

INTERNATIONAL STANDARD



This extended version of IEC 62271-209:2019+AMD1:2022 includes the content of the references made to IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2011

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



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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.

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

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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable terminations

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 62271-209:2019+AMD1:2022 EXV includes the content of the references made to IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2011.

Particular subclauses of IEC 62271-1:2017+AMD1:2021 CSV and IEC 62271-203:2011 are displayed in the content on a blue background.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62271-209 edition 2.1 contains the second edition (2019-02) [documents 17C/696/FDIS and 17C/701/RVD] and its amendment 1 (2022-03) [documents 17C/833/FDIS and 17C/841/RVD].

International Standard IEC 62271-209 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear.

This second edition constitutes a technical revision.

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

- a) New numbering in accordance with ISO/IEC directives, Part 2 (2016) and to IEC 62271-1:2017;
- b) Clause 3: addition of a definition for plug-in cable termination, filling pressure and minimum function pressure for insulation;
- c) Clause 7: An additional dielectric type test for plug-in cable termination was added; also a pressure type test as well as a leak rate test on the insulator of a cable termination was implemented;
- d) Clause 12: New clause about safety practices;
- e) Clause 13: New clause about influence of the product on the environment;
- f) New informative Annex A: Mechanical forces applied on the flange of the cable connection enclosure.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

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

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INTRODUCTION TO Amendment 1

This amendment includes the following modifications:

- a) In accordance with the decision taken at IEC Plenary Meeting October 2019 in Shanghai (17C/Shanghai/Sec07) Subclause 6.103, Figure 1 and Figure 2 have been modified;
- b) The CDV was modified in accordance with the above-mentioned documents and based on the decision taken at the virtual IEC Plenary Meeting in October 2021 (17C/823/RM).

NOTE CIGRE has published TB 784 "Standard design of a common, dry type plug-in interface for GIS and power cables up to 145 kV describing the basis for further standardisation of such a common interface. The matter will be dealt with during the next revision of IEC 62271-209.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable terminations

1 Scope

This part of IEC 62271 covers the connection assembly of fluid-filled and extruded cables to gas-insulated metal enclosed switchgear (GIS), in single- or three-phase arrangements where the cable terminations are fluid-filled or dry-type and there is a separating insulating barrier between the cable insulation and the gas insulation of the switchgear.

The purpose of this document is to establish electrical and mechanical interchangeability between cable terminations and the gas-insulated metal-enclosed switchgear and to determine the limits of supply. It complements and amends, if applicable, the relevant IEC standards. For the purpose of this document the term "switchgear" is used for "gas-insulated metal enclosed switchgear".

It does not cover directly immersed cable terminations, as described in CIGRE brochure 89 [4]¹.

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, *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*

¹ Numbers in square brackets refer to the Bibliography.

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 60068-2-1:2007, *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 60068-2-17:1994, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

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 60141 (all parts), *Tests on oil-filled and gas-pressure cables and their accessories*

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

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

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

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

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

IEC 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 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF₆) and its mixtures*

IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

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*

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.



Documents

Document Sharing Hub

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

3.4.2

disconnecter

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

Note 1 to entry: A disconnecter 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 disconnecter 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 SF₆ 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 SF₆ 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 × m³ × s⁻¹.

3.6.6.5

permissible leakage rate

F_n

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_{lia}

amount of liquid escaped by time unit

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

3.6.7.2**permissible leakage rate** $F_{n(lia)}$

maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

3.6.7.3**number of replenishments per day** N_{lia}

number of replenishments to compensate the leakage rate F_{liq}

3.6.7.4

pressure drop

Δp_{lin}

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.]

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3.1

cable termination

equipment fitted to the end of a cable to ensure electrical connection with other parts of the system and to maintain the insulation up to the point of connection

3.1.1

fluid-filled cable termination

cable termination which comprises a separating insulating barrier between the cable insulation and the gas insulation of switchgear, including a fluid

3.1.2

dry-type cable termination

cable termination which comprises an elastomeric electrical stress control component in direct contact with a separating insulating barrier (insulator) between the cable insulation and the gas insulation of the switchgear, not requiring any fluid

3.2

main circuit end terminal

part of the main circuit of a gas-insulated metal enclosed switchgear forming part of the connection interface

3.3

cable connection enclosure

part of the gas-insulated metal-enclosed switchgear which houses the cable termination and the main circuit end terminal

3.4

cable connection assembly

combination of a cable termination, a cable connection enclosure and a main circuit end terminal, which mechanically and electrically connects the cable to the gas-insulated metal enclosed switchgear

3.5

plug-in cable termination

cable termination where cable/stress cone assembly can be engaged into the insulator assembly that is already installed into switchgear enclosure

3.6

design pressure

pressure used to determine the design of the enclosure and the components of the cable termination subjected to that pressure

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

3.7

fluid

liquid or gas for insulation purposes

3.8

cable system

cable with installed accessories

3.9

filling pressure p_{re} for insulation

filling density ρ_{re} for insulation

pressure (in Pa), for insulation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa, which may be expressed in relative or absolute terms (or density), to which the assembly is filled before being put into service

3.10

minimum functional pressure p_{me} for insulation

minimum functional density ρ_{me} for insulation

pressure (in Pa), for insulation, referred to the standard atmospheric air conditions of 20 °C and 101,3 kPa, which may be expressed in relative or absolute terms (or density), at which and above which the characteristics of the switchgear-cable connection are maintained and at which replenishment becomes necessary

4 Normal and special service conditions

4.1 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 2.1.

If the actual service conditions differ from these normal service conditions, high-voltage switchgear and controlgear and associated operating devices and auxiliary equipment shall be designed to comply with any special service conditions required by the user, or appropriate arrangements shall be made (refer to 2.2).

NOTE 1 Appropriate action should also be 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 (indoor) and IEC 60721-3-4 (outdoor).

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

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

4.2 Normal service conditions

4.2.1 Indoor switchgear and controlgear

- 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 preferred values of minimum ambient air temperature are –5 °C, –15 °C and –25 °C.

- b) The influence of solar radiation may be neglected.

- 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. The manufacturer will assume that, in the absence of specific requirements from the user, there are none.

- 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.

For these conditions, condensation may occasionally occur.

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

NOTE 2 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.

NOTE 3 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.

- f) Vibrations due to causes external to the switchgear and controlgear or earth tremors are insignificant relative to the normal operating duties of the equipment. The manufacturer will assume that, in absence of specific requirements from the user, there are none.

NOTE 4 The interpretation of the term “insignificant” is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his analysis shows that the risk is “insignificant”.

4.2.2 Outdoor switchgear and controlgear

- 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 preferred values of minimum ambient air temperature are –10 °C, –25 °C, –30 °C and –40 °C.

Rapid temperature changes should be taken into account.

- b) Solar radiation up to a level of 1 000 W/m² (on a clear day at noon) should be considered.

NOTE 1 Under certain levels of solar radiation, appropriate measures, for example roofing, forced ventilation, test simulating solar gain, etc., may be necessary, or derating may be used, in order not to exceed the specified temperature rises and design pressure limits.

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

- 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 pollution level II (medium) according to Table 1 of IEC 60815.
- e) The ice coating shall be considered in the range from 1 mm up to, but not exceeding, 20 mm.
- f) The wind speed does not exceed 34 m/s (corresponding to 700 Pa on cylindrical surfaces).

NOTE 3 Characteristics of wind are described in IEC 60721-2-2.

- g) Consideration should be given to condensation or precipitations that may occur.

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

- h) Vibrations due to causes external to the switchgear and controlgear or earth tremors are insignificant relative to the normal operating duties of the equipment. The manufacturer will assume that, in the absence of specific requirements from the user, there are none.

NOTE 5 The interpretation of the term “insignificant” is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his analysis shows that the risk is “insignificant”.

4.3 Special service conditions

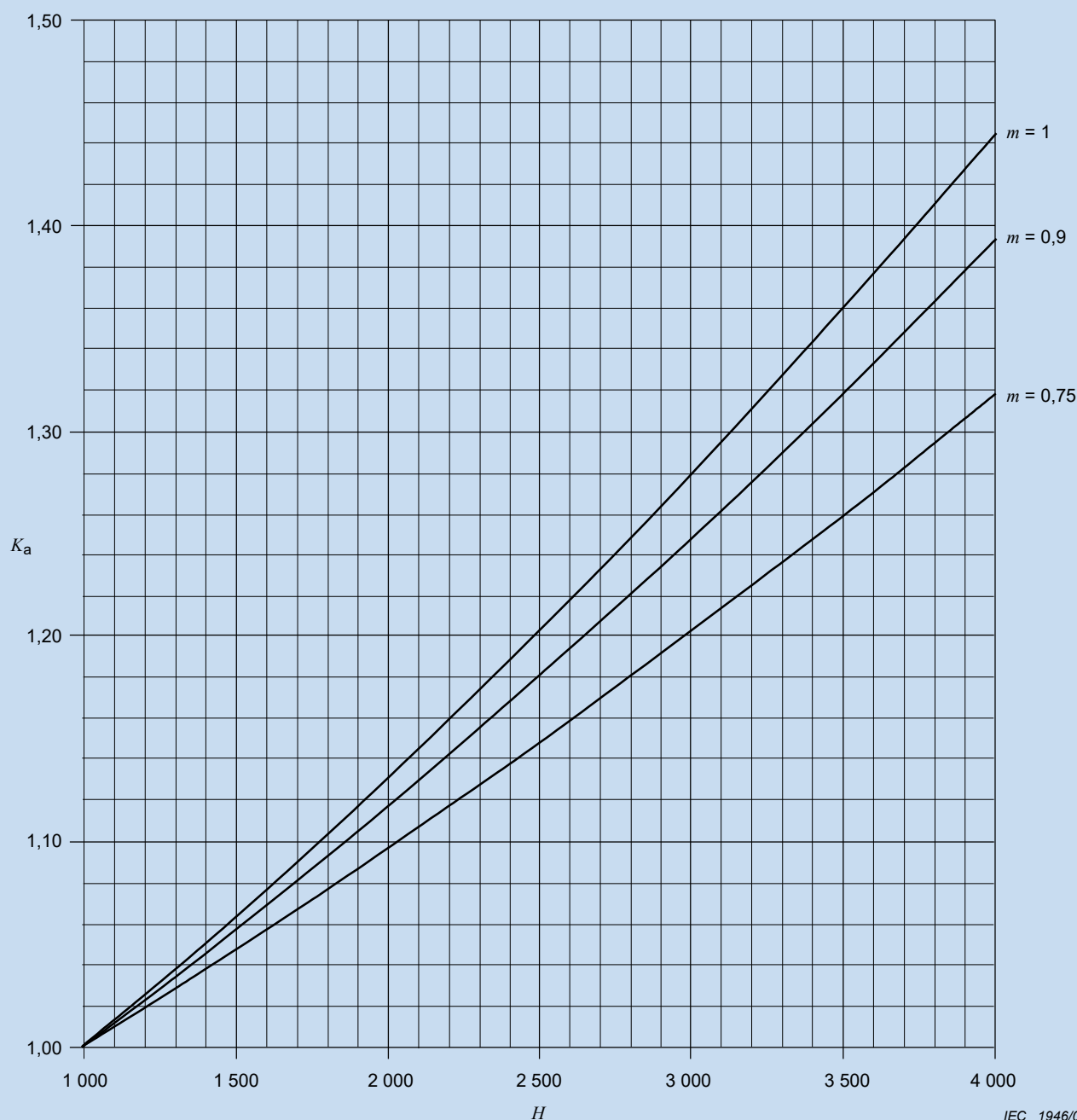
When high-voltage switchgear and controlgear is used under conditions different from the normal service conditions given in 4.2, the user's requirements should refer to standardized steps as follows.

4.3.1 Altitude

For installations at an altitude higher than 1 000 m, the insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels by a factor K_a in accordance with Figure 1.

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.

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.



The altitude correction factor can be calculated from 4.2.2 of IEC 60071-2 with the following equation, which is modified to reflect that no correction is required up to 1 000 m:

$$K_a = e^{m(H-1000)/8150}$$

where

H is the altitude, in metres;

m is taken as a fixed value in each case for simplification as follows:

- $m = 1$ for power-frequency, lightning impulse and phase-to-phase switching impulse voltages;
- $m = 0,9$ for longitudinal switching impulse voltage;

$m = 0,75$ for phase-to-earth switching impulse voltage.

Figure 1 – Altitude correction factor

4.3.2 Pollution

For installation in polluted ambient air, pollution level III (heavy) or IV (very heavy) of IEC 60815 should be specified for outdoor installation.

For indoor installation, reference can be made to IEC 60932.

4.3.3 Temperature and humidity

For installation in a place where the ambient temperature can be outside the normal service condition range stated in 2.1, the preferred ranges of minimum and maximum temperature to be specified should be

- a) $-50\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$ for very cold climates;
- b) $-5\text{ }^{\circ}\text{C}$ and $+55\text{ }^{\circ}\text{C}$ for very hot climates.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature may occur resulting in condensation even indoors.

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

4.3.4 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 abnormal conditions exists, requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level in accordance with IEC 62271-300 or IEC 62271-2 should be specified by the user.

4.3.5 Wind speed

In some regions, for example in North America, a value for the wind speed is 40 m/s.

4.3.6 Other parameters

When special environmental conditions prevail at the location where switchgear and controlgear is to be put in service, they should be specified by the user by reference to IEC 60721.

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

Table 1 – Reference table of service conditions relevant to GIS

Item	Normal		Special	
	Indoor	Outdoor	Indoor	Outdoor
Ambient air temperature:				
Minimum ($^{\circ}\text{C}$)	-5 or -25	-25 or -40	-25	-50
Maximum ($^{\circ}\text{C}$)	$+40$	$+40$	$+50$	$+50$
Solar radiation (W/m^2)	Not applicable	1 000	Not applicable	$>1\ 000$
Altitude (m)	1 000	1 000	$>1\ 000$	$>1\ 000$

Site pollution severity ^a	Not applicable	c	c, d or e	d or e
Ice coating (mm)	Not applicable	1, 10 or 20	Not applicable	>20
Wind (m/s)	Not applicable	34	Not applicable	>34
Humidity (%)	95	100	98	100
Condensation or precipitation	Occasional	Yes	Yes	Yes
Vibration class	Not applicable	Not applicable	IEC 62271-207 IEC/TR 62271-300	IEC 62271-207 IEC/TR 62271-300
NOTE The user's specification may use any combination of normal or special service conditions above.				
^a Site pollution severity c, d or e according to IEC/TS 60815-1:2008, 8.3.				

5 Ratings

5.1 General

When dimensioning the cable connection assembly, the following rated values shall apply:

- a) rated voltage of the equipment of the cable connection (U_{rm});
- b) rated insulation level (U_p , U_d and U_s where applicable);
- c) rated frequency (f_r)
- d) rated continuous current (I_r);
- e) rated short-time withstand current (I_k);
- f) rated peak withstand current (I_p);
- g) rated duration of short circuit (t_k).

5.2 Rated voltage of the equipment of the cable connection (U_{rm})

The rated voltage for the equipment of the cable connection (U_{rm}) is equal to the lower of the values U_m for the cable system and U_r for the gas-insulated metal-enclosed switchgear and shall be selected from the following standard values:

72,5 kV – 100 kV – 123 kV – 145 kV – 170 kV – 245 kV – 300 kV – 362 kV – 420 kV – 550 kV

NOTE 1 Values above $U_r = 550$ kV are not considered.

NOTE 2 $U_m = 100$ kV is not defined in IEC 60840.

5.3 Rated insulation level (U_d , U_p , U_s)

The rated insulation level for the cable connection assembly shall be selected from the values given in IEC 60038 as well as IEC 62271-203.

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)

The connection interface of the main circuit shown in Figures 2 and 3 for fluid-filled cable terminations and Figures 4 and 5 for dry-type cable terminations is applicable at rated continuous currents up to 3 150 A.

The connection interface shall be designed so that at a current equal to the cable rated current corresponding to a maximum temperature of 90 °C, no heat transfer from the switchgear main circuit end terminal to the cable termination will occur.

NOTE As the maximum conductor temperature for cables is limited by the maximum operating temperature for the insulation, there are certain cable dielectrics which cannot withstand the maximum temperature specified for gas-insulated metal-enclosed switchgear if there is heat transfer across the connection interface to the cable terminations.

For cases when the above design requirement of 90 °C at rated continuous current of the cable system cannot be allowed because of cable design limitations, the manufacturer of the switchgear should provide the necessary data on temperature rise of the main circuit end terminal and of the insulating gas as a function of current.

5.6 Rated short-time withstand current (I_k)

Short-time currents of short circuit shall refer to the levels provided by the cable system, not exceeding the values defined for the switchgear in line with IEC 62271-1.

5.7 Rated peak withstand current (I_p)

Peak withstand currents of short circuit shall refer to the levels provided by the cable system, not exceeding the values defined for the switchgear in line with IEC 62271-1.

5.8 Rated duration of short circuit (t_k)

The duration of short circuit shall refer to the levels provided by the cable system, not exceeding the values given in IEC 62271-1.

6 Design and construction

6.1 Gas and vacuum tightness

6.1.1 General

The following specifications apply to all switchgear and controlgear that use vacuum or gas, other than ambient air, as an insulating, switching, combined insulating and switching, or operating medium.

For vacuum tightness no leakage rate F needs to be specified, instead the level of vacuum and the expected operating duration shall be given.

NOTE 1 IEC TR 62271-306 [4] and Cigre Brochure 430 [28] give some information, examples and guidance for tightness.

The absolute leakage rate F shall not exceed the specified value of the permissible leakage rate F_p at standardized ambient temperature of 20 °C.

An increased leakage rate at extreme temperatures is permissible, provided that this rate resets to a value not higher than the permissible value F_p at standardized ambient temperature of 20 °C. The increased temporary leakage rate shall not exceed the values given in 7.8.1.

NOTE 2 The average leakage rate observed during service life can be higher than the specified leakage rate due to the temporary increased leakage rate at temperatures above or below the standardized ambient temperature.

6.1.2 Controlled pressure systems for gas

The tightness of controlled pressure systems for gas is specified by the number of replenishments per day (N) or by the pressure drop per day (Δp). SF₆ gas and SF₆ mixtures are not applicable for controlled pressure systems.

NOTE Most controlled pressure systems use air as the gas; however, other gases can be used.

6.1.3 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 SF₆ and SF₆ mixtures, 0,5 % per year;
- for other gases, 1 % per year.

NOTE 1 Some local or governmental regulations can require a lower SF₆ 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.

6.1.4 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 SF₆ switchgear and controlgear is considered to have insignificant SF₆ losses (less than 0,1 % per year) during their expected operating duration.

For conditions up to the maximum occurring gas operating pressure, the cable termination shall prevent insulating gas from the switchgear diffusing into the interior of the cable termination and into the cable. The cable termination shall prevent insulating fluid from the cable termination entering the switchgear. The insulator (part 4 in Figures 2 and 4) shall be capable of withstanding the vacuum conditions when the cable connection enclosure is evacuated, as part of the gas filling process.

In the case of a gas insulated cable or a gas insulated termination, the gas compartment of the cable or of the gas insulated termination shall be treated independently from the switchgear with respect to tightness.

6.101 Limits of supply

6.101.1 General

The limits of supply of gas-insulated metal-enclosed switchgear and the cable termination shall be in accordance with Figure 2 for fluid-filled cable terminations and Figure 4 for dry-type cable terminations.

6.101.2 Over-voltage protection and earthing

It is necessary to have either a direct low resistance connection or an insulated section bridged by non-linear resistors between part 6 and part 13 of Figure 2 for fluid-filled cable terminations and Figure 4 for dry-type cable terminations. To enable suitable connections to be made to the switchgear, for the purposes of this direct connection or installation of any sheath voltage limiting device, the switchgear manufacturer shall provide four connection

points per phase (evenly spaced around each phase) each comprising an M12 threaded hole of minimum 21 mm length (for all voltage levels). The position of these 4 connection points is different from the mechanical connection points used for fixing the cable termination insulator. The number of connection points used shall be determined by the cable system designer.

Where applicable, the number and characteristics of the non-linear resistors shall be determined by the cable system designer, and they shall be supplied by the cable termination manufacturer, taking into consideration the requirements of the user and the switchgear manufacturer. Reference is made to CIGRE TB 44, 1993 [5], as well as to IEEE 1300-2011, Clause 11 [3].

In addition, the installation design of the area around the cable termination shall take into account the space required to install any non-linear resistors, including adequate clearances to earth.

For three phases in one enclosure arrangements special clarification between the GIS manufacturer, the cable termination manufacturer and the cable system designer may be necessary because of limited space between the three phases.

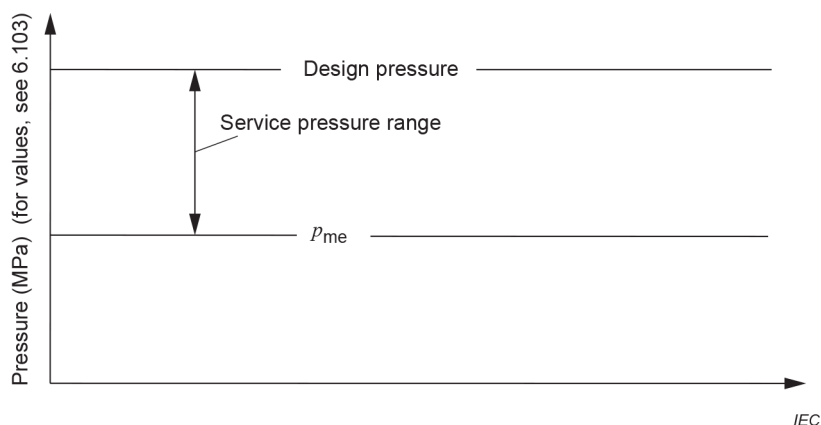
The overvoltage protection elements, i.e. connections between part 6 and part 13 of Figure 2 for fluid-filled cable terminations and Figure 4 for dry-type cable terminations as described above, are not meant to serve as the cable system grounding connection.

Earthing of enclosures shall be in accordance with the relevant subclause of IEC 62271-203:2011.

6.102 Filling pressure of insulating gas in the cable connection enclosure

If SF₆ is used as the insulating gas, the minimum functional pressure for insulation p_{me} used to determine the design of the cable termination insulation shall not exceed $p_{me} = 0,35$ MPa (absolute) at 20 °C for maximum rated voltages up to 300 kV. For maximum rated voltages exceeding 300 kV the minimum functional pressure for insulation p_{me} used to determine the design of the cable termination insulation shall not exceed $p_{me} = 0,4$ MPa (absolute) at 20°C (see Figure 1).

The filling pressure p_{re} of insulating gas is assigned by the switchgear manufacturer but shall in no case be lower than p_{me} . The service pressure is in no case higher than the design pressure as per 6.103.



p_{me} minimal functional pressure for insulation depending on rated voltage

Figure 1 – Operating pressure of the gas insulation in the cable connection enclosure

If a gas other than SF₆ or a gas mixture is used, the minimum functional pressure shall be chosen to provide the same dielectric performance as in case of SF₆. The minimum functional pressure shall be below the maximum service pressure and design pressure of the enclosure as per 6.103.

6.103 Pressure withstand requirements

The design pressure for the outside of the cable termination is determined by the particular GIS design around the GIS/cable interface. Typical maximum gas pressures in service are up to 1,1 MPa (absolute) for SF₆ and up to 1,5 MPa (absolute) for other gases and gas mixtures.

The particular pressure withstand requirements coming from the specific gas and GIS design shall be thoroughly coordinated between GIS and cable termination manufacturer as well as the user.

NOTE Due to the lower service current of a HV-cable connection than the rated current of a GIS, the related temperature and pressure rise within the cable compartment can be lower. The design pressure of the GIS could be higher than the design pressure of the cable termination.

6.104 Mechanical forces on cable terminations

The manufacturer of the cable termination in a three-phase connection shall take into account the total dynamic forces generated during short circuit conditions. These forces consist of those generated within the cable termination and those coming from the main circuit of the switchgear. The maximum additional force applied from the switchgear to the connection interface (Figures 2 or 4) transversely and then being transferred from the main circuit end terminal shall not exceed 5 kN for a three phase arrangement. For single-phase connections, the maximum additional force applied from the switchgear to the connection interface (Figures 2 or 4) transversely and then being transferred from the main circuit end terminal shall not exceed 2 kN. It is the responsibility of the manufacturer of the switchgear to ensure that the specified forces are not exceeded or to agree with the cable termination manufacturer that the cable termination shall withstand the higher forces.

For both single-phase and three-phase connections, additional forces and movements from the switchgear can be experienced due to temperature variations and vibrations in service. These forces can act on both switchgear and cable termination and depend largely on the switchgear layout, termination installation, cable design and the methods of mechanical support. The design of any support structure shall take into account these forces and movements. It is particularly important that the support for the switchgear shall not be affixed to the insulator collar and/or clamping flange, parts 9 and 11 of Figures 2 or 4. Further information regarding mechanical forces on the flanges of the cable connection enclosure are given in Annex A.

For seismic requirements, the switchgear manufacturer carries out a seismic calculation in order to identify the location of mechanical reinforcements; reference is made to IEC 62271-207 [2].

6.105 Switchgear connection interface and cable termination connection interface

The normal current-carrying contact surfaces of the switchgear and cable termination connection interface (refer to parts 2 and 3 of Figures 2 and 4) shall be silver coated or copper coated or non-coated solid copper.

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.

If SF₆ is used, technical grade SF₆ in accordance with IEC 60376 or used SF₆ in accordance with IEC 60480 shall be used.

7.2 Electrical type tests of cable terminations

7.2.1 General

The electric type tests of the cable termination shall be carried out according to the electrical type tests defined in IEC 60141 (all parts) or IEC 60840 or IEC 62067 as relevant for the cable design. Where applicable the insulator shall be tested to 7.2.4.

The cable termination shall be installed in an enclosure as per 7.2.2, filled with insulating gas at the pressure not exceeding $p_{me}+0,02$ MPa with filling pressure specified in 6.102.

The design of the main circuit end terminal (part 1 in Figures 2 or 4 respectively) used in the test as connection to part 3 of the cable connection assembly shall comply with Figures 2 and 4 respectively of this document.

7.2.2 Electrical type test of cable terminations in a single-phase enclosure

The cable termination is surrounded by a metal cylinder connected to earth, the maximum internal diameter is equal to d_5 for the four standard sizes of cable connection enclosure (d_5 in Figure 3 for fluid-filled cable terminations and Figure 5 for dry-type cable terminations). The minimum length of the metal cylinder shall be in accordance with the dimension l_5 given in Figures 3 and 5.

7.2.3 Electrical type test of cable termination in a three-phase enclosure

The single-phase test arrangement using the single-phase cable connection enclosure from the switchgear covers the test requirements of the cable termination in a three-phase enclosure as it imposes a more severe dielectric stress to the test object. It is therefore the referenced type test arrangement.

7.2.4 Additional electrical type tests on the insulator to be installed by switchgear manufacturer (plug in cable termination)

In some applications the termination insulator is installed in the switchgear enclosure by the switchgear manufacturer and is consequently subject to routine and on site test procedures applicable to the switchgear. In order to cover this application the following test shall be carried out.

The insulator shall be installed as specified by the cable termination manufacturer in order to cover later routine test at the switchgear manufacturer's works and on site tests. Because the

cable will not be fitted to the termination, any special devices required shall be fitted on the cable side of the insulator. Such devices shall be provided by the cable termination supplier. The test shall be done at ambient temperature $(20 \pm 15) ^\circ\text{C}$. Test voltages shall be applied as specified in Table 1.

Table 1 – Test voltages for additional electrical type tests according to 7.2.4

Rated voltage of the equipment of cable connection U_{rm} kV (RMS value) (NOTE 1)	Power-frequency voltage tests U_d kV (RMS value)		Switching impulse withstand voltage U_{ss} kV (peak value)	Lightning impulse withstand voltage U_{ps} kV (peak value)
	Phase-to-earth withstand voltage test ($t = 1 \text{ min}$) IEC 62271-203:2011 Cl. 7.1.101 (NOTE 2)	Test voltage for PD measurement $U_{pd\text{-test}}$ ($>1 \text{ min}$) IEC 62271-203:2011, 7.1.102 (NOTE 2)	Phase-to-earth IEC 62271-203:2011, 10.2.101.2.4 (NOTE 3)	Phase-to-earth IEC 62271-203:2011, 10.2.101.2.4 (NOTE 3)
(1)	(2)	(3)	(4)	(5)
72,5	140	$1,2 U_r$	-	260
100	185	$1,2 U_r$	-	360
123	230	$1,2 U_r$	-	440
145	275	$1,2 U_r$	-	520
170	325	$1,2 U_r$	-	600
245	460	$1,2 U_r$	-	840
300	460	$1,2 U_r$	680	840
362	520	$1,2 U_r$	760	940
420	650	$1,2 U_r$	840	1 140
550	710	$1,2 U_r$	940	1 240
NOTE 1 The rated voltage for equipment U_{rm} applies as per 5.2.				
NOTE 2 The AC type test voltages cover the switchgear routine test, which the insulator can be subjected to.				
NOTE 3 The impulse voltage type tests cover the switchgear on site test, which the insulator can be subjected to.				

For further details and test procedure regarding dielectric tests on the insulator, reference is made in Table 1 to the applicable clauses of IEC 62271-203:2011.

7.1.101 Power-frequency voltage tests on the main circuit

The power-frequency voltage test of GIS shall be performed according to the requirements in 6.2.6.1 or 6.2.7.1 to earth, between phases (if applicable) and across the open switching devices. The voltage test across the open switching device may be carried out at one side of the switching device. The withstand voltages for routine tests shall be those specified in column (2) of Tables 2 and 3.

The tests shall be performed at the minimum functional pressure for insulation.

7.1.102 Partial discharge measurement

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

Partial discharge tests shall be performed in accordance with 6.2.9.

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

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

10.2.101.2.4 Test voltages

Considering that

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

the test voltage for dielectric tests on site shall be as shown in Table 7.

Table 7 – On site test voltages

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

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

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

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

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

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

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

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

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

7.3 Pressure test on the insulator of a cable termination

The insulator shall be secured in exactly the same manner as in service. The test shall be carried out at ambient temperature (20 ± 15) °C. Hydraulic pressure shall be applied to the switchgear side of the insulator with the cable side open to atmosphere. The pressure shall be increased at a rate of not more than 0,4 MPa/min until it reaches three times the design pressure (e.g. design pressure of 0,85 MPa absolute leads to a test pressure of $3 \times 0,75 \text{ MPa} = 2,25 \text{ MPa}$ relative), which shall be held for 1 min.

7.4 Leak rate type test on the insulator of a cable termination

The test shall be performed at ambient temperature (20 ± 15) °C on an insulator of a cable termination installed in a suitable chamber. The insulator shall be installed in a manner close to the service conditions. The test shall be carried out in accordance with IEC 60068-2-17:1994, Clause 8 (the test method Qm is the preferred method to determine the relative leakage rate).

The measured leak rate shall not exceed $10^{-7} \text{ Pa} \times \text{m}^3/\text{s}$ at minimal functional pressure for insulation p_{me} (see Figure 1).

NOTE The volume of the cable termination compartment is unknown during type test, therefore a leak rate flux instead of leak rate percentage is given.

8 Routine tests

8.1 General

Routine tests of a cable termination shall be carried out according to IEC 60141 (all parts) or IEC 60840 or IEC 62067 as applicable. In addition the tests in the following 8.2 and 8.3 shall be carried out.

If the cable termination insulator is pre-installed during switchgear manufacturing, this insulator will be subject to routine tests and on site tests specified in IEC 62271-203 when these are carried out on the switchgear. For these tests the insulator shall be installed and special devices shall be fitted if required for the test, as specified by the cable termination manufacturer. Such devices shall be provided by the cable termination supplier.

8.2 Pressure test

Routine pressure tests of the insulator of a cable termination shall be carried out at 2 times design pressure (relative) for one minute. The insulator shall be secured in exactly the same manner as in service and the pressure shall be applied from the switchgear side. The insulator shall not show any signs of overstress or leakage.

8.3 Visual inspection

The visual inspection shall be made of all surfaces and shall not show any signs of significant defects. Critical machined dimensions shall be confirmed by measurements.

9 Standard dimensions

9.1 General

Standard dimensions are specified in order to ensure compatibility between switchgear and cable terminations conforming to this document.

9.2 Fluid-filled cable terminations

Standard dimensions for fluid-filled cable connection enclosures, main circuit end terminals and cable terminations applied to single-phase enclosures are shown in Figure 3. Four standard sizes cover the voltage range (U_r) from 72,5 kV to 550 kV.

9.3 Dry-type cable terminations

Standard dimensions for dry-type cable-connection enclosures, main circuit end terminals and cable terminations applied to single-phase enclosures are shown in Figure 5. Four standard sizes cover the voltage range (U_r) from 72,5 kV to 550 kV. Figure 4 shows the two types of dry-type cable termination. Type A incorporates an elastomeric electrical stress control component inside the insulating barrier. Type B incorporates the insulating barrier inside the elastomeric electrical stress control component.

For use of dry type cable terminations according to Figure 5 in enclosures for fluid-filled terminations according to Figure 3, suitable interface adaptor(s) shall be supplied by the cable termination manufacturer.

9.4 Three-phase cable connection enclosure

The minimum dimensions of the three-phase cable connection enclosure are defined by the minimum phase to phase distance arising out of d_{10} and the minimum phase to ground distance arising out of $d_5/2$ in accordance with Figures 3 and 5 respectively.

10 Information to be given with enquiries, tenders and orders

Refer to IEC 60840 or IEC 62067 or IEC 60141 (all parts), and IEC 62271-203. In addition, the user and the manufacturers shall consider the installation requirements of the equipment. Manufacturers shall state the specific requirements for civil, electrical and installation clearances applicable to the switchgear, cable termination and cable. Information shall be provided in particular and if required in relation to switchgear/cable termination installation sequence as well as positioning and temporary fixing of the relevant components.

At the time of ordering or manufacturing a switchgear, it is very often not known whether and how the foreseen cable systems will be tested at site. In order to improve this situation, the user of the switchgear has to identify in his inquiry each cable feeder and which testing method will be applied. It is assumed that generally an AC or DC test will be executed at site. The following main test methods are defined:

- a) in case that one end of the cable is installed outdoors, the outdoor located accessible cable end may be used to apply the test voltage;
- b) in case of a cable connection between two switchgears or between switchgear and transformer, the cable connection enclosure in the switchgear may be used to apply the test voltage.

It is the responsibility of the user to indicate in the enquiry for the switchgear which feeders of the switchgear shall be foreseen for cable testing and which test method is required.

11 Rules for transport, storage, erection, service 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.

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.

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

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

These instructions should include:

- a schedule of recommended site tests to establish correct operation;
- procedures for carrying out any adjustment that may be necessary to obtain correct operation;
- recommendations for any relevant measurements that should be made and recorded to help with future maintenance decisions;
- a procedure for qualitative gas tightness test at site (sniffing test) on all field assembled connections for closed pressure systems, reference is made to 8.5.3;
- instructions for final inspection and putting into service.

Guidance for electromagnetic compatibility site measurements is given in Annex H (informative).

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;
 - 2) in-service conditions or operating restrictions that apply;
 - 3) 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.

11.4 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.

11.5 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:

- j) type and required quantity and quality of liquid to be used in switchgear and controlgear;
- k) 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 SF₆);
- 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;