tests on auxiliary and control circuits

Environmental tests on auxiliary and control circuits need not be repeated if performance requirements are validated during environmental tests on a whole switchgear and controlgear.

Parts, or pieces of equipment, of auxiliary and control circuits validated in a given arrangement are validated also when used in a different arrangement of auxiliary and control circuits belonging to the same range of switchgear and controlgear equipment.

Tests performed with a given supply voltage for auxiliary and control circuit cover similar auxiliary and control circuits designed for lower supply voltages.

Annex K
(informative)

Exposure to pollution

K.1 General

The quality of ambient air with respect to pollution by dust, smoke, corrosive and/or flammable gases, vapours, or salt is a consideration under normal and special service conditions (refer to Clause 4 of this document). This annex defines levels of pollution as well as recommendations for the minimum specific creepage distance across external insulation.

K.2 Pollution levels

For purposes of standardization, the levels of pollution, very light, light and medium, are qualitatively defined. The qualitative examples given in Table K.1 are approximate descriptions of some typical corresponding environments. Other more extreme environmental conditions may merit further consideration, e.g., snow and ice in heavy pollution, heavy rain, and arid areas. For these special conditions, reference is given to IEC TS 60815-1:2008, IEC TS 60815-2:2008 and IEC TS 60815-3:2008.

K.3 Minimum requirements for switchgear

The minimum creepage distance expressed as a specific creepage in mm/kV are for the normal service conditions of atmospheric contamination and altitudes up to 1 000 m. This minimum creepage provides generally satisfactory service operation under these conditions.

For each level of pollution described in Table K.1, the corresponding minimum recommended nominal unified specific creepage distance (USCD) in mm/kV across the insulator is given in Table K.2.

NOTE The information in Table K.1 is adapted from IEC TS 60815-1:2008; the values in Table K.2 are taken from IEC TS 60815-2:2008.

Table K.1 – Environmental examples by site pollution severity (SPS) class

SPS Class	Example of typical environments
Very light	Example 1: > 50 km[a] from any sea, desert, or open dry land > 10 km from man-made pollution sources [b] Within a shorter distance than mentioned above of pollution sources, but: • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing
Light	Example 2: 10 km to 50 km[a] from the sea, a desert, or open dry land 5 km to 10 km from man-made pollution sources [b] Within a shorter distance than example 1 from pollution sources, but: • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing
Medium	Example 3: 3 km to 10 km[c] from the sea, a desert, or open dry land 1 km to 5 km from man-made pollution sources [b] Within a shorter distance than mentioned above of pollution sources, but: • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing Example 4: Further away from pollution sources than mentioned in example 3, but: • dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season • and/or heavy, high conductivity rain occurs • and/or there is a high non-soluble deposit level (refer to IEC TS 60815-1:2008)
Heavy and Very heavy	Refer to IEC TS 60815-1:2008.

[a] During a storm, the ESDD level at such a distance from the sea may reach a much higher level.

[b] The presence of a major city will have an influence over a longer distance, i.e. the distance specified for sea, desert and dry land.

[c] Depending on the topography of the coastal area and the wind intensity.

Table K.2 – Minimum nominal specific creepage distance by pollution level

SPS class	Minimum recommended nominal unified specific creepage distance (USCD) [a] mm/kV
Very light	22
Light	27,8
Medium	34,7
Heavy and Very heavy	Refer to IEC TS 60815-1:2008, IEC TS 60815-2:2008, and IEC TS 60815-3:2008

[a] The unified specific creepage distance (USCD) is the creepage distance of an insulator divided by the RMS value of the highest operating voltage across the insulator.

[SOURCE: IEC TS 60815-2:2008, 3.2]

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).

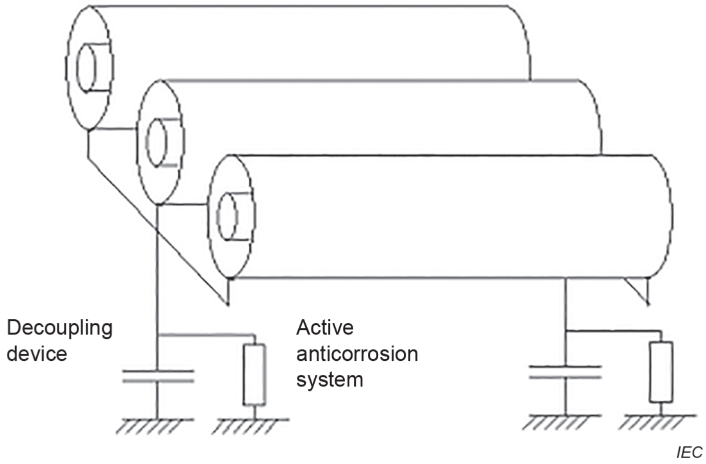


Figure B.1 – Example of earthing system together with active anti-corrosion system in the case of solid bonding of the enclosure at both ends

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

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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[62] IEC 60309-2, *Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

[63] IEC TR 60083, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

[64] IEC 60130 (all parts), *Connectors for frequencies below 3 MHz*

[65] IEC 62326-1, *Printed boards – Part 1: Generic specification*

[66] IEC 60393-1, *Potentiometers for use in electronic equipment – Part 1: Generic specification*

[67] IEC 60115-4 (all parts), *Fixed resistors for use in electronic equipment – Part 4: Sectional specification: Fixed power resistors*

[68] IEC 60081, *Double-capped fluorescent lamps – Performance specifications*

[69] IEC 60064, *Tungsten filament lamps for domestic and similar general lighting purposes – Performance requirements*

[70] IEC TR 62063, *High-voltage switchgear and controlgear – The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear*

[71] IEC TR 60816:1984, *Guide on methods of measurement of short duration transients on low-voltage power and signal lines*

[72] IEC TR 62271-307, *High-voltage switchgear and controlgear – Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

[73] IEEE C37.100.1, *IEEE Standard of Common Requirements for High Voltage Power Switchgear Rated Above 1000 V*

[74] IEC 60059, *IEC standard current ratings*

[75] IEC 60068-2 (all parts), *Environmental testing – Part 2: Tests*

[1] IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

[2] CIGRE Brochure 163:2000, *Guide for SF_6 gas mixtures*

[3] CIGRE Brochure 260:2004, *N_2/SF_6 mixtures for gas insulated systems*

[4] CIGRE Brochure 360:2008, *Insulation co-ordination related to internal insulation of gas insulated systems with SF_6 and N_2/SF_6 gas mixtures under AC condition*

[5] ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

[6] IEC 60287-1-1:2006, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*
IEC 60287-1-1:2006/AMD1:2014

[7] IEC TR 60943:1998, *Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*
IEC TR 60943:1998/AMD1:2008

[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*

[26] ISO 22825, *Non-destructive testing of welds – Ultrasonic testing – Testing of welds in austenitic steels and nickel-based alloys*

[27] ISO 23279, *Non-destructive testing of welds – Ultrasonic testing – Characterization of discontinuities in welds*

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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)

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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

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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.

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[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:

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

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

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

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).

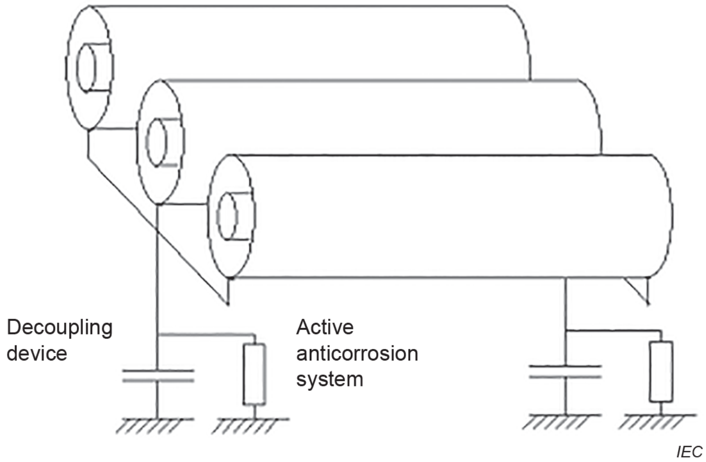

Figure B.1 – Example of earthing system together with active anti-corrosion system in the case of solid bonding of the enclosure at both ends

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

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[2] CIGRE Brochure 163:2000, *Guide for SF_6 gas mixtures*

[3] CIGRE Brochure 260:2004, *N_2/SF_6 mixtures for gas insulated systems*

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[5] ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

[6] IEC 60287-1-1:2006, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*
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IEC TR 60943:1998/AMD1:2008

[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*

[26] ISO 22825, *Non-destructive testing of welds – Ultrasonic testing – Testing of welds in austenitic steels and nickel-based alloys*

[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

AVANT-PROPOS

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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
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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

- reconduit,
- supprimé,
- 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".